THE CORONAVIRUS (COVID-19) AND DENTISTRY: INFECTION CONTROL, PUBLIC HEALTH AND BEYOND

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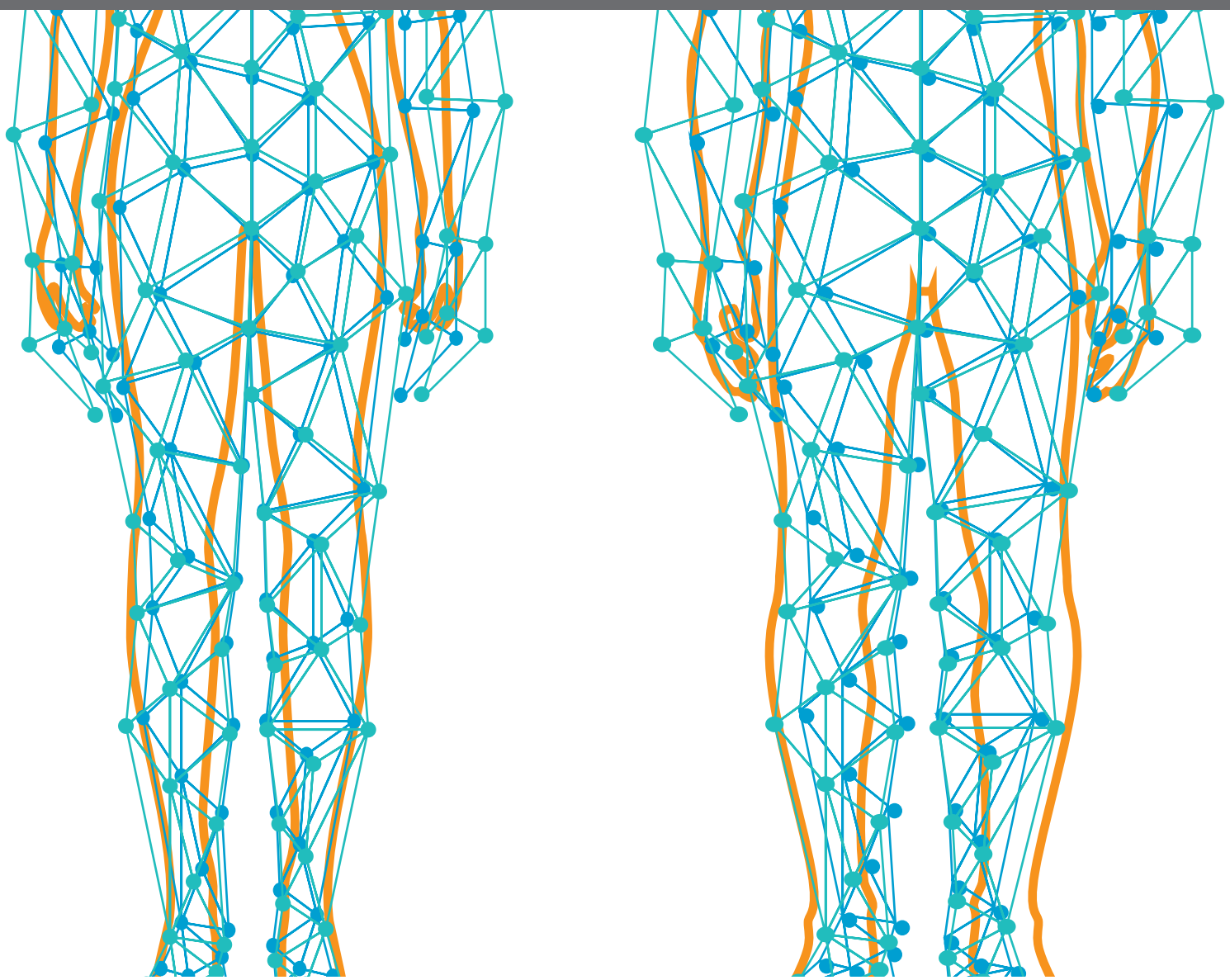

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THE CORONAVIRUS (COVID-19) AND DENTISTRY: INFECTION CONTROL, PUBLIC HEALTH AND BEYOND

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COVID-19 Related Experience, Knowledge, Attitude, and Behaviors Among 2,669 Orthodontists, Orthodontic Residents, and Nurses in China: A Cross-Sectional Survey

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Objectives: To assess the current COVID-19 related experiences, knowledge, attitudes, and behaviors among orthodontists, orthodontic residents, and orthodontic nurses in China, and to identify factors associated with their self-perceived and actual level of knowledge, as well as their willingness to treat/care for COVID-19 patients.

Materials and Methods: A cross-sectional online survey was conducted in China using a 37-item questionnaire developed based on previous research. A professional online survey tool (www.wjx.cn) and a social media platform (WeChat) were used to display and distribute the questionnaire. Data were collected during April 11 to 13, 2020, when most regions of China had resumed dental practice except for high-risk regions such as Wuhan. Then the data were analyzed with multivariable generalized estimating equations.

Results: A total of 2,669 valid questionnaires were collected. Orthodontic services were suspended for nearly all respondents (97.8%) during the epidemic, and 68.0% had resumed work by the time they completed the questionnaire. The majority of respondents (80.2%) were confident that they understood COVID-19 related knowledge, but most of them only correctly answered less than half of the questions testing their actual level of knowledge. About two-thirds (64.1%) were willing to treat/care for patients with confirmed or suspected COVID-19. The completion of relevant training programs was significantly associated with more confidence in knowledge mastery ($P < 0.001$) and a higher actual level of knowledge ($P < 0.001$), but did not increase their willingness to treat/care for patients with COVID-19 ($P = 0.235$).

Conclusions: Before work resumption, COVID-19-related training programs are essential for the improvement of knowledge, confidence, and preparedness of

orthodontic professionals. Sufficient and proper protection should also be provided to ensure safety and reduce the psychological burden on them.

Clinical Relevance: The findings can provide evidence for policy-making related to the resumption of elective dental services.

Keywords: COVID-19, coronavirus, infection control, orthodontics, questionnaire

INTRODUCTION

After being discovered in Wuhan, China, last December, the coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has spread quickly to most parts of the world (1). The World Health Organization (WHO) officially declared the COVID-19 outbreak a public health emergency of international concern on January 30, 2020 (2), and then a global pandemic on March 11, 2020 (3). As of May 29, 2020, there have been a total of 5,701,337 laboratory-confirmed COVID-19 cases and 357,688 deaths in 217 countries, territories, or areas (4).

Current observations have suggested that people of all ages are generally susceptible to COVID-19. However, those who are in close contact with confirmed cases or asymptomatic carriers, including health care workers (HCWs) and other patients within hospitals and/or clinics, are at higher risk of infection (5). As of February 24, 2020, a total of 3,387 HCWs from 476 medical institutions across China were reported to be infected with SARS-CoV-2 (including 2,055 confirmed cases, 1,070 clinically diagnosed cases, and 157 suspected cases), among whom over 90% were from Hubei province and over 20 had died (6, 7). More recently, the WHO announced that there had been at least 22,073 COVID-19 cases among HCWs from 52 countries by April 8, 2020 (8). However, currently there are no data available for cross-transmission in dental settings or cases reported among dental HCWs (9, 10).

As many dental procedures can generate a large number of droplets and aerosols, standard protective measures used in daily practice are not enough to prevent cross-infection among dental practitioners and dental patients (11). In light of this, most provinces and cities in China released regulations in late January, which explicitly restricted dental services to emergency care only, and suspended all elective treatments until further notice (11). As a result of these regulations, as well as public health interventions such as traffic suspension and home quarantine (12), many dental professionals stayed at home during the epidemic, communicating with existing and potential new patients via smartphones and online consultation platforms (13, 14).

Combined, the above-mentioned changes in work and life due to COVID-19 can have a huge impact on HCWs, including non-frontline workers. Findings of a recent study have suggested that the level of psychological stress among non-frontline nurses could be significantly higher than frontline nurses (15). In addition, as China moves from the 2-month containment phase to the mitigation stage (16), the preparedness of non-frontline HCWs to resume work is of great importance. Two recent studies have investigated the knowledge and attitudes regarding COVID-19 among Chinese HCWs in psychiatric hospitals (17) and Jordanian dentists (18), respectively. However, to our knowledge, similar research has not been carried out among HCWs in the field of orthodontics.

Therefore, the objectives of this study were: (1) to assess the current COVID-19-related experiences, knowledge, attitudes, and behaviors among orthodontists, orthodontic residents, and orthodontic nurses in China; (2) to identify factors associated with the self-perceived and actual level of knowledge; and (3) to explore the association between willingness to treat/care for patients with confirmed or suspected COVID-19 and potentially related factors.

MATERIALS AND METHODS

Ethical Approval

This study was a convenience-sample open online survey, written in accordance with the CHEcklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines (19). The study protocol was approved by the Ethics Committee of School & Hospital of Stomatology, Wuhan University (No. 2020-B25). Informed consent was obtained from all respondents. A brief introduction to the study was provided in the first part of the questionnaire, including the target population, study objectives, the time needed to complete the questionnaire, as well as the names and contact information of the investigators. Participation in the survey was voluntary, with neither reward nor penalty. All respondents were informed that they were free to continue or quit at any time, and the submission of the questionnaire would be regarded as consent to participate. To protect respondents' privacy, the survey was anonymous, and all the raw data were stored in one author's computer and kept confidential.

Survey Design

A 37-item questionnaire (**Supplementary Material 1**) was developed according to previous research on knowledge, attitudes, and behaviors of HCWs (17, 20). We added several questions for background information of the participants, and rephrased questions to make them relevant to orthodontics; the construction of the measured concepts and scoring methods remained the same. The survey consisted of four aspects: background information, knowledge, attitudes, and behaviors. The first 16 questions were regarding the background characteristics, including seven for demographics, five for workplace information, and four for COVID-related personal experience. Ten questions were in the knowledge section, including three Likert-scale items (#17, #19, and #20) for the

self-perceived level of knowledge, one semi-open question (#18) for their source of knowledge, and six (3 single-choice and 3 multiple-choice, #21 to #26) questions for the assessment of actual knowledge level. Among five questions in the attitude section, three were Likert-scale (#27 to #29) to evaluate the attitudes toward personal protective equipment (PPE) in the context of COVID-19. In addition, respondents were asked a yes-no question (#30) about their willingness to treat/care for orthodontic patients with confirmed or suspected COVID-19, and if "no" was selected, they should explain the reasons for this choice (a semi-open question, #31). The behavior section contained six questions. Respondents were required to rate their actual or expected behaviors after the resumption of orthodontic services for five Likert-scale questions (#32, #33, and #35 to #37), and their compliance to PPE on a percentage scale (#34). For all Likert-scale questions, a five-point Likert scale was used ranging from 1 (completely disagree) to 5 (completely agree). In addition, each aspect contained several Likert-scale items to ensure reliability and validity.

Participant Recruitment

Eligible participants were orthodontists, orthodontic residents, orthodontic nurses, and general dental practitioners and nurses offering orthodontic care. The sample size was calculated using an online calculator (www.raosoft.com/samplesize.html). With a 5% margin of error and a 95% confidence level, the required sample size was 377.

Prior to its official release, the questionnaire was sent to a small group of around 20 orthodontic professionals to record the time needed to complete it and check if the questions were clear and unambiguous. After this pilot survey, the questionnaire was distributed and publicized to orthodontic professionals nationwide.

We used purposive and snowball sampling routes to recruit participants. The survey was distributed from April 11 to 13, 2020, when most regions of China had resumed dental practice, except for high-risk regions such as Wuhan. We first disseminated the questionnaire link through orthodontics-related blogs on WeChat (Tencent, Shenzhen, China), which has been the most widely used social media platform in China (21). Then we sent messages to chat groups of orthodontic practitioners and asked them to invite their friends, engaging orthodontics to participate. Also, professor H.H invited her professional network personally.

The questionnaire was collected using a professional online survey platform (www.wjx.cn). Since respondents could submit their answers only when all the questions are finished, this platform guaranteed the completeness of the collected questionnaires. To prevent multiple answers from the same individual, the questionnaire could only be accessed through WeChat, and each WeChat account could only answer once. The respondents could not change their answers once submitted. All valid responses were included, and the expected valid response rate was 90% after excluding invalid answers. As planned *a priori*, questionnaires with incomplete responses, apparent errors, and atypical timestamps (<2 min or more than 30 min) (22) were considered invalid and excluded.

Statistical Analysis

The original data were downloaded from the online survey platform. For the semi-open question, reasons for their unwillingness to treat/care for COVID-19 patients (#31), themes were manually extracted and coded by three authors (F.H., D.Q., and T.Z.), independently and in duplicate, with all discrepancies resolved by discussion. Each response could be coded into multiple themes if containing miscellaneous information, and then the count for each theme were calculated. The self-perceived level of knowledge about COVID-19 was evaluated by averaging the scores of three Likert-scale items (#17, #19, and #20). Regarding the actual level of knowledge, we gave 1 point for each question of #21 to #26 answered correctly, and no point for any item incorrectly answered. Then a total knowledge score (score range: 0 to 6) for each respondent was calculated by totaling the scores of all these six items.

Descriptive statistics were performed to summarize the characteristics and the answers of each question. Categorical data were presented as counts and percentages. Continuous data were expressed as means ± standard deviations (SDs) and range, and skewed data and Likert-scale responses were presented as medians and interquartile ranges. Chi-square tests and Fisher's exact tests were used to analyze categorical data, with pairwise comparisons adjusted by Bonferroni correction. Likert-scale questions were analyzed with Kruskal-Wallis tests, followed by Dunn's tests for *post-hoc* pairwise comparisons. The self-perceived level of knowledge and the total knowledge score were compared using one-way analysis of variance (ANOVA) with Tukey adjustment.

Generalized estimating equations (GEE) regression analyses were performed to explore factors associated with the self-perceived level of knowledge, total knowledge score, and the willingness to treat/care for COVID-19 patients (#30). Robust estimate of covariance and the independent correlation matrix were adopted. For continuous outcomes (the self-perceived level of knowledge and the total knowledge score), we used a GEE with a normal distribution for the response variables and identity link; for the binary outcome (the willingness to treat/care for COVID-19 patients), we used a GEE with a binomial distribution and logit link. As determined *a priori*, all the characteristics in the first part of the questionnaire (#1 to #16) were served as independent variables, namely age, gender, profession, years of practice, academic degree, marital status, cohabitants, location of workplace, settings, provision of online orthodontic consultation, current status of orthodontic services at the workplace, participation in anti-epidemic activities, current status of personal orthodontic practice, completion of any COVID-19-related training program, and experience of treating/caring for COVID-19 patients. In addition, self-perceived level of knowledge and total knowledge score also served as the predictors of the willingness to treat/care for COVID-19 patients. In these analyses, we carried out univariable analyses first, and then entered all significant factors into multivariable analyses. Tolerance and variance inflation factor (VIF) were used to detect multicollinearity, and predictors with tolerance < 0.1 or VIF > 10 were excluded from the final model. Two-sided $P < 0.05$ was considered statistically significant.

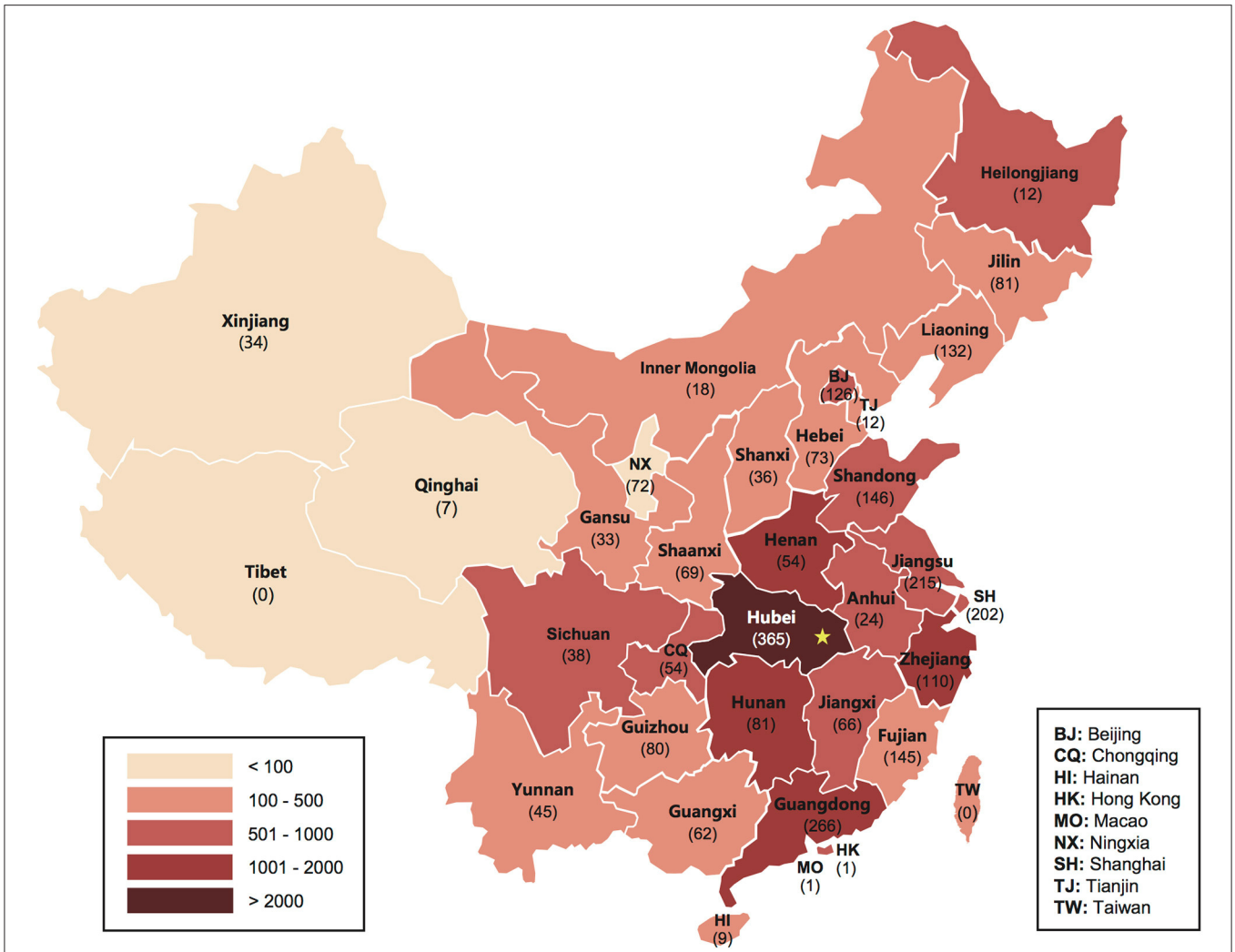

FIGURE 1 | The geographical distribution of respondents to this survey (n = 2,669). Gradient of colors represents the cumulative number of confirmed COVID-19 cases in each provincial-level administrative region (as of April 10, 2020). Numbers in parentheses indicate the number of respondents from each region. The star marks the location of Wuhan.

RESULTS

Due to the character of our recruitment methods, it was impossible to estimate the total number of orthodontic practitioners who had received our survey invitation. Among the 2,890 questionnaires collected, 221 responses were invalid according to the predetermined eligibility criteria: four failed to complete the survey before the deadline, 15 submitted with an unusual completion time, and 202 questionnaires had obvious mistakes such as abnormal age and contradictory answers to similar questions. After removing these invalid responses, 2,669 questionnaires from 2,669 respondents were included in analyses, resulting in a valid response rate of 92.4%.

General Information

The respondents came from 32 of the 34 provincial-level administrative regions of China. **Figure 1** illustrates the geographical distribution of respondents together with the cumulative number of confirmed COVID-19 cases in each region as of April 10. There were 739 (27.7%) males and 1,930 (72.3%) females between 19 and 62, with an average age of 34.3 (SD, 8.5). The majority of the respondents were orthodontists (64.8%), followed by orthodontic residents/postgraduate students (20.5%) and orthodontic nurses (14.6%). Nearly half (47.7%) of them had a relatively short working experience in orthodontics (≤5 years). The majority (91.0%) lived with other people, and nearly three-fifths (58.2%) lived with their parents and/or children.

As shown in **Table 1**, almost all respondents (97.8%) stated that the dental hospitals or clinics in which they worked had full (49.2%) or partial (48.6%) suspension of orthodontic treatment during the epidemic. Also, a majority of them (87.4%) stated that their workplaces provided online orthodontic consultation to either existing orthodontic patients only (30.9%), or both

TABLE 1 | Demographic and workplace information of the respondents to this survey.

Characteristics	*N*	%
Demographics		
Age[§]	34.3 ± 8.5	19–62
Gender		
Female	1,930	72.3
Male	739	27.7
Profession		
Orthodontist	1,731	64.8
Orthodontic resident/postgraduate student	547	20.5
Orthodontic nurse	391	14.6
Years of orthodontic practice		
≤5 years	1,274	47.7
5–10 years	620	23.2
10–20 years	516	19.3
>20 years	259	9.7
Highest degree		
PhD	211	7.9
Master	778	29.1
Bachelor	1,371	51.4
Junior college	297	11.1
Technical secondary school	12	0.4
Marital status		
Single	944	35.4
Married, without children	240	9.0
Married, with children	1,465	54.9
Others	20	0.7
Cohabitants		
Live alone	241	9.0
Parents and/or children	1,553	58.2
Others	875	32.8
Workplace information		
Location		
Wuhan	267	10.0
Hubei province (excluding Wuhan)	98	3.7
Others	2,304	86.3
Setting		
Public	1,980	74.2
Private	689	25.8
Orthodontic services during epidemic		
Complete suspension	1,313	49.2
Partial suspension	1,297	48.6
No suspension	59	2.2
Online consultation		
No	337	12.6
Provided, only to existing orthodontic patients	824	30.9
Provided, to both existing and potential new orthodontic patients	1,508	56.5
Current status of orthodontic services		
Not resumed yet	338	12.7
Partially resumed	1,176	44.1
Completely resumed	1147	43.0
No suspension	8	0.3
Total	2,669	100.0

[§]*Displayed as mean ± SD, and range.*

existing and potential new orthodontic patients (56.5%). In addition, 87.1% of the respondents reported that their workplaces had recently resumed orthodontic services in full (43.0%) or in part (44.1%).

Personal Experience

Table 2 shows the respondents' COVID-19-related personal experience during the epidemic. Although 28.6% of them had participated in anti-epidemic activities, including supporting fever clinics or designated COVID-19 hospitals, and acting as community volunteers, only 3.9% had the experience of treating or caring for patients with confirmed COVID-19. Approximately 80% of the orthodontists and nurses had resumed their orthodontic practice, whereas only one-fifth (19.4%) of the orthodontic residents had returned to work. Additionally, the majority of orthodontists (84.4%) and nurses (90.3%) had finished COVID-19-related training programs, while only 55.2% of orthodontic residents received relevant training.

As listed in **Supplementary Table 1**, the proportion of respondents that had not resumed orthodontic work was significantly different among location groups ($P < 0.001$). The highest proportion occurred in Wuhan (93.3%), followed by other parts of Hubei province (52.0%) and regions outside Hubei (23.8%). Accordingly, the proportion of respondents who had not completed COVID-19-related training programs was significantly higher in Wuhan (29.2%) than places outside Hubei (19.8%). In addition, the experience of treating or caring for COVID-19 patients was more common among respondents from Wuhan (9.0%) and other parts of Hubei (9.2%) than those from areas outside Hubei province (3.1%).

Knowledge

As described in **Supplementary Table 2**, the mean self-perceived level of knowledge of COVID-19 was 4.03 (SD 0.65), which means the respondents agreed that they were confident in their knowledge. Most respondents (80.2%) expressed agreement or complete agreement that they understood COVID-19-related knowledge. In addition, most were confident that they understood the risk of COVID-19 to patients and HCWs (84.1%), as well as how to protect themselves and patients during the epidemic (76.1%). As shown in **Figure 2**, the Internet (92.8%) was the respondents' primary source of knowledge, followed by training programs (74.6%), television (70.5%), medical journals (31.3%), and newspapers (26.0%). However, the mean total knowledge score was 2.74 (SD, 0.85), which suggests the respondents only correctly answered less than half of the six questions testing their actual level of knowledge on average.

Table 3 shows the results of GEE regression analyses for the self-perceived level of knowledge about COVID-19. According to multivariable analysis, respondents who had finished COVID-19-related training programs had significantly more confidence in knowledge mastery than those who had not ($B = 0.406$, 95% CI: 0.341 to 0.471, $P < 0.001$). In addition, a significantly higher self-perceived level of knowledge was also found in orthodontic nurses ($P < 0.001$), older people ($P = 0.008$), male individuals ($P < 0.001$), those who were living with parents and/or children (P

TABLE 2 | Respondents' personal experience during the COVID-19 epidemic by profession.

Personal experience[§]	Total (n = 2,669)	Orthodontists (n = 1,731)	Orthodontic residents (n = 547)	Orthodontic nurses (n = 391)	P-value[†]
Participation in anti-epidemic activities[¶]					**<0.001**
No	1,907 (71.4)	1,150 (66.4)[a]	490 (89.6)[b]	267 (68.3)[a]	
Yes	762 (28.6)	581 (33.6)[a]	57 (10.4)[b]	124 (31.7)[a]	
Current status of orthodontic practice					**<0.001**[‡]
Not resumed yet	849 (31.8)	326 (18.8)[a]	441 (80.6)[b]	82 (21.0)[a]	
Resumed, less than 2 weeks	478 (17.9)	379 (21.9)[a]	46 (8.4)[b]	53 (13.6)[c]	
Resumed, 2 to 4 weeks	725 (27.2)	586 (33.9)[a]	38 (6.9)[b]	101 (25.8)[c]	
Resumed, more than 4 weeks	611 (22.9)	436 (25.2)[a]	22 (4.0)[b]	153 (39.1)[c]	
No suspension	6 (0.2)	4 (0.2)[a]	0 (0.0)[a]	2 (0.5)[a]	
Completion of COVID-19 related training program					**<0.001**
No	553 (20.7)	270 (15.6)[a]	245 (44.8)[b]	38 (9.7)[c]	
Yes	2,116 (79.3)	1,461 (84.4)[a]	302 (55.2)[b]	353 (90.3)[c]	
Experience of treating or caring for COVID-19 patients					**<0.001**[‡]
No	2,564 (96.1)	1,652 (95.4)[a]	543 (99.3)[b]	369 (94.4)[a]	
Yes	105 (3.9)	79 (4.6)[a]	4 (0.7)[b]	22 (5.6)[a]	

[§] *Displayed as N (%).*

[¶] *Including activities in fever clinics or designated hospitals for COVID-19 patients, as community volunteers, and other COVID-19-related works.*

[†] *P-values in bold are statistically significant (<0.05).*

[‡] *Fisher' exact test.*

[a,b,c] *Groups with the same letters in the same row are not statistically different (P > 0.05) according to post hoc tests.*

= 0.024), those who suspended their orthodontic practice during the epidemic (P = 0.029), and those who had the experience of treating or caring for COVID-19 patients (P = 0.040).

However, in terms of the actual level of knowledge, a higher total knowledge score was significantly associated with the completion of COVID-19-related training programs (B = 0.181, 95% CI: 0.099 to 0.264, P < 0.001), working in a public hospital or clinic (P < 0.001), 5 to 10 years of working experience in orthodontics (P = 0.006), and having a master's degree (P = 0.018). In contrast, male individuals (P < 0.001), those who had the experience of treating or caring for COVID-19 patients (P < 0.001), as well as those working outside Hubei province (P = 0.007) had a significantly lower total knowledge score (**Table 4**). In addition, the current status of personal orthodontic practice was on the borderline statistical significance, and those who had resumed their work <2 weeks before had a significantly higher knowledge score (P = 0.031).

Attitude

In general, most respondents agreed about the effectiveness of PPE. They also admitted that it would be somewhat inconvenient to use PPE while treating patients. **Supplementary Table 3** shows the differences in attitude among profession groups. Orthodontic nurses expressed significantly more agreement that PPE could protect orthodontic staff (P = 0.010) and orthodontic patients (P = 0.001) from COVID-19, and felt less inconvenient to use PPE when treating/caring for patients (P < 0.001).

About two-thirds of the participants (64.1%) stated that they were willing to treat or care for patients with confirmed or suspected COVID-19. According to multivariable GEE analysis, the odds of being willing to treat/care for COVID-19 patients were significantly higher among orthodontic nurses (P < 0.001), those with a higher self-perceived level of knowledge (P < 0.001), those who worked at a public hospital or clinic (P < 0.001) that provided online consultation to both existing and potential new orthodontic patients (P = 0.001), those with a junior college (P = 0.011) or bachelor's degree (P = 0.019), and those who had an experience of anti-epidemic activities (P = 0.022) (**Table 5**).

As depicted in **Figure 3**, among respondents who were unwilling to treat/care for COVID-19 patients, the most common reasons were concern about the possible infection of their family members (80.2%) and possible infection of themselves (72.0%). Except for the above two choices we provided in this semi-open question, respondents also gave other reasons including concern about possible nosocomial infection (8.8%), the non-emergent nature of orthodontic treatment (6.6%), a lack of COVID-19-related knowledge and experience (5.7%), concern about the possible spread of infection (3.1%), and inadequate protective measures and equipment (2.9%).

Behaviors

In the final part of the questionnaire, respondents were asked about their behaviors after the resumption of orthodontic services (**Supplementary Table 4**). Most respondents (72.3%) agreed that their hospitals/clinics had adequate PPE for them to use, and 61.7% reported that they were 100% sure that after work resumption, they would use the recommended PPE during treatment. In addition, orthodontic nurses reported better compliance with PPE (P = 0.001) and were less likely to forget to change PPE between patients (P < 0.001).

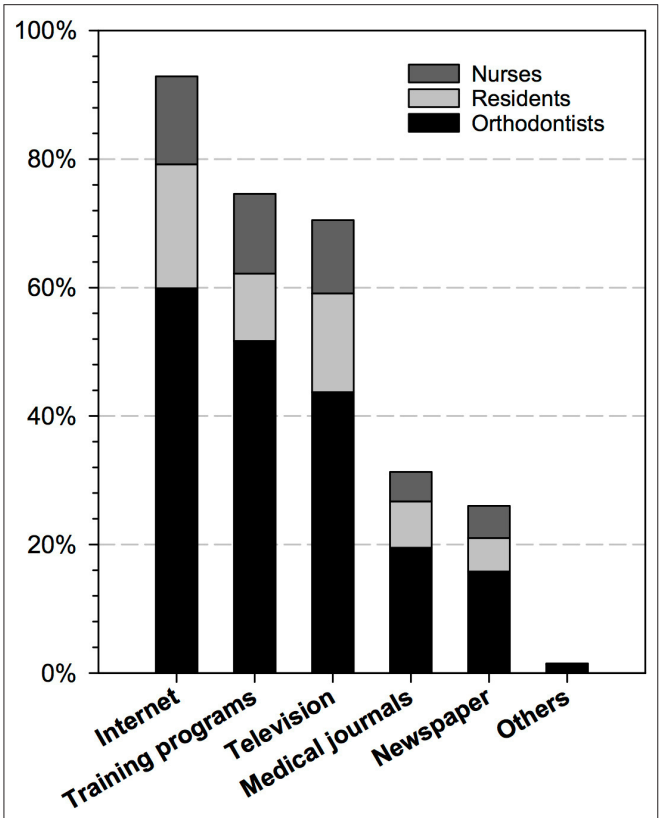

FIGURE 2 | The sources of COVID-19-related knowledge among respondents (semi-open question, #18) ($n = 2,669$).

DISCUSSION

After the announcement of human-to-human transmission and infections among HCWs on January 20, 2020, China imposed more rigorous public health interventions (e.g., compulsory wearing of face masks in public places, intensive intercity and intracity traffic restriction, social distancing, home isolation, and centralized quarantine) to control the spread of SARS-CoV-2 (12). Since around January 27, 2020, relevant government agencies of most provinces and cities in China began to release their regulations on dental practices during the epidemic, which explicitly suspended all elective dental services, including orthodontic treatment (13, 14). About 1 month later, as the number of daily new cases had decreased substantially in China, provinces and cities began to loosen public health interventions and gradually resume non-emergency dental services, according to their own situation. For instance, as the hardest-hit city in China, Wuhan officially lifted its lockdown on April 8, 2020, and its largest dental care provider—Hospital of Stomatology, Wuhan University, started to provide elective treatments on April 20, 2020. Therefore, with 2,669 responses collected from across China during April 11–13, the present study provides valuable insights into the COVID-19-related experiences, knowledge, attitudes, and behaviors of orthodontic professionals during such a period of transition.

The COVID-19 epidemic had a huge impact on orthodontic practice. In this study, a majority of the respondents stated that, during the epidemic, their workplaces had suspended orthodontic treatment (97.8%) and provided online orthodontic consultation to patients (87.4%). These figures are generally in line with those of a previous study conducted during February 17–23, which found that all of the surveyed 48 public tertiary dental hospitals in China had suspended non-emergent dental services, and 33 of them (68.8%) had been offering online dental consultations during suspension (14). Similarly, some other countries implemented mandatory suspension of dental non-emergencies, including orthodontic treatment to fight against the COVID-19 pandemic and ensure the safety of patients and medical staff (23–25).

With the gradual recovery of normal dental services in China, most of the respondents (87.1%) reported that their workplaces had resumed orthodontic services completely or partially. Compared to orthodontists and nurses, significantly fewer orthodontic residents/postgraduate students had resumed orthodontic work, completed any COVID-19-related training programs, or had experience in anti-epidemic activities or treatment for COVID-19 patients, This could be explained by the fact that they are considered students in China, and had been required by the Ministry of Education to remain at home and not to return to their dental schools until further notice (13). In addition, Wuhan and other parts of Hubei had a significantly lower proportion of people who had resumed work. These results are in accordance with the severe situation in Wuhan and other parts of Hubei during the COVID-19 epidemic, as well as the fact that they were the latest in China to loosen public health interventions.

As part of the preparation before work resumption, nearly 80% of the respondents had finished training; three-quarters reported that the training was their primary source of COVID-19-related information. In addition, most respondents also acquired information from the Internet and television during home quarantine. However, only one-third stated that they obtained the relevant knowledge from medical journals. As COVID-19 was an up-to-date topic and most related articles were published in English, language could be a potential barrier to the knowledge acquisition from medical journals for Chinese practitioners. They could turn to other resources, such as authority websites and official notification, for relevant information.

Responses to our questions regarding knowledge have shown a discrepancy between the self-perceived and actual level of knowledge. Although the majority of respondents stated that they understood COVID-19-related knowledge, risks, and protective measures very well, their total knowledge score was generally suboptimal. According to multivariable analyses, after the adjustment of potential confounding variables, the completion of relevant training programs was significantly associated with both more confidence in knowledge mastery and a higher total knowledge score. This is consistent with previous studies, which suggested additional training and education

TABLE 3 | Results of univariable and multivariable generalized estimating equations (GEE) regression analyses for self-perceived level of knowledge.

Variable	Univariable analysis			Multivariable analysis		
	B	95% CI	*P*-value¶	*B*	95% CI	*P*-value¶
Demographics						
Age	0.012	(0.009, 0.015)	**<0.001**	0.008	(0.002, 0.014)	**0.008**
Gender						
Female	Reference			Reference		
Male	0.112	(0.058, 0.166)	**<0.001**	0.107	(0.054, 0.160)	**<0.001**
Profession			**<0.001**			**<0.001**
Orthodontist	Reference			Reference		
Orthodontic resident/postgraduate student	−0.264	(−0.325, −0.203)	**<0.001**	−0.012	(−0.100, 0.077)	0.797
Orthodontic nurse	0.094	(0.023, 0.164)	**0.009**	0.148	(0.070, 0.225)	**<0.001**
Years of orthodontic practice			**<0.001**			0.370
≤5 years	Reference			Reference		
5–10 years	0.095	(0.033, 0.158)	**0.003**	−0.059	(−0.128, 0.011)	0.099
10–20 years	0.184	(0.119, 0.249)	**<0.001**	−0.051	(−0.137, 0.035)	0.246
>20 years	0.259	(0.178, 0.339)	**<0.001**	−0.030	(−0.162, 0.102)	0.656
Academic degree			0.430			
Marital status			**<0.001**			0.090
Single	Reference			Reference		
Married, without children	0.170	(0.085, 0.255)	**<0.001**	0.078	(−0.011, 0.167)	0.088
Married, with children	0.191	(0.138, 0.245)	**<0.001**	−0.046	(−0.133, 0.042)	0.308
Others	0.095	(−0.247, 0.437)	0.586	0.005	(−0.344, 0.355)	0.976
Cohabitants			**<0.001**			**0.030**
Live alone	Reference			Reference		
Parents and/or children	0.141	(0.045, 0.234)	**0.004**	0.113	(0.015, 0.212)	**0.024**
Others	0.007	(−0.092, 0.106)	0.895	0.048	(−0.047, 0.144)	0.323
Workplace information						
Location			**0.020**			0.191
Wuhan	Reference			Reference		
Hubei province (excluding Wuhan)	0.198	(0.059, 0.338)	**0.005**	0.121	(−0.010, 0.252)	0.069
Others	0.078	(−0.008, 0.164)	0.075	0.056	(−0.052, 0.165)	0.309
Setting			0.612			
Orthodontic services during epidemic			**0.003**			0.130
Complete suspension	Reference			Reference		
Partial suspension	−0.040	(−0.090, 0.010)	0.313	−0.040	(−0.089, 0.010)	0.116
No suspension	0.225	(0.063, 0.387)	**0.032**	0.084	(−0.089, 0.257)	0.342
Online consultation			0.158			
Current status of orthodontic services			**<0.001**			**<0.001**
Not resumed yet	Reference			Reference		
Partially resumed	−0.018	(−0.098, 0.062)	0.658	−0.073	(−0.182, 0.037)	0.193
Completely resumed	0.081	(0.001, 0.161)	**0.047**	−0.045	(−0.163, 0.073)	0.452
No suspension	0.711	(0.388, 1.034)	**<0.001**	0.672	(0.463, 0.881)	**<0.001**
Personal experience						
Participation in anti-epidemic activities						
No	Reference			Reference		
Yes	0.160	(0.107, 0.213)	**<0.001**	−0.073	(−0.182, 0.037)	0.193
Current status of orthodontic practice			**<0.001**			**0.048**
Not resumed yet	Reference			Reference		
Resumed, less than 2 weeks	0.167	(0.096, 0.238)	**<0.001**	0.054	(−0.036, 0.145)	0.241
Resumed, 2 to 4 weeks	0.206	(0.143, 0.270)	**<0.001**	0.056	(−0.033, 0.145)	0.217

(Continued)

TABLE 3 | Continued

Variable	Univariable analysis			Multivariable analysis		
	B	**95% CI**	***P*-value[¶]**	***B***	**95% CI**	***P*-value[¶]**
Resumed, more than 4 weeks	0.241	(0.173, 0.309)	**<0.001**	0.073	(−0.024, 0.169)	0.140
No suspension	0.728	(0.335, 1.120)	**<0.001**	−0.402	(−0.762, −0.042)	**0.029**
Completion of COVID-19 related training program						
No	Reference			Reference		
Yes	0.478	(0.417, 0.539)	**<0.001**	0.406	(0.341, 0.471)	**<0.001**
Experience of treating or caring for COVID-19 patients						
No	Reference			Reference		
Yes	0.277	(0.154, 0.399)	**<0.001**	0.137	(0.006, 0.268)	**0.040**

[¶] *P-values in bold are statistically significant (<0.05).*

improved dental practitioners' knowledge of infection control (26, 27). This finding highlights the importance for dental hospitals, clinics, and relevant professional societies to organize adequate training activities for HCWs before the resumption of dental services. We also found that the time of work resumption was a borderline predictor of the actual level of knowledge; those who had just resumed work performed better. Although COVID-19-related training was required before work resumption in China, orthodontic professionals may forget relevant knowledge as time elapsed. This possibly suggests that regular training is essential to enhance their knowledge mastery. In addition, although respondents with the experience of treating/caring for COVID-19 patients had higher self-perceived knowledge, they performed significantly poorer in the questions that tested their actual knowledge. The possible reason may be that during the epidemic, the highest level of protection was taken in the treatment. However, in this transition period of work resumption, the focus of dental practice shifted from emergencies to routine procedures, and particular caution and different precautions should be taken.

With regard to the respondents' attitude, 64.1% of them were willing to treat/care for patients with confirmed or suspected COVID-19. Eighty percent of those who were reluctant expressed their concern over possible infection of their family members. Researchers found that fear of transmitting the virus to family and coworkers was the top concern of dentists and frontline HCWs (28). Previous studies have shown that knowledge and education could positively affect dentists' attitudes toward the treatment of patients with highly infectious diseases (27, 29). In the present study, however, both the actual knowledge level and the completion of relevant training programs did not increase respondents' willingness to treat COVID-19 patients. Due to the sudden outbreak and quick spread of COVID-19, as well as there being no vaccine or approved treatment, the fear of the unknown and uncertainty about the disease was the main obstacle to the treatment of COVID-19 patients (30). Home quarantine is crucial to the diffusion of coronavirus, but added difficulties to dental treatment and triggered excessive anxiety (31). We also found that respondents from public dental institutions with online consultation were more willing to treat COVID-19 patients. This is probably because these institutions have adequate prevention measures and sufficient medical sources to protect their staff, while the shortage of PPE is strongly associated with the stress and anxiety of HCWs (32).

In the present study, although many respondents had a suboptimal total knowledge score, most of them believed that they could improve their adherence to PPE. A previous study indicated that dental practitioners were generally ill-prepared for COVID-19, as they did not routinely wear recommended respirators during treatment (33). The use of PPE is crucial for protection, and practitioners need to understand which level of protective measures should be used (34). Hand hygiene is also considered a critical measure for infection control, with poor adherence believed to be a major contributor to disease transmission (35). Researchers found that the implementation of recommended infection control measures varied among dentists, and those who were aware of the importance of infection control had better compliance with guidelines (26). This suggests that the use of effective strategies and different modes of training is necessary to enhance dental professionals' awareness of infection control. It has been recommended that the use of a checklist in handy places for repeatable procedures improves the compliance with infection control precautions, including what PPE should be used in certain circumstances, the correct donning and doffing procedures of PPE, and the recommended hand hygiene measures (36).

A questionnaire-based survey is a useful tool to efficiently acquire information regarding opinions and experiences covering wide demographics of participants (37). In the present study, we obtained a sufficiently large sample for data analysis; however, careful interpretation of the results is required. First, this was an online survey and many participants were recruited via one professor's network, which was a potential source of bias. Second, some categories of the respondents' characteristics had a very small sample size, which caused the imprecision of the results and compromised representativeness of certain populations. In addition, a more thorough investigation

TABLE 4 | Results of univariable and multivariable generalized estimating equations (GEE) regression analyses for total knowledge score.

Variable	Univariable analysis			Multivariable analysis		
	B	95% CI	*P*-value[¶]	*B*	95% CI	*P*-value[¶]
Demographics						
Age			0.977			
Gender						
Female	Reference			Reference		
Male	−0.171	(−0.244, −0.097)	**<0.001**	−0.151	(−0.226, −0.077)	**<0.001**
Profession			0.887			
Years of orthodontic practice			**0.007**			**0.031**
≤5 years	Reference			Reference		
5–10 years	0.146	(0.062, 0.230)	**0.001**	0.124	(0.035, 0.212)	**0.006**
10–20 years	0.063	(−0.022, 0.147)	0.146	0.054	(−0.038, 0.146)	0.247
>20 years	0.013	(−0.096, 0.122)	0.809	−0.012	(−0.131, 0.107)	0.844
Academic degree			**<0.001**			**0.001**
PhD	Reference			Reference		
Master	0.137	(0.010, 0.265)	**0.035**	0.156	(0.027, 0.284)	**0.018**
Bachelor	−0.028	(−0.148, 0.092)	0.645	0.039	(−0.086, 0.164)	0.539
Junior college	−0.207	(−0.368, −0.067)	**0.005**	−0.081	(−0.242, 0.079)	0.321
Technical secondary school	−0.073	(−0.509, 0.364)	0.744	0.156	(−0.362, 0.523)	0.721
Marital status			0.439			
Cohabitants			0.418			
Workplace information						
Location			**0.016**			**0.002**
Wuhan	Reference			Reference		
Hubei province (excluding Wuhan)	0.044	(−0.169, 0.257)	0.685	0.065	(−0.140, 0.270)	0.535
Others	−0.133	(−0.249, −0.018)	**0.023**	−0.175	(−0.302, −0.048)	**0.007**
Setting						
Public	Reference			Reference		
Private	−0.231	(−0.303, −0.160)	**<0.001**	−0.174	(−0.253, −0.096)	**<0.001**
Orthodontic services during epidemic			0.199			
Online consultation			0.675			
Current status of orthodontic services			0.417			
Personal experience						
Participation in anti-epidemic activities			0.439			
Current status of orthodontic practice			**0.003**			0.050
Not resumed yet	Reference			Reference		
resumed, less than 2 weeks	−0.159	(−0.253, −0.064)	**0.001**	−0.113	(−0.216, −0.010)	**0.031**
resumed, 2 to 4 weeks	0.020	(−0.064, 0.105)	0.640	0.025	(0.124, 0.246)	0.620
resumed, more than 4 weeks	−0.001	(−0.090, 0.089)	0.990	−0.024	(0.081, 0.200)	0.655
No suspension	0.070	(−0.483, 0.623)	0.804	0.109	(0.668, 0.147)	0.701
Completion of COVID−19 related training program						
No	Reference			Reference		
Yes	0.204	(0.125, 0.283)	**<0.001**	0.181	(0.099, 0.264)	**<0.001**
Experience of treating or caring for COVID-19 patients						
No	Reference			Reference		
Yes	−0.265	(−0.429, −0.101)	**0.002**	−0.324	(−0.483, −0.165)	**<0.001**

[¶] *P-values in bold are statistically significant (<0.05).*

into the impact of COVID-19 on orthodontists' provision of healthcare services was out of the scope of this study and therefore not included. This could be explored in future research.

CONCLUSIONS

Results of the present study suggest that, during the mitigation stage of the COVID-19 epidemic when orthodontic services

TABLE 5 | Results of univariable and multivariable generalized estimating equations (GEE) regression analyses for willingness to treat/care for patients with COVID-19.

Variable	Univariable analysis			Multivariable analysis		
	OR	95% CI	*P*-value[¶]	OR	95% CI	*P*-value[¶]
Demographics						
Age	0.982	(0.973, 0.992)	**<0.001**	1.007	(0.985, 1.030)	0.538
Gender			0.091			
Profession			**<0.001**			**<0.001**
Orthodontist	Reference			Reference		
Orthodontic resident/postgraduate student	1.249	(1.023, 1.526)	**0.029**	1.006	(0.746, 1.357)	0.968
Orthodontic nurse	3.210	(2.429, 4.241)	**<0.001**	1.920	(1.377, 2.678)	**<0.001**
Years of orthodontic practice			**0.001**			0.175
≤5 years	Reference			Reference		
5–10 years	0.836	(0.684, 1.023)	0.082	0.931	(0.725, 1.197)	0.578
10–20 years	0.705	(0.570, 0.870)	**0.001**	0.713	(0.514, 0.989)	**0.043**
>20 years	0.650	(0.495, 0.854)	**0.002**	0.619	(0.372, 1.029)	0.064
Academic degree			**<0.001**			**<0.001**
PhD	Reference			Reference		
Master	0.992	(0.730, 1.349)	0.961	0.967	(0.701, 1.333)	0.837
Bachelor	1.615	(1.203, 2.170)	**0.001**	1.485	(1.069, 2.065)	**0.019**
Junior college	1.801	(1.245, 2.605)	**0.002**	1.781	(1.142, 2.776)	**0.011**
Technical secondary school	1.517	(0.443, 5.193)	0.507	1.952	(0.588, 6.481)	0.274
Marital status			**0.007**			0.273
Single	Reference			Reference		
Married, without children	0.890	(0.660, 1.200)	0.444	0.916	(0.654, 1.283)	0.610
Married, with children	0.754	(0.634, 0.896)	**0.001**	0.824	(0.618, 1.098)	0.186
Others	0.470	(0.194, 1.142)	0.096	0.447	(0.175, 1.141)	0.092
Cohabitants			0.078			
Workplace information						
Location			0.623			
Setting						
Public	Reference			Reference		
Private	0.645	(0.541, 0.771)	**<0.001**	0.643	(0.517, 0.799)	**<0.001**
Orthodontic services during epidemic			0.052			
Online consultation			**<0.001**			**<0.001**
No	Reference			Reference		
Provided, only to existing orthodontic patients	1.031	(0.798, 1.332)	0.817	1.091	(0.827, 1.438)	0.538
Provided, to both existing and potential new orthodontic patients	1.658	(1.302, 2.112)	**<0.001**	1.586	(1.219, 2.063)	**0.001**
Current status of orthodontic services			0.847			
Personal experience						
Participation in anti-epidemic activities						
No	Reference			Reference		
Yes	1.428	(1.193, 1.710)	**<0.001**	1.270	(1.035, 1.559)	**0.022**
Current status of orthodontic practice			0.929			
Completion of COVID-19 related training program						
No	Reference			Reference		
Yes	1.479	(1.222, 1.790)	**<0.001**	1.176	(0.941, 1.470)	0.153
Experience of treating or caring for COVID-19 patients						
No	Reference			Reference		
Yes	2.046	(1.280, 3.272)	**0.003**	1.348	(0.823, 2.208)	0.235
Knowledge						
Self-perceived level of knowledge	1.724	(1.518, 1.957)	**<0.001**	1.705	(1.482, 1.962)	**<0.001**
Total knowledge score	1.026	(0.934, 1.126)	0.595			

[¶] *P-values in bold are statistically significant (<0.05).*

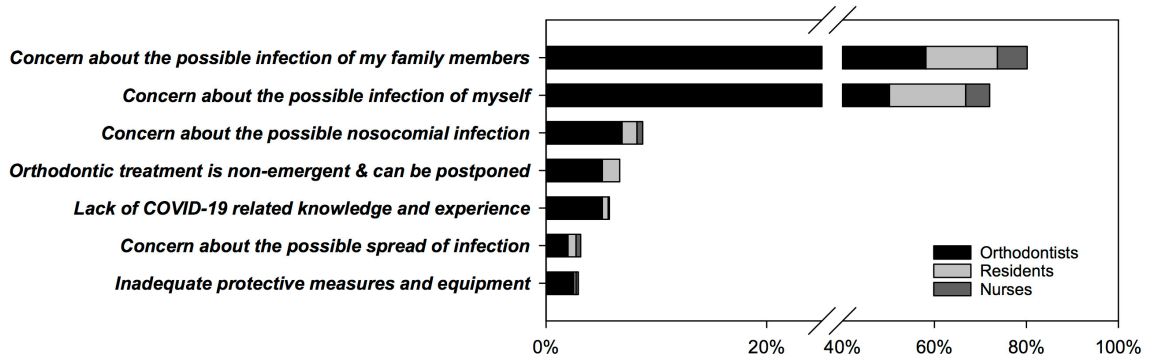

FIGURE 3 | The reasons for being unwilling to treat or care for patients confirmed or suspected with COVID-19 (semi-open question, #31) ($n = 958$).

are gradually resuming, orthodontic professionals in China are generally confident that they understand COVID-19-related risks and knowledge, and about two-thirds of them are willing to treat or care for COVID-19 patients. In addition, COVID-19-related training programs are essential for the improvement of knowledge, confidence, and preparedness of orthodontic professionals before work resumption. Sufficient and proper protection should also be provided to ensure safety and reduce the psychological burden on them.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of School & Hospital of Stomatology, Wuhan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

FH: study conception. FH, DQ, and HH: study design. FH, DQ, JY, TZ, and HH: data collection. FH and DQ: data analysis and manuscript drafting. HH: data interpretation. JY, TZ, and HH: critical revision of the manuscript. All authors: approval of the final version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2020.00481/full#supplementary-material

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A Dental Response to the COVID-19 Pandemic—Safer Aerosol-Free Emergent (SAFER) Dentistry

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Dental services are significantly impacted by the COVID-19 pandemic. Almost all dental procedures carry a high infection risk for providers and patients due to the spread of aerosols. As a consequence, public health agencies and professional associations have issued guidelines for enhanced infection control and personal protection equipment and have also limited care to urgent or emergency services. However, there is no dental service concept for pandemic disaster preparedness or response that might be applied. Moreover, pathways to dental care provision in a post-pandemic future with persisting risks are needed. We propose *Safer Aerosol-Free Emergent Dentistry* (SAFER Dentistry) as one approach to dental services during and emerging from the pandemic. The concept's starting point is the identification of the most common patient needs. The next step is to replace common treatments addressing the most frequent needs with alternative interventions involving a lower infection risk because they do not generate aerosols. SAFER Dentistry is innovative, avoids risk, and responds to the requirements of a pandemic and post-pandemic emergency where the risk of airborne disease transmission remains high. SAFER Dentistry thereby ensures continuity of dental services while protecting providers and patients from infectious pathogens. Moreover, SAFER Dentistry allows dental service providers to remain operational and generate income even under pandemic conditions. Potential implementation and policy options for SAFER Dentistry include universal availability without co-payments by patients and a uniform bundled payment scheme for providers to simplify budgeting, reimbursement, and administration during a pandemic. Adaptations and adjustments of the concept are possible and encouraged as long as the principle of avoiding aerosol-generating procedures is maintained.

Keywords: COVID-19, infection control, pandemic preparedness and response, infectious dental aerosols, airborne transmission of diseases, dental care, emergency dental service

SARS-CoV-2 DISRUPTS HEALTH CARE AND DENTISTRY WORLDWIDE

In a crisis, be aware of the danger, but recognize the opportunity. John F. Kennedy.

Healthcare services are adapting to the COVID-19 pandemic, yet oral health care and dentistry are particularly affected due to the proximity to the patient and the generation of aerosols through common treatment procedures. The SARS-CoV-2 virus seriously disrupts routine dental procedures around the world. The reports, analyses, and recommendations emerging alongside first-hand experience from dental settings in China are alarming (1, 2). The risks of infection for oral health personnel as well as cross-infection between patients and anyone in a dental care setting are high.

The toll of the COVID-19 pandemic on health systems and availability of dental care has been unprecedented. At the height of the pandemic in the U.S., about 80% of practices offered only limited emergency services, and 17% did not see patients at all (3). This impacts heavily on service availability and patient access to essential services. At the same time, such service limitations result in significant economic losses for the entire dental sector, leading to layoffs of dental teams and growing unemployment. In addition, the prospect of re-starting services remains bleak and uncertain and will be so for months to come (4). Little is known so far about the impact on dental services in low- and middle-income countries, though recommendations for service limitations to emergency care and increased precautions were issued in many countries (5).

THE INFECTION RISK FROM AEROSOLS IN DENTISTRY

Dental teams are generally used to high standards of infection control and personal protection measures owing to the fact that dental personnel are among the most at risk for any kind of infection transmitted via contaminated aerosols and saliva, bodily fluids, blood, or tissue particles (6, 7).

Current evidence suggests three main pathways for virus transmission in dental settings: (1) direct transmission through inhalation of cough, sneeze, or droplets containing the virus; (2) transmission via eye, nasal, or oral mucous membranes; and (3) contact transmission through contaminated surfaces (2). All these transmission pathways are facilitated and possibly amplified by aerosols that are generated by most dental procedures (7, 8).

In reaction to the COVID-19 pandemic, international and U.S. federal public health agencies, as well as dental professional associations, have issued specific guidance for the control of SARS-CoV-2 in dental practice (5, 9–13).

These recommendations focus on three main areas where adaptation to the pandemic context is required to break potential transmission chains: patient management and teledentistry to prevent sick or possibly infected patients from coming to the practice, enhanced infection-control measures that include strict protocols for personal protective equipment (PPE), and limitation of dental care to urgent and emergency procedures. Some authorities demand that for patients with COVID-19 symptoms, emergency oral health care should be performed in a negative-pressure operatory with maximum PPE to reduce infectious health hazards (14, 15). Countries like the UK have therefore established special dental care centers to ensure appropriate protection (16).

In the U.S., the Occupational Safety and Health Administration (OSHA) considers work environments where aerosols may occur to be of high or very high infection risk for COVID-19 (14). In a specific update for dentistry, the OSHA requires telephone triage, office engineering controls that include air circulation and patient isolation, universal precautions for airborne pathogens, the use of PPE appropriate for the pandemic, limiting care to urgent and emergency procedures that do not generate aerosols, and environmental cleaning post-care. The recommendation for airborne infection isolation rooms (AIIR) with negative pressure is in line with the U.S. Centers for Disease Control and Prevention's (CDC) existing guidance (17).

Such measures beyond the standard dental infection-control procedures are challenging due to limited or costly supplies of PPE, and they would require significant infrastructure investments. Many of the requirements are unrealistic to achieve even in sophisticated university dental college settings, at least in the short term. For many dental care contexts, such as mobile dental services for schools, remote communities, nursing homes, prisons, homeless shelters, or refugee camps, as well as dental services in low-resource settings where the shortage of supplies is a constant challenge, such enhanced protective measures are near impossible.

The risks from infectious aerosols are central to all recommended alterations of current dental practice, yet uncertainties and open questions related to transmission details remain and oblige dental practitioners to assume they are operating under the highest possible infection risk and to act accordingly with appropriate precautions (18).

Dentistry as we know it is seriously disrupted and may not be able to return to the clinical routines of a pre-COVID-19 time. At this point of the pandemic, dentistry needs a concept for continued dental services that avoids procedures generating infectious aerosols while being able to address the most frequent patient oral health needs.

SAFER AEROSOL-FREE EMERGENT (SAFER) DENTISTRY

With aerosol-generating procedures being at the core of the current challenge for dental services, interventions that avoid aerosol generation should be the interventions of choice. Such procedures exist and may replace possibly hazardous "standard" therapies in an emergency context with airborne pathogens such as SARS-CoV-2. We propose the concept of *Safer Aerosol-Free Emergent Dentistry* (SAFER Dentistry). SAFER Dentistry builds on a prioritization of the most common patient needs, and systematically selects bundles of effective,

TABLE 1 | SAFER Dentistry Packages and intervention options.

	Package	Intervention options without aerosol risk	Conventional options with aerosol risk	References
1	Examination	• Teledentistry–remote triage, examination and counseling • Pre-examination antiseptic mouthrinse • Visual examination • Examination with instruments ○ Probing, percussion test ○ Pulp vitality testing (ice-pellet/heated gutta-percha/electric testing) • Extraoral X-ray if available and required (OPG)	• Intraoral x-ray (risk of avulsion & coughing) • Temperature test with cold air blow (saliva splatter) • Tactile examination/palpation	(19) (2) (20) (21) (1) (22)
2	Pain: Swelling & infection	• Local anesthesia • Incision of abscess & drainage • Or/and antibiotic therapy • Or tooth extraction (avoiding surgical separation or drilling)		(23) (1)
	Pain: Toothache & pulpitis	• Local anesthesia • Trepanation/opening of pulp chamber with hand instrument (excavator), extirpation & disinfection of root canal, temporary filling • Or tooth extraction (avoiding surgical separation or drilling)	• Trepanation with drill & spray • Machine preparation and cleaning of root canals	(22) (23) (24) (1)
3	Pain: Toothache & caries Caries prevention	• Silver diamine fluoride (SDF) • Glass ionomer sealants • Atraumatic Restorative Treatment (ART) with glass ionomer • Fluoride varnish • Fluoride gel/5,000 ppm F toothpaste	• Caries excavation & traditional restorative care (drilling & filling)	(25) (26) (27) (28) (29)
4	Acute periodontitis/pericoronitis	• Cleaning and scaling with hand instruments • Antibiotic therapy (if indicated) • Antiseptic mouthrinse/gel (i.e., CHX)	• Ultrasonic scaling and machine polishing	(22) (1) (30)
5	Broken denture Orthodontic emergency & post-surgery care	• Direct reline/rebase • Removal/adjustment of broken orthodontic wire causing serious irritation • Removal of stitches from previous surgery	• Indirect repair with impression/laboratory technician (risk of avulsion & coughing)	(31) (22)

evidence-based, and value-based care that do not require aerosol-generating procedures.

Focusing on emergency and urgent dental services, SAFER Dentistry addresses common care scenarios with a set of bundled interventions. **Table 1** details the treatment options with significantly lower risk of generating aerosols, including scientific references for the respective non-aerosol options. They comprise the following.

1. Examination/diagnosis via in-person teledentistry: when performed in person, this includes antiseptic mouthrinse and visual and/or tactile inspection without intraoral radiography for diagnosis.
2. Acute pain, swelling, or infection: depending on the diagnosis, pulp devitalization/temporary filling (pulpitis), antibiotic therapy (acute inflammation), and/or local anesthesia and tooth extraction.
3. Toothache due to caries without pulpal involvement: silver-diamine-fluoride application (SDF), glass-ionomer sealants/Atraumatic Restorative Treatment (ART), fluoride varnish/gel, and/or toothbrushing with high fluoride-containing toothpaste (HFT, 5,000 ppm fluoride).
4. Acute periodontitis: hand scaling and metronidazole/amoxicillin combination for 1 week.
5. Denture repair/reline, lost crown or orthodontic bracket, or orthodontic wire: denture repair with soft re-line, crown and bracket re-cementation, and wire adjustment, repair, or removal as well as removal of stiches from previous surgery.

The interventions of SAFER Dentistry are effective and realistic, even for resource-poor settings. Individually, they have been used for decades and have been promoted widely (30). The systematic bundling and prioritization, however, is new and innovative and responds to a pandemic and post-pandemic

context where the risk of disease transmission remains high or might be intermittently increasing or decreasing. This approach ensures that dental services can continue during a pandemic by providing oral health care for the most frequent patient needs, while protecting providers and patients from pathogens. Dental teams will require little to no additional training to perform the interventions of SAFER Dentistry, since none of the procedures are new or unknown.

There is no clinical dental care situation without any infectious risk. The alternative interventions suggested are not completely risk-free, but carry a significantly lower and more manageable risk. We therefore use the acronym SAFER Dentistry in analogy to the HIV pandemic's response concept of *Safer Sex*, which also significantly reduces the risk of transmission of HIV and other sexually transmitted diseases (32).

HEALTHY SYSTEM OPTIONS FOR IMPLEMENTING SAFER DENTISTRY

Pandemics are a constant challenge to public health and reveal with relentless clarity the shortcomings of health systems in terms of capacity, coverage, quality, and financing. The same applies to inequalities and differential impact of the pandemic on different population groups. Oral health status and access to dental care has long been recognized as a prime example for such challenges (33). With millions of people unemployed due to the COVID-19 pandemic, many are losing their health insurance benefits at a time when most needed. There is growing recognition that basic health (and oral health) services are a public good that should be universally available for everyone, irrespective of their employment status (34). SAFER Dentistry, covering the most frequent oral health needs, is one starting point for a basic oral health benefit package. Further adaptations and evolving implementation may also include aerosol-free cavity prevention (dental sealants and the like) and other preventive measures to reduce the need for dental care as pandemics continue to emerge. In order to ensure maximum population coverage, we propose that SAFER Dentistry be universally available with no co-payments. Initial economic modeling for children shows that SAFER Dentistry is cost-saving and cost-effective compared to conventional aerosol-generating interventions (35).

Providers could be reimbursed through a single, uniform payment for any combination of examination and additional procedure, thereby simplifying documentation, billing, and reimbursement, which is of particular importance in an emergency context. Such an approach would work for health systems relying on a fee-for-service approach as well as for capitation-based systems. However, the details of the required changes in guidelines, service directives or other adaptations need to be determined nationally/locally depending on existing conditions, resources, local guidelines, and political support. Aspects of teledentistry should be included in the benefit package since they will become a more frequent practice and specific reimbursement positions are often not yet in place (19).

As the pandemic and related limitations of clinical practice endure, more and more patients will have to use emergency hospital services for relief of their dental problems. In the US, even without a pandemic, every 15 s a patient visits a hospital emergency service for dental care due to millions lacking dental insurance coverage (36). Universally available SAFER Dentistry would reduce such hospital visits for common dental ailments and unburden hospital personnel, infrastructure, and resources; it would instead offer an opportunity for dental service providers to remain operational and generate income. At the same time, SAFER Dentistry allows providers to offer a safe and hygienic service environment as a key component to regaining patient trust in the period of pandemic recovery.

CONCLUSIONS

The early experiences in dentistry from China during this COVID-19 pandemic are instructive and telling: They implemented rapid and bold actions to contain the pandemic, including limited emergency dental services in a tertiary care center with maximum precautions (1). The UK and other countries also established specialized emergency care centers for dentistry (37, 38). Yet, the level of infrastructure and service provisions possible in such centers are not realistic for general dental practices or oral health training programs in the U.S. or globally.

SAFER Dentistry, together with general measures to mitigate risk in dental settings, is an adaptation to a pandemic emergency and a pandemic recovery process by avoiding hazardous infectious aerosols. It is also a first step toward oral health care that does not require complex technology, as envisaged in the landmark Lancet Series on Oral Health (39). If continued and institutionalized as a universally available benefit and coverage feature, substantial gains in oral health status and significant reductions in oral health care expenditure could be achieved in the long run.

The dangers of the crisis are clear. Continuation of dentistry as usual during the COVID-19 pandemic will result in incalculable risks for patients and providers. For U.S. governmental agencies and professional organizations, oral healthcare training institutions, clinicians, and patients not willing to accept a complete shutdown of oral healthcare, including deterioration of health and well-being, there is no alternative to SAFER Dentistry.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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The Role of Dentists in COVID-19 Is Beyond Dentistry: Voluntary Medical Engagements and Future Preparedness

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The emergence of the highly infectious novel coronavirus SARS-CoV-2 has led to a global COVID-19 pandemic. Since the outbreak of COVID-19, worldwide healthcare systems have been severely challenged. The rapid and explosive surge of positive cases has significantly increased the demand for medical care. Herein we provide a perspective on the role dentists can play in voluntary medical assistance and future preparedness for a similar pandemic. Though dentists and physicians have different scopes of practice, their trainings share many similarities. Hence, dental professionals, with their knowledge of basic human science and sterile surgical techniques, are an invaluable resource in the COVID-19 pandemic response. Overall, it is commendable that many dentists have risen to the challenge in the fight against COVID-19. For example, in Singapore, National Dental Centre Singapore (NDCS) deployed dental clinicians as well as volunteers from research laboratories to screen for suspected cases, provide consultations as well as conduct swabbing operations. Dental practice will be considerably changed in the post-COVID-19 era. There is a greater need to have refresher courses for practicing dentists on new infection control strategies. Moreover, the curriculum in dental schools should be expanded to include competencies in pandemic and disaster relief. In addition, voluntary medical work should be made a part of the community dentistry curriculum. This volunteerism will leave a positive impact on developing the careers of young dentists. Hence, the contribution of dentists beyond dental practice in this pandemic situation will be appreciated by future generations.

Keywords: COVID-19, dentistry, voluntary work, preparedness, infection control

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BACKGROUND

The emergence of the highly infectious novel coronavirus has led to a global pandemic in a span of just 3 months. It was only on 31 December 2019 that first reports of pneumonia of an unknown cause detected in Wuhan, China, began to surface to the World Health Organization (WHO). Provisionally named as 2019 novel coronavirus (2019-nCoV), there was evidence of exponential human-to-human transmission in the early outbreak stage (1–3). Consequently, on 30 January 2020, the WHO declared the outbreak a Public Health Emergency of International Concern (PHEIC). Subsequently, assessment by the Coronavirus Study Group (CSG) of the International

Committee on Taxonomy of Viruses found that SARS-CoV-2 clusters phytogenetically with the species *Severe acute respiratory syndrome-related coronavirus* (SARS-CoVs) and genus *Betacoronavirus*, and formally designated it as *Severe acute respiratory syndrome coronavirus 2* (SARS-CoV-2) (4). CSG also emphasized that the name SARS-CoV-2 has no relationship to the name of the SARS disease caused by SARS CoV-1. In fact, the SARS CoV-2 genome shares only 79.6% similarity to that of SARS-CoV-1 (5). The initial sequencing of the new coronavirus revealed that it is closely related to betacoronaviruses of bat origin i.e., bat-SL-CoVZC45 (87.99% similarity) and bat-SL-CoVZXC21 (87.23% similarity) (5). More recent genome sequencing showed that a bat coronavirus BatCoV RaTG13 originally found in the bat *Rhinolophus affinis* from Yunnan Province, China has 96.2% genome similarly to that of SARS CoV-2 (6). These foregoing studies indicate that the bats are the likely zoonotic reservoir host for SARS CoV-2. Although bats may be the original source of the new coronavirus, it is assumed to be transmitted to humans via an intermediate host, possibly pangolins or wild animals currently yet unknown (7). On 11 February 2020, the WHO announced coronavirus disease 2019 (COVID-19) to be the disease caused by SARS-CoV-2. Subsequently, many countries continued to experience clusters of cases and community transmissions. This led the WHO to declare the COVID-19 outbreak a pandemic on 12 March 2020.

GLOBAL HAVOC CAUSED BY COVID-19

As of 26 July 2020, more than 15.78 million confirmed cases of COVID-19 and 640,016 associated deaths have been reported worldwide (8). With the number of infected cases surging each day, researchers are racing to understand what makes it spread so easily. From the evidence so far, the transmission of SARS-CoV-2 can occur via respiratory droplets, contact and aerosols (9). A major factor facilitating the transmission of COVID-19 is the high level of SARS-CoV-2 shedding in the upper respiratory tract, even among pre-symptomatic patients (10). It has been reported that pharyngeal virus shedding of SARS-CoV-2 reaches its peak on day 4 of symptoms onset, and it can be over 1,000 times higher than SARS-CoV-1 (11). Numerous cases have been reported wherein patients who had positive test results were asymptomatic at testing (12). Moreover, the asymptomatic incubation period for infected individuals could be ∼1–14 days in general, although longer incubation periods as long as 24 days have been reported. Thus, symptom-based screening alone may have failed to detect a high number of COVID-19 positive cases and most likely contributed to the rampant transmission.

IMPACT OF COVID-19 ON HEALTHCARE PROVIDERS

Since the outbreak of COVID-19, worldwide healthcare systems have been severely challenged. The rapid and explosive surge of positive cases have led to a significant increase in the demand for medical care. On the infrastructure front, hospitals have actively scaled up their capacity of basic and critical care beds. However, global medical manpower resources are finite. Consequently, many hospital-based healthcare workers have had to work over-hours and take on extra shifts. Such stressors have been associated with reduced job performance and fatigue-related errors which could harm patients (13). In responding to this crisis with a multi-sectorial, equitable and human-rights focused approach, the United Nations entities have called for voluntary support from professionals with medical backgrounds for various job capacities to manage the pandemic (14).

ARE DENTISTS EQUIPPED TO SUPPORT WORKFORCE WORKING AGAINST COVID-19?

Though dentists and physicians have different scopes of practice, their trainings share many similarities. The dental student, like his medical counterpart, has to attain proficiency in his understanding of the basic sciences such as anatomy, physiology, pharmacology, and microbiology. This is essential given that dentists are expected to competently manage dental issues of medically compromised patients. Moreover, dentists must be able to expeditiously and effectively manage medical emergencies that may arise in routine dental practice. To this end, many dental practitioners would have undergone basic cardiac life support training. Thus, the robust training of clinical medicine in dentistry strengthens the candidature of dentists to volunteer services for COVID-19 control and spread.

The outbreak of COVID-19 has significantly affected the practice of dentistry. Dental treatment can generate large amounts of aerosols and droplets mixed with the patient's saliva or blood (15). This poses a risk to dental professionals as SARS-CoV-2 has been detected in saliva of infected individuals (16). Many dentists have therefore discontinued the provision of elective dental treatment, in accordance with guidelines released by national-level government healthcare authorities such as the Centers for Disease Control and Prevention (CDC) in the US and National Health Service (NHS) in the UK. Only limited cases that require urgent or emergency dental care continue to be seen. The significantly reduced workload during this time, coupled with robust training in a medical setting, makes the dentist a prime candidate to volunteer in the fight against COVID-19.

HOW CAN THE DENTAL FRATERNITY PLAY THEIR PART IN THE CURRENT CRISIS?

Dental professionals, with their knowledge of basic human science and sterile surgical techniques, are an invaluable resource in the COVID-19 pandemic response. Licensed dentists are eligible to administer COVID-19 diagnostic tests such as nasopharyngeal and oropharyngeal swabs. With their detailed understanding of head and neck anatomy, dentists are well placed to perform such procedures accurately and atraumatically. This is imperative as irritation to the oral or nasal mucosa while swabbing risks the patient sneezing or coughing, potentially releasing contaminated droplets and aerosols to the environment.

TABLE 1 | Key considerations and recommendations on how dental fraternity can play their part in the current crisis and recommendations for dental implementation in post-COVID-19 era.

Key considerations	Recommendations
How dental fraternity can play their part in the current crisis	Administer COVID-19 diagnostic tests • Nasopharyngeal swabs • Oropharyngeal swabs • Salivary sampling
	Volunteer appropriately equipped dental clinics as screening facility • Negative pressure rooms • High-volume excavators
	Assist medical counterparts in the inpatient setting
	Develop online platforms to promote oral hygiene and oral health maintenance
Recommendations for dental implementation in post-COVID-19 era	Revise and strengthen education on infection control measures in dental practice
	Dental education should include competencies in pandemic and disaster relief • Training to administer COVID-19 diagnostic tests • Training to be part of an effective surveillance network
	Include voluntary medical work in the community dentistry curriculum
	Organize refresher courses for practicing dentists on infection control and best practices

Unlike negative-pressure rooms, many makeshift medical screening facilities are unable to limit the aerosol spread of SARS-CoV-2. This may lead to contamination of open-air healthcare facilities. In this context, dental clinics that are well equipped with facilities to control aerosol spread of infections, such as negative pressure rooms and high-volume excavators, can offer help to augment the capacity for COVID-19 screening. In this regard, global health authorities as well as health ministries from the respective countries have provided clear standard infection control procedures for dentists (17–19).

Dentists can also assist their medical counterparts in the inpatient setting. Such duties include patient triage, monitoring vital signs, administering oxygen and injectables, and writing prescriptions. Should emergency procedures need to be performed, dentists are capable of administering local anesthesia and suturing. In addition, oral surgeons and dentist anesthesiologists are competent in performing intubation, deep sedation and general anesthesia services (20).

The COVID-19 outbreak as well as harsh lock down practices worldwide have created a stressful environment for many people globally. Such stressful situations have been shown to lead to poor oral health (21, 22). Therefore, oral healthcare professionals should consider developing online platforms to provide information on oral hygiene and oral health maintenance. Digitalized healthcare services can be implemented with a qualified team of dentists being available online to provide reliable oral healthcare solutions in an accessible, affordable and appropriate manner and allay patients' dental concerns during the lockdown period. Oral healthcare professionals can also engage in voluntary service for residents in community housing to promote good oral health. The recommendations on how the dental fraternity can play their part in the current crisis are summarized in **Table 1**.

EVIDENCE REPORTS OF VOLUNTEERING ACTS BY DENTISTS ON THE GLOBAL FOREFRONT

In Singapore, while limited community transmission of COVID-19 remains, there has been a rapid surge in the number of infected cased among foreign workers living in dormitories. Such facilities become conducive for rapid spread of SARS-CoV-2 as residents are housed in close proximity and share many common amenities. In a whole-of-government approach to isolate and eradicate the virus, the Singapore government implemented aggressive mass-scale testing for COVID-19 for foreign workers residing in dormitories. This major operation was undertaken by multiple agencies including Singapore Health Services (SingHealth), Singapore Police Force and Singapore Armed Forces. Supporting this move, National Dental Centre Singapore (NDCS) deployed dental clinicians as well as volunteers from research laboratories to the foreign worker dormitories to conduct swab operations. All patients were treated as suspect cases, and all volunteers observed universal precautions and donned appropriate personal protective equipment (PPE). The use of specially manufactured swab booths further minimized the risk of cross-infection between patients and volunteers (**Figure 1**). In this massive operation, NDCS staff worked collaboratively with colleagues across various professional backgrounds including clinicians, nurses, pharmacists, radiographers, and medical social workers (**Figure 2**). Without the cohesive and coordinated effort, it would have been a considerable task to successfully establish and staff the field swab clinics within a short period of time.

In the UK, dentists, dental support teams as well as clinical academics have played a vital role in supporting the NHS (23). For instance, there are news reports that dental staff from Bath Health NHS Trust and QMUL Institute of Dentistry are helping in maternity, critical care, and emergency units. Dental hospitals have undergone reconfiguration to support medical care. In the US, dentist volunteers in states such as Virginia and California have responded to appeals to assist with critical emergency care needs, and have been redeployed to the frontlines. Importantly, states such as California have made changes to their law to allow greater flexibility in scope and licensure in the time of a catastrophic emergency. The law provides immunity from liability for care provided "in good faith" during an emergency for a person who "voluntarily and without compensation or expectations of compensation, and consistent with the dental education and emergency training that he or she has received,

FIGURE 1 | Dental clinicians from National Dental Centre Singapore were trained to conduct swab procedure using swab booths manufactured in Singapore (Photo credit: National Dental Centre Singapore).

FIGURE 2 | A team of Singapore Health Services (SingHealth) volunteers assigned to manage a medical clinic at a foreign workers' dormitory in Singapore. This team included a neurologist, a dental scientist, a pharmacologist, a cancer patient service associate, a radiographer and nurses (Photo credit: National Dental Centre Singapore).

provides emergency medical care to a person during a state of emergency." This would be an important consideration for other countries to follow.

RECOMMENDATIONS FOR DENTAL IMPLEMENTATION IN POST-COVID-19 ERA

COVID-19 has been an unprecedented experience for mankind. The scale and extent of the pandemic has forced many governments to take drastic and decisive action, resulting in considerable disruption in daily life and damage to global economies. This episode has revealed the need to be better prepared for future pandemics. To this end, educational institutions can take the lead. Dental schools should revise and strengthen education on infection control measures in dental practice. Some areas where universal precaution protocols can be re-evaluated and strengthened include hand hygiene, donning and doffing of PPE, respiratory hygiene/cough etiquette, sterilization of instruments and devices, and disinfection of workplaces. Additionally, with the growing evidence of asymptomatic transmission of COVID-19, infection control practices should be re-examined and improved to prevent cross-infection in a dental setting. Notwithstanding, recent attempts have been made to review the current literature on precautions when providing dental care during the current pandemic, and make recommendations for dental practitioners (24, 25).

The curriculum in dental schools should also be expanded to include competencies in pandemic and disaster relief. Such exposure enable dentists and their dental auxiliaries to augment the existing medical professionals in response to declared medical emergencies. Dentists have already been trained to undertake oral swab procedures and biopsies as part of oral cancer screening. However, in the wake of a pandemic outbreak, dental students should be additionally trained to perform nasopharyngeal and oropharyngeal swabs, as well as saliva sampling procedures. Dentists can also be a part of an effective surveillance network by notifying public health authorities about unusual oral symptoms or clinical presentations detected in questionable frequency in a population. Thus, dentists can facilitate the early detection of a disease outbreak or bioterrorism attack, and prevent mass casualties by prompt interventions.

In addition, voluntary medical work should be made a part of the community dentistry curriculum. In dentistry, clinical outreach programs during undergraduate training are still in their infancy. Such programs should be quickly scaled up. Several studies have reported that overseas voluntary outreach programs are a fulfilling and life-changing experience for dentists (26), and that community-based learning experience brings significant positive outcomes in terms of productivity and higher professional standards of dental students (27). With the expanded level of contact with patients from various strata of society, students will have additional opportunities to see the complexities of social and cultural aspects of their future patients. In addition, students are likely to gain appreciation for alternative career paths in public health as well as volunteer work. These experiences also have a positive impact on their understanding of ethical and social issues related to oral health care (28).

Some dental schools have already included community engagement programs as a part of the dental curriculum. Such engagements instill a sense of voluntarism in the minds of the dental graduates and prepare them to contribute in future disease outbreaks. A study looking at Stony Brook University's humanitarian dental mission to rural Madagascar found that all dental students who participated gained experience and confidence in their clinical ability and increased their speed in performing procedures under demanding conditions (29). Beyond medical training, such programs also nurture team work, communication skills and leadership qualities in young dentists.

Moving forward, it is likely that dental practice will be considerably changed in the post-pandemic era. Therefore, there is a greater need for refresher courses for practicing dentists on infection control in order to adjust with patients' apprehension in the post-COVID-19 world. Dental authorities and dental schools should urgently look into this need and appoint taskforces to develop protocols and appropriate courses for dental practitioners. Concurrently, research on infection control in the dental setting needs to be advanced. In order to formulate best practices, new research should be conducted across all disciplines of dentistry covering all procedures and their respective infection control strategies. The field of public oral health should find new research avenues on community oral health that can provide an insight on the perception and apprehension of patients during hospital visits. Such information would help to revive the financial viability of public hospitals and private clinics. The recommendations for dental implementation in the post-COVID-19 era are summarized in **Table 1**.

OCCUPATIONAL HEALTH AND SAFETY

Volunteers are being selfless in providing services amid crisis. However, it should be borne in mind that similar with medical staff, volunteers are also a vulnerable group. Preparation and medical support for volunteers during their placement is a significant aspect of any overseas voluntary work. Lack of understanding and preparation may expose volunteers to certain diseases during community engagement as well as subject them to psychological problems (30). Hence, it is highly advisable that proper training is provided to the volunteers. Volunteers should be trained on proper donning and doffing of PPE. It is important not just to minimize cross-infection but to keep it to zero. Therefore, strict infection control measures such as correct use of gloves and hand hygiene steps should be practiced. Volunteers working in close contact with COVID-19 positive patients should check for proper fit and size of N95 masks. It is very likely for cross-contamination to occur during public mass-scale swabbing operations. A single breach of the chain of infection control will put the whole team in jeopardy leading to quarantine of its members and closure of the medical facility.

Not all volunteers have the same physical and mental strength and the amount of volunteering work that one can engage must be monitored by group leaders and higher level authority. Frequent breaks in between and off days are necessary, in particular for a longer engagement, to support

mental and psychosocial well-being of the volunteers. It is also important to provide an understanding of the precautionary safe-distancing measures to be taken with family during and after engagement in risk activities. It is essential that volunteers are mindful of their own and their family's health while serving others.

CONCLUSION

Overall, it is commendable that many dentists have risen to the challenge in the fight against COVID-19. The role of the dentist in a pandemic can be beyond dentistry. By virtue of their training and practical experience, dentists can provide services in various ways to reduce the strain on the healthcare sector. Volunteerism in such a time also leaves a positive impact on the individual. Pandemics rarely occur, and practical experience gained will be a lifelong lesson for the volunteer. In fact, the fighting spirit of a volunteer working in risky operations instills a high moral esteem and self-confidence. The rejuvenated personality of the volunteer can prove to be valuable in developing his career in future. The selfless voluntary service will be appreciated by the larger community and future generations. Together we will be able to pull through this crisis and emerge stronger than before.

ETHICS STATEMENT

Written informed consent was obtained by the Ministry of Health Singapore for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

CJS and ML contributed to the conception. CJS, ML, and BTG drafted and critically revised the manuscript. All authors contributed to the article and approved the submitted version.

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COVID-19 Awareness Among Dental Professionals in Indonesia

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Background: The COVID-19 pandemic caused by SARS-CoV-2 has claimed thousands of lives worldwide. To enhance knowledge and awareness of COVID-19, considerable online resources have been made available, including aspects related to the dental profession. The study aim was to examine the knowledge, perception, and attitude of dental professionals in Indonesia toward COVID-19. We conducted a survey via a questionnaire created using Google docs and distributed to 632 members of the Indonesian Dental Association in the context of a webinar hosted by the Indonesian Oral Biology Association on first June, 2020.

Materials and Methods: The questionnaire consisted of 17 items pertaining to demographic data, knowledge and virus identification, awareness regarding drugs commonly used in dentistry during pandemic and research opportunities. Participants were asked to complete the questionnaire after the webinar by choosing one answer to each question. For the analysis, participants were divided into three groups according to their professional background i.e., employment at national hospital, private hospital, or academic faculty. Data were analyzed using descriptive statistics and expressed as frequencies and percentages. The chi-square test was used to investigate the association between professional activity and the level of knowledge, perceptions, and attitudes about COVID-19.

Results: Sixty percent of the participants correctly identified the pathogenesis of the disease. This knowledge was not associated with their professional affiliation ($p = 0.95$). Sixty-seven percentage had comprehensive knowledge about virus detection methods. This knowledge was not associated with their affiliation either ($p = 0.54$). Questions regarding drugs of choice, prevention, and the spread of COVID-19 were correctly answered by 89, 96, and 82% of the participants, respectively. Knowledge of these aspects were significantly associated with the professional affiliation ($p < 0.05$). All respondents were optimistic regarding research opportunities ($p < 0.01$). Respondents from academics were more interested in joining COVID-19-related research projects with governmental institutions ($p < 0.01$).

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Conclusion: Knowledge and awareness of COVID-19 among Indonesian dentists are reasonably good. However, further improvement would be beneficial to manage patients during this pandemic. As the number of COVID-19 cases continue to rise in Indonesia, it is important that dentists keep abreast of the updated knowledge on this moving field. Dentist knowledge on infection control should be strengthened through continuous educational programs.

Keywords: SARS-COV-2, knowledge, dentist, COVID-19, awareness

INTRODUCTION

Since it was first reported in Wuhan City, Hubei Province, Central China in December 2019, coronavirus disease 2019 (COVID-19) has become a major health concern worldwide (1). COVID-19 is caused by a novel coronavirus called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which causes pneumonia, with symptoms ranging from mild to deadly. SARS-CoV-2 infection can cause an acute inflammatory response (cytokine storm) and respiratory failure (2, 3). The World Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020 (4). As of July 6, 2020, COVID-19 had spread to 216 countries, causing 11,496,926 confirmed cases and over 535,390 deaths (5). Indonesia reported its first two cases on March 2, 2020. By July 6, it had reported 63,749 cases and 3,171 deaths (6). Indonesia currently has the highest COVID-19-related mortality rate in Southeast Asia.

Dental schools and their affiliated hospitals, as well as research laboratories have also been significantly affected by the pandemic. As a consequence, most research work has been stopped or undergone radical changes with severe limitations. These difficulties have been compounded by the absence of technical support as some experienced laboratory personnel belong to high-risk groups. However, this challenging situation has offered an opportunity to re-evaluate the our knowledge and understanding of the infection control measures related to dentistry and formulate new strategies in the post-COVID era (7).

The risk of viral transmission is higher for those who are close to or work near patients, such as relatives and health workers. To evaluate the preparedness of dentists to cope with the pandemic, many researchers around the globe are trying to assess their knowledge of COVID-19. In this study, we included the knowledge of characterization and method identification of SARS-CoV-2.

Due to the involvement of aerosol generating procedures, the dental profession is regarded as one of the occupations at the highest risk of SARS-CoV-2 infection. Therefore, it is critical that the risk of transmission through dental procedures is minimized through proper understanding and actions. Dentists should be well-aware of the characteristics of SARS-CoV-2 and new infection control standards. In the Indonesian context, many dentists, particularly in the private practice has opted to perform only emergency procedures during the pandemic. Hence, dental pain of the patients has been commonly managed with prescription of analgesics. In order to enhance knowledge on COVID-19 and the management of dental patients during the pandemic, Indonesian Oral Biology Association organized a series of webinars through Zoom platform. However, there

TABLE 1 | Demographic characterisatic of participants.

Characteristic		*n*	%
Sex	Woman	524	82.9
	Man	108	17.1
Age	20–30 years	139	22.0
	31–40 years	188	29.7
	41–50 years	146	23.1
	51–65 years	159	25.2
Occupation	Academic	175	27.7
	Government hospital	158	25
	Private hospital/private practice	299	47.3
Province	Riau	10	1.6
	Riau Islands	7	1.1
	Bangka-Belitung Islands	5	0.8
	Aceh	6	1.0
	North Sumatra	10	1.6
	West Sumatra	12	1.9
	South Sumatera	14	2.2
	Bengkulu	3	0.5
	Jambi	2	0.3
	Lampung	3	0.5
	Banten	42	6.7
	Jakarta	155	24.6
	West Java	109	17.3
	Central Java	54	8.6
	Yogyakarta	25	4.0
	East Java	88	13.9
	Bali	18	2.9
	East Nusa Tenggara	2	0.3
	West Nusa Tenggara	4	0.6
	Central Kalimantan	4	0.6
	North Kalimantan	4	0.6
	South Kalimantan	1	0.2
	West Kalimantan	3	0.5
	East Kalimantan	10	1.6
	South Sulawesi	29	4.6
	North Sulawesi	3	0.5
	North Maluku	1	0.2
	Papua	7	1.1

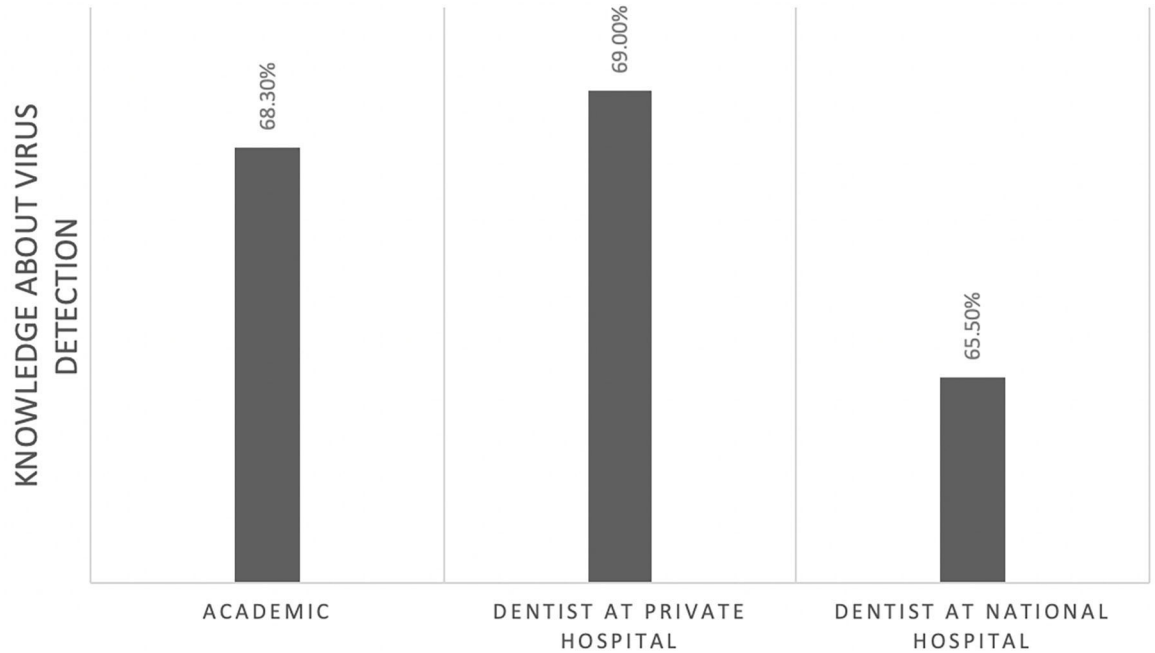

FIGURE 1 | Sixty percent of the participants correctly identified the pathogenesis of COVID-19. This knowledge was not associated with the professional affiliation ($p = 0.95$).

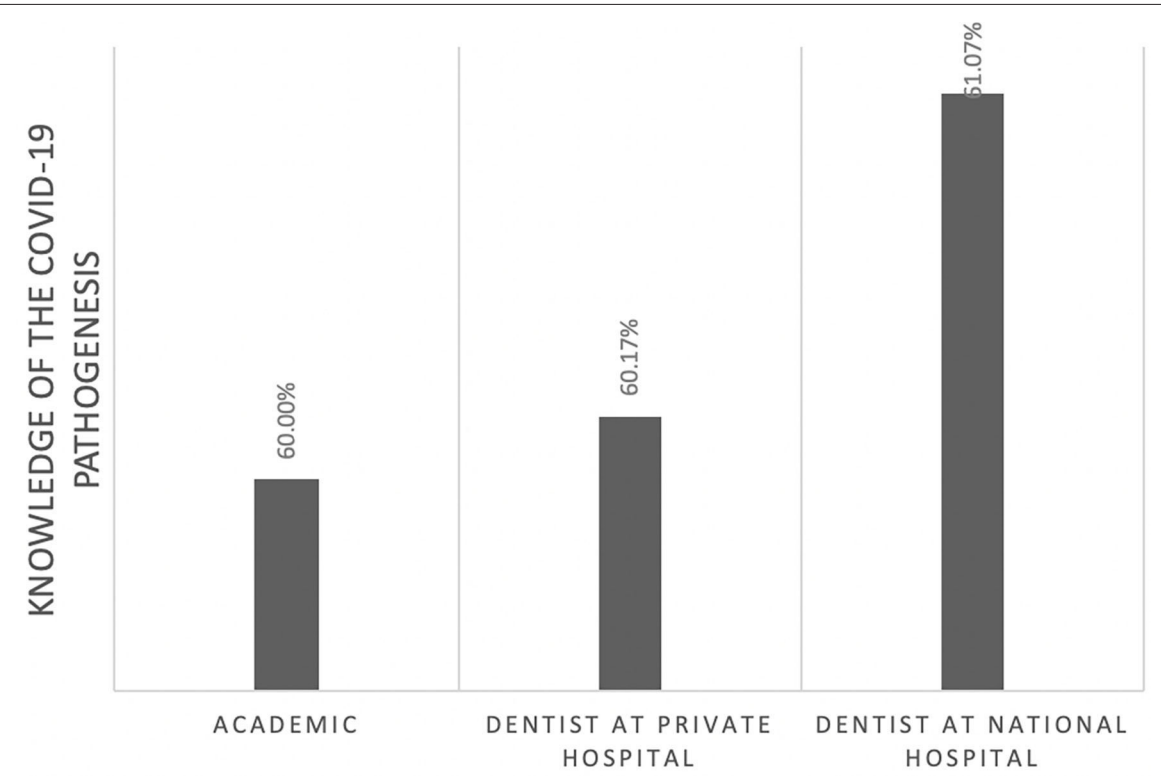

FIGURE 2 | Sixty-seven percent of the participants had comprehensive knowledge about virus detection. This knowledge was not associated with the professional affiliation ($p = 0.54$).

are no studies which has assessed the knowledge, perception, and attitude of Indonesian dentists on COVID-19. Considering this research gap, in the present study we evaluated the level of knowledge on SARS-CoV-2 and COVID-19 among dental professionals in Indonesia. In this study, we highlighted the most important research questions concerning the knowledge of the virus, the pathogenesis as well as the virus detection and infection prevention of COVID-19.

MATERIALS AND METHODS

This was a survey-based study conducted via a questionnaire distributed to all dentist members of the Indonesian Dental Association attending a webinar hosted by the Indonesian Oral Biology Association on first June, 2020 on COVID-19 related topic. The questionnaire was prepared in Indonesian native language. The original and translated version the questionnaire to English is given in the **Supplementary Material**. Google docs were used as a platform to create the questionnaire, which was then distributed online. Participants from any region of Indonesia were granted password-protected access to a URL hosting the questionnaire. A unique study ID ensured confidentiality of all self-reported data. The participants' responses were stored in a cloud database, where the data were automatically sorted, scaled, and scored using custom Microsoft Office Excel formulas. This study was approved by the Institutional Review Board of Faculty of Dentistry, Trisakti University (Jakarta, Indonesia) with approval number: 360/s3/KEPK/FKG/2020.

The questionnaire consisted of 17 items, including four pertaining to demographic information (age, gender, and residence and work locations), three regarding knowledge about the virus, two regarding the method identification of COVID-19, two regarding knowledge about its pathogenesis, two about infection control and precautions, two pertaining to awareness regarding drugs commonly used in dentistry during the pandemic, one regarding research opportunities, and one regarding research collaborations (Questionnaire is given in the **Supplementary Material**). The questionnaire was developed and confirmed after review by a panel of experts (EWB, BMB, MSD, and DNS). Construct validity of this questionnaire was done through intense discussion. The reliability of the questionnaire was statistically scaled as alpha Cronbach = 0.66. The participants were asked to choose one answer to each question. The level of optimism regarding research opportunities during the pandemic was assessed with a question that had three possible answers: "optimistic," "doubtful," and "pessimistic." Participants' willingness to cooperate with the government in COVID-19-related research projects was assessed with a question that had three possible answers: "yes," "maybe," and "no."

For the statistical analysis, the participants were divided into three groups according to their professional affiliation i.e., dentists employed at national hospital consist of dentist who work in the health center and government hospital. Dentists employed at private hospital consist of dentist who

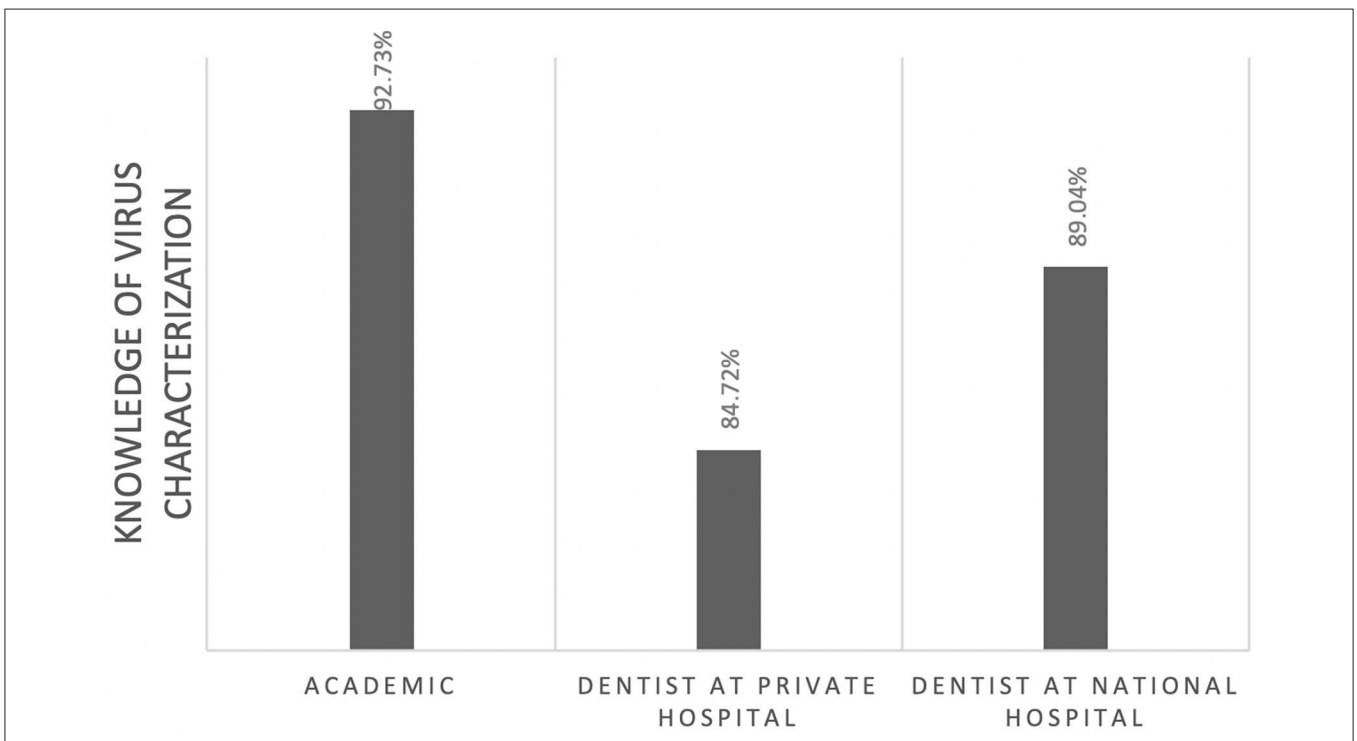

FIGURE 3 | Eighty-nine percent of the participants correctly identified the characterization of the virus. This knowledge was associated with the professional affiliation ($p < 0.05$).

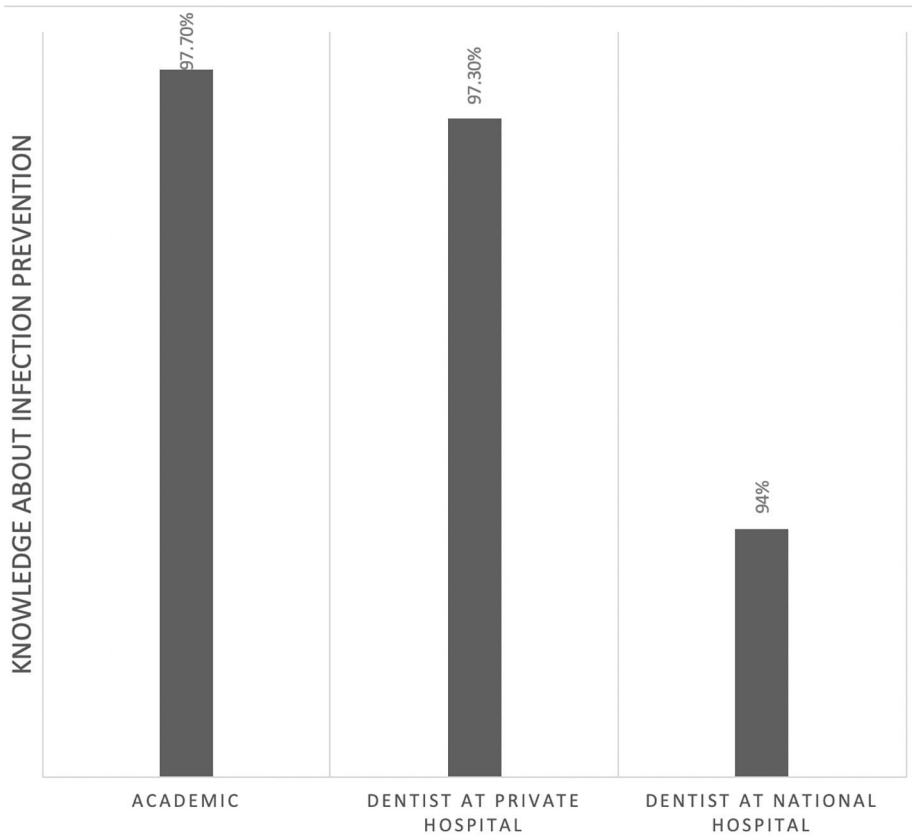

FIGURE 4 | Ninety-six percent of the participants were knowledgeable about infection prevention methods. The distribution showed a significant association between professional affiliation and knowledge ($p < 0.05$).

work in private hospital, private dental practice or dental clinic and employment as an academic in a dental school. Researchers downloaded questionnaire responses in multiple formats (Microsoft Office Excel), which were then analyzed using descriptive statistics and expressed as frequencies and percentages. The response rate to the study was 100%. We exclude participants who did not answer all the questions. We analyzed the correctness rate by calculating the average percentage of correct answer for all related questions in each topic. The chi-square test was used to investigate associations between professional background and knowledge, perceptions, attitudes about COVID-19 and to compare the levels of optimism regarding research opportunities and willingness to collaborate with the government between the three groups. IBM SPSS Statistics version 25 (IBM, Armonk, NY, USA) was used for the statistical analyses. The $p < 0.05$ was considered statistically significant.

RESULTS

The study cohort consisted of a total of 632 dentists who participated in the survey. Demographic features include 524 (82.9%) female and 108 (17.1%) male, age range from 20 to 65 years old, and from 28 provinces in Indonesia. The distribution of the professional affiliation includes 175 (27.7%) academics, 158 (25%) national hospital practitioners, and 299 (47.3%) private hospital/private practice practitioners as shown in **Table 1**.

Of those, 60% correctly identified the pathogenesis of COVID-19 (**Figure 1**). However, this knowledge was not significantly associated with their professional affiliation ($p = 0.95$). Sixty-seven percent had comprehensive knowledge about virus detection methods (**Figure 2**). This knowledge was not associated with their professional affiliation either ($p = 0.54$). Questions regarding virus characterization, prevention and drugs of choice for the dental treatment during COVID-19 pandemic were correctly answered by 89, 96, and 82% of the participants, respectively (**Figures 3**–**5**). Knowledge related to these aspects was significantly associated with the professional affiliation ($p < 0.05$). All respondents were optimistic regarding research opportunities ($p < 0.01$) (**Figure 6**). Respondents with an academic background from the dental schools were more interested in participating in collaborative research with governmental institutions ($p < 0.01$) (**Figure 7**).

DISCUSSION

This is the first study to assess the knowledge of COVID-19 among the dental professional in Indonesia. The most of

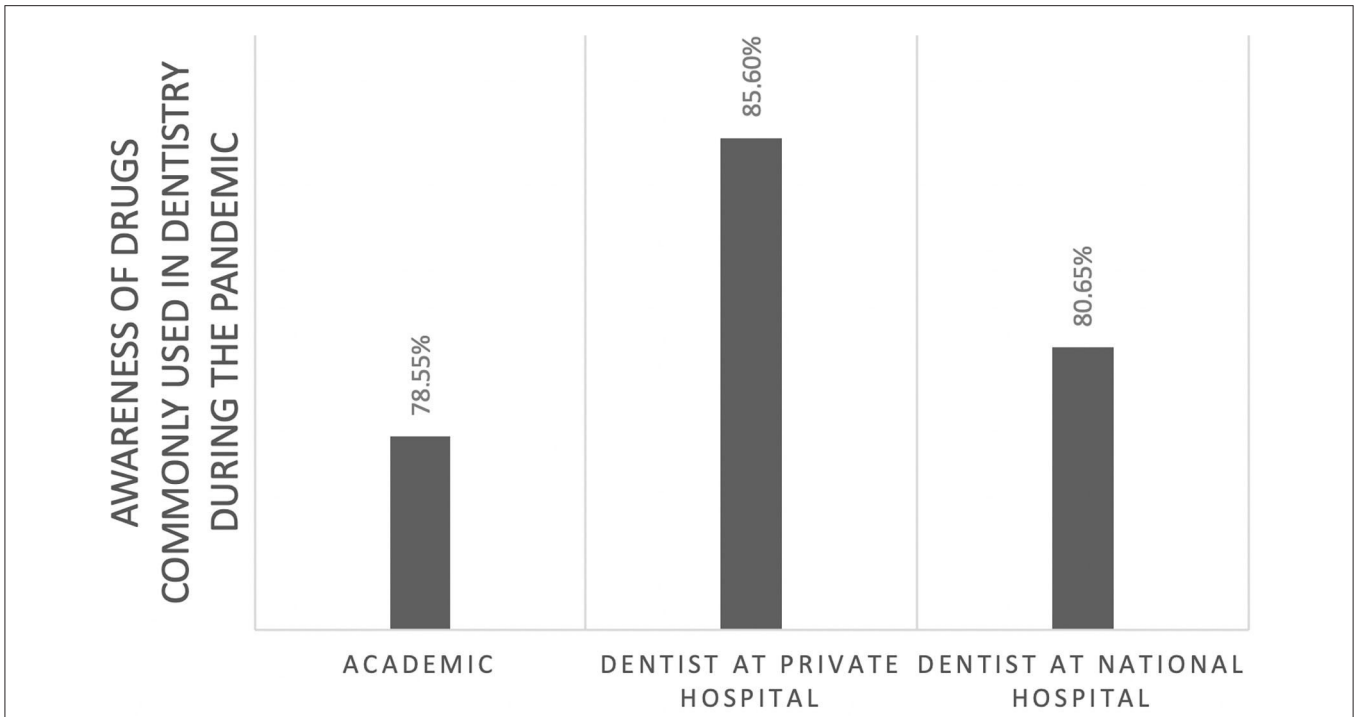

FIGURE 5 | Eighty-two percent of the participants correctly identified the drugs of choice. The distribution showed a significant association between professional affiliation and knowledge ($p < 0.05$).

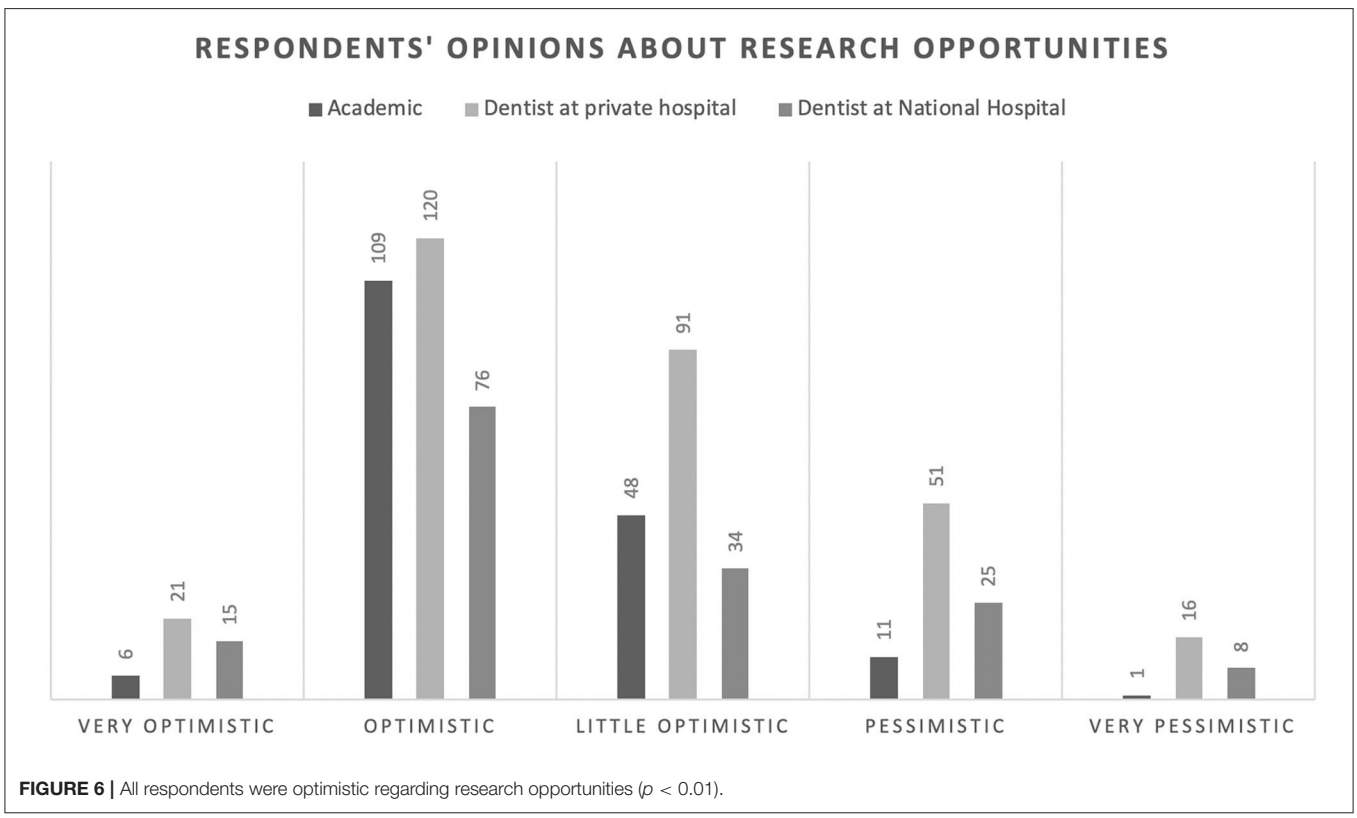

FIGURE 6 | All respondents were optimistic regarding research opportunities ($p < 0.01$).

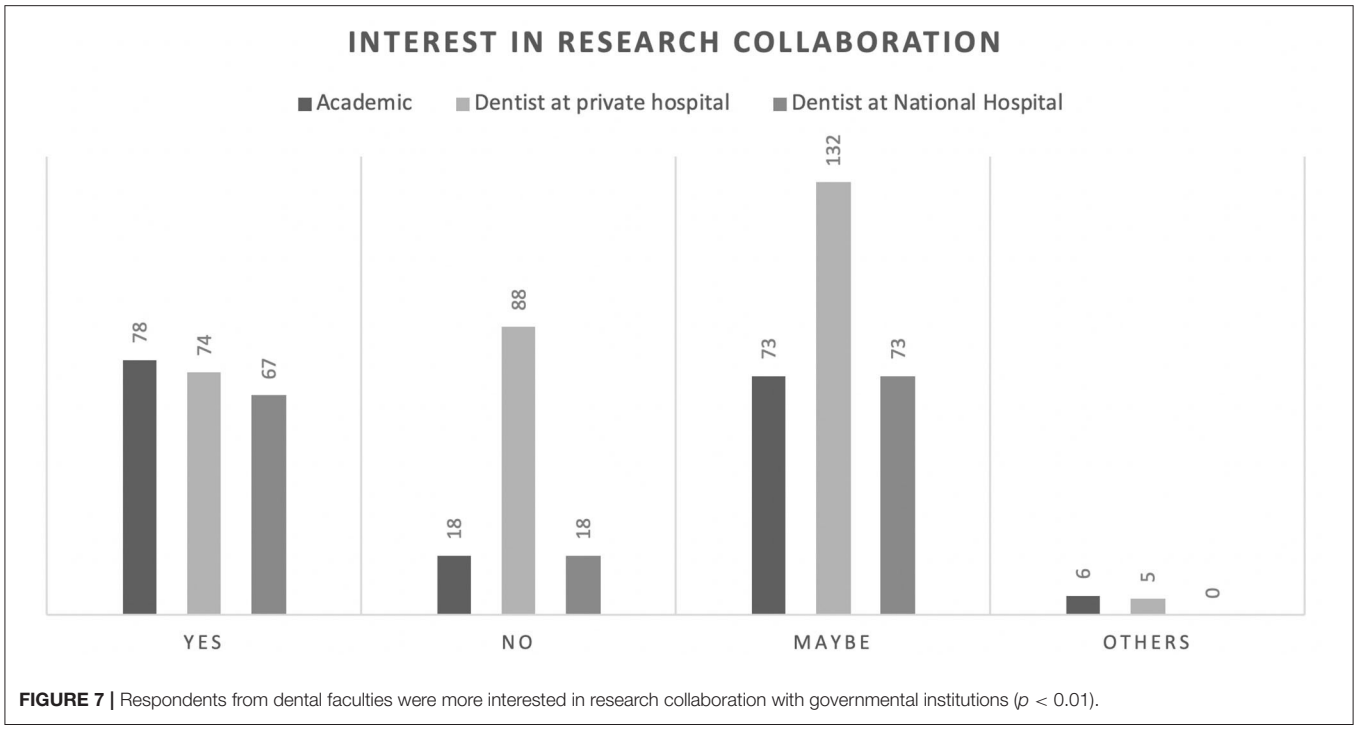

FIGURE 7 | Respondents from dental faculties were more interested in research collaboration with governmental institutions ($p < 0.01$).

the participants (47.3%) were dentists practicing in private hospitals or private practitioners. This result may be attributed to the fact that the recent increase of number of private dental hospitals in Indonesia. Although the government has launched an infrastructure development strategy in the recent years, with a target of 54 government dental hospitals in 2018 and 64 hospitals in 2019, much of this growth were seen in the private healthcare sector (8). Hence, it is important to educate the private dental practitioners in Indonesia on the post-COVID infection control measures.

The role of dental professionals in preventing the transmission of COVID-19 is critically important. In this study, 96% of the participants were knowledgeable about infection prevention methods. The distribution showed a significant association between professional affiliation and knowledge. In a similar study in Jordan which conducted among practicing dentists, it was found that 71.7% were aware of mode of transmission of COVID-19, and infection controls measures in dental clinics, and has the perspective that COVID-19 is a dangerous disease (9).

Our results showed that the knowledge regarding the general information and transmission, of COVID-19 among the dentist in Indonesia is sufficient, since most of dentists answer the survey questions correctly. Not only that, they also acknowledge their profession as a high-risk zone for virus transmission. This knowledge was associated with the professional affiliation, as dentists affiliated in private hospital and academics had a better knowledge compared to dentists in national hospital ($p < 0.05$). However, the majority of dentist who participated in this study was not able to differentiate the clinical symptom between common cold and COVID-19, as both of them share the same symptoms, such as fever, cough, sore throat, headache, and fatigue. Moreover, COVID-19 patients could be asymptomatic or even without fever. Therefore, suspected cases should be tested positive with specific molecular tests to confirm (10). Similar observations have been reported by researchers in United Arab Emirates, Iran and India in a study led by Bhagavathula et al. involving health care workers globally showed that factors such as age and profession were associated with inadequate knowledge and a poor perception of COVID-19 (11). Another study conducted in Saudi Arabia showed that the basic knowledge on COVID-19 among the dental health care workers in Saudi Arabia is acceptable (12).

Herein we also assessed how professional background and affiliation affect the knowledge of COVID-19 among Indonesian dentists. In general, dentists irrespective of their professional background i.e., in private practice or academics in dental school had a good understanding regarding SARS CoV-2, COVID-19 and its relationship with their professional affiliation, and the differences between the virus and the disease. However, our data showed that academics were more knowledgeable about the characterization of SARS-CoV-2, whereas private hospital dentists tended to know more about the identification method of SARS-CoV-2. This may be due to specific professional interests. Dentists in an academic background especially affiliated to basic sciences are likely to be more interested in biomolecular and technological approaches, while practicing dentists are more interested in applied sciences (13).

Private hospital dentists showed a better understanding of medicines used in dentistry than the other two groups. Academics exhibited the lowest level of understanding. The academics teaching basic science subjects in the dental schools may not engage in clinical practice which may have contributed

to their relatively lower understanding of the medicine. On the contrary, private hospital dentists who engage in patient care on daily basis continuously learn about developments in medicines to uphold their professional care (14).

At the beginning of the COVID-19 pandemic, a study claimed that taking ibuprofen could increase the risk factor of severe with SARS-CoV-2 because it could increase the levels of angiotensin-converting enzyme 2, to which the virus binds to infect the host (15). Subsequently, studies reported that ibuprofen was not found to increase risk of severe consequences from SARS CoV-2 (16–18). This is an example of why practicing dentists follow the latest developments about safe analgesics during the pandemic, as shown by the results of this study.

Dentists with academic background had a better understanding of infection control measures than the other two groups. Comparatively dentists serving government hospitals had a lowest understanding of infection control. Knowledge of infection prevention and daily preventive practices is critical during the COVID-19 pandemic.

Academics were the most optimistic regarding research opportunities (65.7%). Moreover, they were more willing to collaborate with governmental institutions (41.1%) in COVID-19 research. This is in line with the increasing number of studies on COVID-19. As of the time of writing this manuscript, according to the WHO, 39,608 COVID-19-related studies were published globally (19). Despite this exponential growth of research on COVID-19, further studies are needed to address many remaining research questions.

CONCLUSION

Although knowledge and awareness of COVID-19 among Indonesian dentists are reasonably good, further improvement would be beneficial to manage patients during this pandemic. As the number of COVID-19 cases continue to rise, it is important that dentists keep abreast of the updated knowledge on this moving field. The Indonesian government has assumed a major role in containing the spread of COVID-19, however more efforts are needed to protect dentists in their daily practice. Their knowledge on infection control should be strengthened through continuous educational programs.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of Faculty of Dentistry, Trisakti University (Jakarta, Indonesia). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ASW, EWB, and BMB contributed to the concept and design of the study. ASW and CFT collected and analyzed the data. ASW, MSD, and DNS interpreted the results. CFT, MIR, ASW, and MOR wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2020.589759/full#supplementary-material

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OPINION
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The Dental Team: An Additional Resource for Delivering Vaccinations

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Keywords: COVID-19, coronavirus, dentistry, dental team, vaccinations, influenza, flu, immunisation

INTRODUCTION

Influenza is regarded by the World Health Organization (WHO) as a "serious global health threat" and is responsible for a significant number of deaths worldwide (1, 2). Influenza vaccines are usually delivered in primary care physician practices as well as in pharmacy settings. Dental practices are generally not seen as routine providers of influenza vaccines, although certain countries have been recently starting to develop frameworks to facilitate this (3, 4). Potential workforce capacity gaps, expansion of the eligible cohorts, requirement to drive improvements in uptake, and to reduce inequalities support the rationale for members of the dental team to join the vaccinator workforce. We propose a few potential models, some of which are currently being piloted in certain areas of the United Kingdom, and suggest that the members of the dental team might be ideally placed to contribute to national immunization programs.

The coronavirus pandemic has had a devastating effect on people's lives, pushing the limits of healthcare systems and placing enormous economic and political pressures on governments. As with other pandemics throughout history it has also highlighted the vulnerabilities of our society and forced us to reflect on our values and priorities, compelling us to develop new ways of delivering care, adapted to the new realities of the world around us (5). Face to face consultations became the exceptions and remote consultations the new norm (6). Thousands of clinical and non-clinical staff have been redeployed from their usual workplace into new settings to support the pandemic response (7).

In several countries around the world, the multi-skilled dental workforce has demonstrated that dentistry is ready to support the national health systems response in a time of emergency (8, 9). Members of the dental team were redeployed based on their set of competencies into various roles including medical history taking, phlebotomy, cannulation, suturing, and others (10). A properly trained and indemnified dental workforce would be ideally placed to support the delivery of the flu vaccination program for the next season (11). In 2009, during the H1N1 (swine flu) pandemic a precedent has been established when certain US states commissioned dentists to administer flu vaccines in order to increase capacity for delivery and meet the increased demand in a short time frame (12, 13).

DELIVERY MODELS

The delivery models for seasonal flu vaccinations and for school vaccination programs vary between different healthcare systems around the globe. The next section presents some of the models that are currently being explored in the UK. These could be adapted for different healthcare settings based on the existing structures and processes developed nationally (14). The members of the dental team could support the delivery of the seasonal influenza vaccine, as well as other immunization

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programs such as the childhood vaccination program and potentially the large-scale delivery of COVID-19 vaccines, should a safe and effective vaccine become available in the future.

Flu Vaccinations

Every year, the arrival of autumn means also the beginning of the flu season. Seasonal influenza has been a constant challenge for healthcare systems across the world and it is estimated to be responsible for nearly 400,000 deaths every year world-wide (2).

The uptake of influenza vaccines varies between different countries. The most accurate and comparable data is on vaccination rates for people over the age of 65. These rates present large variations from 10.2% in Estonia to 85.1% in South Korea (15). This year, national health systems are facing the risk of a dual threat created by seasonal influenza and the potential resurgence of COVID-19, which could have devastating effects especially in the high-risk groups. Certain governments have recognized this threat and established a set of preventative measures. For example, the UK Government has decided to expand the eligibility criteria for influenza vaccinations to include additional groups in the national immunization schemes. These additional groups consist of all people over the age of 50, people who are shielding from COVID-19 and their households, as well as secondary school children in England. This represents an estimated total of 30 million people, which represent an increase of 5 million people compared to the previous year (16, 17). This broadening of the eligibility criteria would lead to operational and logistical challenges for delivery in a timely manner. Expanding the workforce capacity to include the members of the dental team could attenuate some of these challenges.

The following models might serve as potential avenues that could be explored by policy makers in different countries.

Provision of Additional Personnel for Local Delivery Programs

Additional health protection measures have been imposed by COVID-19, such as dental surgery fallow time after an aerosol generating procedure and increased decontamination demands (18, 19). As a result, some dental teams may be utilizing less personnel and therefore these staff members could join existing immunization teams to deliver vaccinations in various settings such as schools, primary care, and specially allocated community settings. This would increase the available workforce capacity to deliver vaccinations in a short time frame. This is an important advantage as to maximize protection for the entire flu season, it would be essential to cover as many eligible people as possible as soon as the vaccines become available in the first few months of the season (20, 21). The most cost-effective solution would be to utilize dental nurses or hygienists/therapist to support this model however we believe that the option to administer vaccinations should be available to all members of the dental team as long as they are properly trained, competent, and indemnified.

Use of Premises

Dental surgeries represent a large network of clinical settings that are known and easily accessible to the public. Evidence suggests that certain cohorts of patients visit the dental surgery more frequently than their general physician (22). Larger dental surgeries are likely to have capacity in terms of surgery or floor space that could be used temporarily by immunization teams. Dental practices are also well-equipped to deal with rare but serious adverse reactions.

One-Stop Shop

Patients could choose to receive their influenza vaccine at the same time as their dental appointment. This model would support the principle of reduction of the number of contacts between patients and healthcare settings and reduce the risks associated with multiple journeys, especially in more rural areas where traveling longer distances is often required. It could be done both opportunistically as well as in a targeted manner for specific cohorts. This approach has already been successfully implemented in certain states in the US (13).

Childhood Immunization Programs

Besides helping the delivery of influenza vaccines, members of the dental team could be deployed to support the catch-up initiatives for childhood immunization programs. In several countries around the world, the COVID-19 pandemic has led to school closures for a significant amount of time and this has created a backlog in terms of delivering immunization programs for school aged children with the increased risk of community outbreaks (23).

COVID-19 Vaccinations

It is believed that a COVID-19 vaccine would be the best way to speed up the economic recovery and protect public health from the damage caused by the pandemic. The race to develop a safe and effective coronavirus vaccine has demonstrated the need for innovative thinking and collaboration between researchers from different scientific disciplines (24). The success or failure of any large-scale immunization program depends on the uptake of the vaccines by the majority of the population and it will raise significant logistic challenges (25, 26). If the above-mentioned models for flu vaccination could be piloted and evaluated, the lessons learned from these initiatives could inform the planning and delivery of a large-scale COVID-19 mass immunization program, with a vaccinator workforce which included dental team members.

DISCUSSION

Any of the above models would need to take into consideration certain factors such as:

- Approval from the regulatory bodies of dental care providers and professional indemnity providers;
- Approval from national regulatory agencies for medicines;
- Information governance and access to clinical data including patients' full medical history and robust intra-operability between data systems across dental and medical systems;
- Clear funding mechanism.

Research into the effectiveness, safety and cost-effectiveness of these interventions should be encouraged in order to

inform future evidence-based decisions. Any service evaluation should also include a qualitative component for capturing the experiences of the new dental vaccinators as well the views of the existing vaccinating teams and patients.

It has become clear that the coronavirus pandemic highlighted the stark inequalities in our society. It was marked by a strong socioeconomic gradient, affecting disproportionately the most vulnerable groups. Public health measures such as prevention and health promotion are the among the key interventions to reduce the impact of inequalities (27, 28). Dental leaders have long been advocating the idea of "putting the mouth back in the body" (29, 30). There is a short window of opportunity, before the beginning of the flu season, to explore the untapped resource of the dental workforce in supporting the delivery of an enhanced immunization program. There is no better time to consider innovative solutions aimed to challenge the traditional boundaries between the different parts of the healthcare system (31). This is a crucial time to reconsider the segregated models of the past and move toward more integration of resources to support the uptake of one of the largest flu vaccination programs to date (32). Seasonal influenza has the potential to place additional strains on the health and social care systems which were already hard-hit by the coronavirus pandemic. This is the time to design preventative measures to mitigate the dual threat caused by influenza and COVID-19 and to think holistically about the resources available in the healthcare system. Engaging the dental team for delivering influenza vaccinations could further strengthen the collaboration between medicine and dentistry and is likely to set an important precedent to meet the demands of future public health crisis.

AUTHOR CONTRIBUTIONS

SS prepared the first draft of the manuscript. All the other co-authors contributed with comments and approved the final version.

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CORRECTION
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Corrigendum: The Dental Team: An Additional Resource for Delivering Vaccinations

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In the original article, there was an error. The examples of countries where dentists can deliver flu vaccinations included New Zealand. This is a mistake as New Zealand should not have been on that list.

A correction has been made to the **Delivery Methods**, **Flu vaccinations**, **Subsection One-Stop-Shop**:

"Patients could choose to receive their influenza vaccine at the same time as their dental appointment. This model would support the principle of reduction of the number of contacts between patients and healthcare settings and reduce the risks associated with multiple journeys, especially in more rural areas where traveling longer distances is often required. It could be done both opportunistically as well as in a targeted manner for specific cohorts. This approach has already been successfully implemented in certain states in the US (13)."

Reference 23 was also removed from the reference list.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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A Risk-Based Approach to the COVID-19 Pandemic: The Experience in National Dental Centre Singapore

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The emergence of a highly infectious coronavirus strain, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has led to a major global public health emergency. The increasing number of infected cases and fatalities worldwide forced several countries into lockdown in a bid to control virus transmission. The practice of dentistry is considered high-risk due to the generation of aerosols associated with most dental procedures, and healthcare professionals must take appropriate precautions whilst working in this challenging environment. This review aims to provide an overview on transmission routes and shares a risk-based approach to coronavirus disease 2019 (COVID-19) in a specialty tertiary center. Risk assessment and mitigation focussed on staff and patient safety, adopting a wide safety margin, and responding dynamically to the level of risk at the workplace. As the severity of the pandemic depends on many still-unknown factors and shows little sign of abating, the routine practice of dentistry will continue to be disrupted in the near future. We describe a color-coded framework to maximize safety and to minimize disease spread. Areas covered include healthcare team management, personal protective equipment, clinical work, and dental education. Guidelines in each category change with the corresponding severity of the situation, and we believe it will be useful for the safer practice of dentistry in this current climate and can be modified for future similar disease outbreaks.

Keywords: communicable diseases, emerging/epidemiology/therapy/virology, disease outbreaks, dental care/standards, infection control, dental, coronavirus infections/epidemiology/prevention & control/transmission, COVID-19

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INTRODUCTION

Coronaviruses are single-stranded RNA viruses with an envelope. They were first identified around 70 years ago, and are capable of causing respiratory, gastrointestinal, and central nervous system diseases in humans and animals (1). The name "corona" implies a crown-like structure with spikes on the surface. These spike proteins are critical for binding of host cells receptors to facilitate entry, they may undergo evolutionary changes over time (2). Notable coronavirus infections in human history include severe acute respiratory syndrome-related coronavirus (SARS-CoV) in 2003 and Middle East Respiratory syndrome-related coronavirus (MERS-CoV) in 2012. SARS-CoV and

MERS-CoV were highly virulent and deadly, causing ∼10 and 35% mortality in infected individuals (3, 4).

The first confirmed cluster of patients with pneumonia associated with a novel strain of coronavirus virus emerged in December 2019 (5). Since then, next-generation sequencing of the virus genome has found it to be around 79% similar to SARS-CoV and 50% similar to MERS-CoV, although sufficiently divergent to be considered a novel virus (6). The official name of the disease has been termed "COVID-19," with SARS-CoV-2 announced as the virus causing this disease (7). The announcement of COVID-19 as a pandemic by the World Health Organization (WHO) in March 2020 marked a turning point in the containment of this disease.

COVID-19 IS A GLOBAL AND NATIONAL PUBLIC HEALTH EMERGENCY

COVID-19 was declared to be a public health emergency of international concern on 30 January 2020 (8). On 6 October 2020, WHO reported over 35 million cases globally, with over one million deaths and rising each day (9).

At the time of writing (6 October 2020) Singapore had 57,792 confirmed cases and 27 fatalities. A large majority of the confirmed cases were clinically well and were isolated and cared for at community facilities. There were 153 cases are at community facilities, 42 cases are hospitalized but are medically stable, none of the cases are in critical condition, and 57,597 cases have been discharged after successful recovery (10). A total of 88 healthcare workers and support staff were infected with COVID-19 between January and April 2020, representing 1.7% of total confirmed COVID-19 cases during the same period (11). Most of these infected healthcare workers and support staff were in the public sector (68.2%) or served at the frontlines with frequent patient contact (63.6%) (11). While most of these healthcare workers acquired COVID-19 infection locally, epidemiological links of cross-infection between healthcare workers and COVID-19-positive patients have not been demonstrated (11, 12). Singapore's management of this crisis has been based on a structured nation-wide strategy for global infectious disease outbreaks termed Disease Outbreak Response System Condition (DORSCON). This is a four-tiered color-coded crisis management plan and ranges from green, yellow, orange and red (13). The color code is based on the nature of the disease (severity and degree of spread locally and abroad) and amount of disruption to daily life on a community and individual level. The current status in Singapore since 7 February 2020 has been DORSCON orange. Accordingly, various measures such as daily health checks at workplaces, temperature screening at hospitals, and suspension of inter-school and external activities for schools were put in effect. As part of its early containment strategy, Singapore was already conducting contact tracing for confirmed cases, quarantining close contacts, issuing stay-home notices for citizens recently arriving from China, and issuing travel bans into the country to reduce the risk of imported cases into the community (14). Stay home notices were later broadened to anyone who had traveled outside Singapore, with travel bans imposed for all short-term visitors from any country (15, 16). As the transmission of COVID-19 progressed, anyone coming in from abroad were given stay-home notices or issued with quarantine orders, depending on their exposure to the virus. Others were instructed to take a leave of absence from their employers. If they presented with respiratory symptoms, they were given a mandatory 5 days of medical leave and were not allowed to leave their place of residence.

In March 2020, a suspect case was defined as one who presented with an acute respiratory illness of any degree of severity, who, within the last 14 days before onset of illness had traveled abroad to high-risk areas, or had close contact with a COVID-19-positive patient. Any person with clinical signs and symptoms suggestive of pneumonia or severe respiratory infection with breathlessness was also considered a suspect case. A close contact was defined as anyone who provided care for the COVID-19-positive patient, including a healthcare worker or a family member, or who had other similarly close physical contact; anyone who had stayed (e.g., household members) at the same place with the patient; or anyone who had close (< 2 m) and prolonged contact (30 min or more) with the patient (15). Suspect cases who were medically stable were referred to a medical general practitioner for further evaluation immediately. Suspect cases who required urgent dental treatment such as the need to alleviate oral infection or pain were referred to the national specialty centers for management.

From 7 April to 1 June 2020 Singapore entered a "circuit breaker" period (**Table 1**) due to a surge in locally transmitted

TABLE 1 | Different stages of the national response in Singapore to COVID-19.

Disease Outbreak Response System Condition (DORSCON): a four-tiered color-coded crisis management plan for an infectious disease outbreak and ranges from green, yellow, orange, and red. Singapore has been under DORSCON orange since February 2020 at the time of writing (6 October 2020). At NDCS, all non-essential dental review appointments were rescheduled for at least 4 months at the onset of DORSCON orange. Patients on active therapy had their treatment deferred if they presented with a specific set of respiratory symptoms, contact history, or travel history.

Safe distancing measures: These measures were implemented in March 2020 where seats were to be separated by at least a meter apart in public venues; places where people gathered in close contact for long periods of time such as bars, cinemas, places of worship were closed; and gatherings outside school and work were limited to 10 or fewer people. These measures were adopted at NDCS.

"Circuit breaker" period: A 2-month period (7 April to 1 June 2020) where heightened restrictions to community movement was imposed nationwide to further prevent community spread of SARS-CoV-2. This included the closure of non-essential workplaces and schools. Food establishments were not allowed to offer dine-in options, and all members of the public were to leave their homes only for essential needs. At NDCS, only essential services requiring urgent or emergency care were performed.

Singapore has since transited from the "circuit breaker" period to a **phased staged of reopening**. Phase 1 lasted from 2 June to 19 June 2020. Singapore is currently in Phase 2 as of 6 October 2020. Schools and business have gradually been allowed to re-open, with social gatherings of up to five people allowed. Since Phase 1 till the time of writing, NDCS requires patient appointments to be booked 15 min apart from each other. This has reduced the number of patients seen each day, reducing the potential risk of transmission between patients and staff.

cases, new clusters developing among large groups of people housed together, and to mitigate the risk of widespread community transmission. As a result, heightened measures were implemented to minimize further community spread of the virus. Residents were prohibited from leaving their homes except for essential purposes (17). The wearing of masks was made compulsory outside one's home, and all workplaces were closed except for essential services. Elderly people and those with co-morbidities were advised to stay home as much as possible. Similarly, all elective dental procedures were halted during this period, except for essential services. Essential services were defined as procedures "if not provided or performed, would result in significant or rapid deterioration of the patient's condition, potentially threatening their health and well-being" (18). Hence, only patients requiring urgent/emergency dental care were seen.

The practice of dentistry is considered high-risk due to the close proximity between patients and dental practitioners and the generation of aerosols associated with most dental procedures (19). The potential for unknown interaction with COVID-19 patients due to asymptomatic spread is a concern as well. In this paper we provide an overview on transmission routes of COVID-19 and describe a risk mitigation approach during the period of DORSCON orange at National Dental Centre Singapore (NDCS), a referral tertiary center for patients needing specialist oral healthcare in Singapore. A color-coded framework to maximize safety and minimize disease spread is also described.

TRANSMISSION ROUTES

The transmissibility of COVID-19 remains poorly understood. Droplet transmission from respiratory secretions is the postulated principal mechanism of spread of COVID-19. Coughing consists not only of short-range semiballistic emission, but also consists of a turbulent gas cloud and may travel as far as 7–8 m (20). Droplets may vary in size, with small particles dehydrating and existing as droplet nuclei or aerosolised forms (21). Droplet generation into the surroundings decreases significantly to background levels when a cloth is placed over the mouth during speech (22). Virus particles have been found in air exhaust outlets in a Singapore study, demonstrating airflow displacement of the virus and spread through ventilation systems (23). Airborne transmission was also shown to occur in closed spaces with air re-circulation with no evidence of contact between patients (24, 25). SARS-CoV-2 has been shown to be suspended in the air as aerosols in crowded places and may also be resuspended from medical staff personal protective equipment while they are being removed (26). The virus has also been found to be viable in aerosols for a duration of 3 h (27). The transmission distance of the virus in aerosolised form has been detected up to 4 m from COVID-19-positive patients (28). In addition, the conjunctival mucosa and bronchial epithelium appear to be portals of entry in getting infected with COVID-19 (29). This underscores the need for healthcare workers to be socially responsible and ensure that they remain appropriately masked during work, even with 1–2-m safe distancing advisories. It also implies that many routine procedures performed in dentistry are potentially hazardous due to the aerosol generation from handpieces and ultrasonic scaler tips.

Environmental contact is another possible mode of transmission. Human coronaviruses can survive on inanimate objects and can remain viable for up to 5–9 days at temperatures of 22–25°C and relative humidity of 40–50% (30, 31). Surface type seems to play a role in the viability of the virus. An experimental study using a SARS-CoV-2 strain reported viability on plastic for up to 72 h, for 48 h on stainless steel and up to 8 h on copper (27). Another study showed that the virus could still be detected on glass and banknotes after 4 days, and surgical masks, stainless steel and plastic after 7 days (32). The virus has also been found on the floor, computer mice, trash cans, and doorknobs, emphasizing the need for thorough decontamination of surfaces (28). The persistence on surfaces is particularly worrying because inadvertent self-inoculation may be possible after touching such contaminated surfaces. Some of these studies used samples of the virus that were several orders of magnitude higher than those in droplets in real-life scenarios and it may be argued that the risk of transmission of COVID-19 through surfaces is extremely small (33). However, as environmental transmission remains a theoretical possibility, disinfection of the clinical environment with prescribed workflows and trained dental personnel is prudent in reducing transmission. SARS-CoV-2019 is susceptible to standard disinfectants such as 70% alcohol, 0.5% hydrogen peroxide, 0.1% sodium hypochlorite, 7.5% povidone-iodine, 0.05% chloroxylenol, 0.05% chlorhexidine, and 0.1% benzalkonium chloride (30, 32). Decontamination can also be achieved with a combined detergent/disinfectant solution at a dilution of 1,000 parts per million available chlorine (31).

The last postulated mode of transmission is the fecal-oral route. Digestive symptoms have been found in 50% of patients with COVID-19, they may present before respiratory symptoms (34). Indeed, viable virus has been isolated from stool samples, testing positive although respiratory tract tests were negative (35). Therefore, fecal-oral transmission may occur even after viral clearance from the respiratory tract. SARS-CoV-2 has also shown to be present in toilet bowl samples in another Singapore study, strengthening the hypothesis of possible transmission through fecal matter (36).

It was initially suggested that patients with COVID-19 are not infectious until the onset of symptoms, and that the infectivity depends on the severity of their symptoms and illness (31). However, from an analysis of a group of seven clusters in Singapore it appears that transmission of SARS-CoV-2 can occur even before patients develop symptoms (37). While there are also case reports of asymptomatic transmission where patients remain asymptomatic throughout the course of infection, its exact risk of transmission is unclear, and the prevalence and detection of asymptomatic infection is not well-understood (38–40). Emerging evidence suggests that 20% of subjects that test positive for COVID-19 remain asymptomatic throughout the course of infection, and asymptomatic individuals have a relative risk of 0.35 in transmitting the disease when compared to symptomatic individuals (41). SARS-CoV-2 has an incubation period of up to 14 days, with a median time of 4–5 days before onset of symptoms (42, 43). In another study, 97.5% of persons

develop symptoms within 11.5 days (44). The time for recovery after onset of symptoms generally takes 2 weeks for mild cases, and 3–6 weeks for severe cases (8, 45).

HEALTHCARE TEAM MANAGEMENT

In Singapore, public provision of health services (medical and dental) is through three integrated clusters, divided according to geographical location. Each cluster comprises of primary care centers, general hospitals, community hospitals and specialty centers (46). National Dental Centre Singapore (NDCS) is a tertiary dental specialist center in the Singapore Health Services cluster, and is located in the Singapore General Hospital campus, together with four other national specialty centers.

At the beginning of the COVID-19 outbreak, an important consideration was the risk of transmission unknowingly between patients and staff as there were concerns of local clusters of infection, unlinked cases, and the risk of widespread community transmission. Evidence has since shown that asymptomatic individuals that are infected with COVID-19 can have a high viral load similar to symptomatic individuals (47, 48). Both infected individuals who never develop symptoms ("asymptomatic") or infected individuals who later develop symptoms ("pre-symptomatic") have shown to be able to transmit the disease, with a relative risk of 0.35 and 0.63, respectively, in transmitting the disease when compared to symptomatic individuals (41). A staff member getting infected or exposed to the virus could lead to clinic downtime in its provision of core services. Movement of healthcare workers across different healthcare institutions was limited in order to mitigate this. At NDCS, dental operatories are located on the first, second, fourth, fifth and sixth levels of the building (**Figure 1**). The first, fifth, and sixth levels consist of closed operatories or separate rooms, while the second and fourth levels consist of both open and closed operatories. The open operatories have walls between them that are just high enough to screen patients from each other when seated upright. Day ambulatory surgeries are located on the first, third and fourth levels. Since DORSCON orange, dental specialists and general dentists were segregated to work in three independent teams, and each team had access to two levels and a day ambulatory surgery (i.e., the first team worked on first and sixth levels, the second team worked on second and third levels, and the third team worked on fourth, and fifth levels). Each team was self-contained with the complement of clinicians (specialists and general dentists), dental surgery assistants, lab technicians, patient service associate executives and health attendants. Administrative staff were similarly divided into teams during this period. Other mitigation measures included twice daily temperature taking with checks on compliance, and safe distancing of at least 1 m during all meetings and meals. Any staff member with a fever and/or acute respiratory symptoms was not allowed entry into the workplace and was advised to seek medical treatment at the staff clinic immediately. These staff members would be issued stay home notices during their medical leave period. Staff feeling unwell during the course of the day were told to stop work immediately and to seek medical attention.

To support the government's stricter measures for social and physical distancing during the "circuit breaker" period (7 April to 1 June), dental procedures were limited to emergency and urgent dental care services. The three teams in NDCS took turns to be deployed out of the center to support whole-of-government COVID-19 efforts as needed.

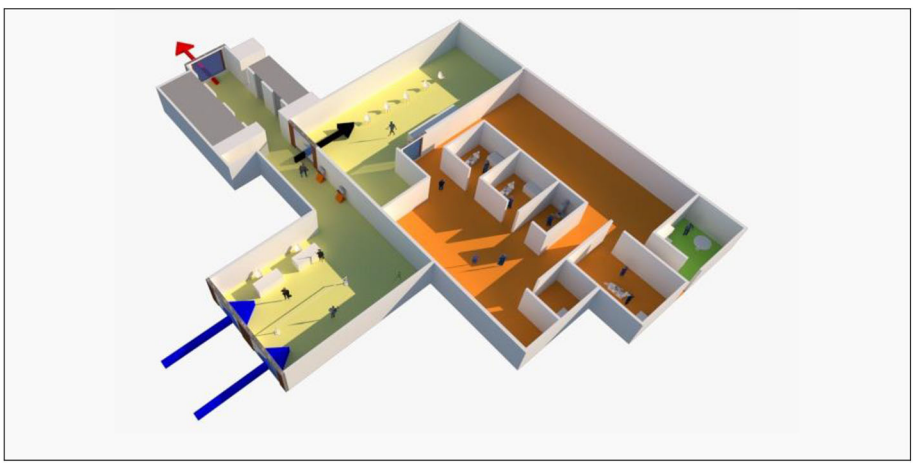

FIGURE 1 | Schematic layout of the first level of National Dental Centre Singapore. Patients and staff enter through two separate centralized entrances (blue arrow on left for patients, blue arrow on right for staff). A thermal scanner is used to screen staff and patients for any signs of fever. Queues are demarcated such that patients stand at least 1 m apart. Patients are screened immediately for travel history, contact history, and for any respiratory symptoms. Known suspect cases requiring urgent or emergency care would be received and isolated at a separate holding area and treated in an isolated dental operatory unit (not shown). Patients head to the Level 1 clinic reception (black arrow) or take the lifts (demarcated gray) to clinics on the other levels. Self-check-in counters outside the clinic minimizes contact between staff and patients. Yellow floor: triage and waiting area. Orange floor: clinical area which include dental operatories (simplified as two units in this schematic), radiographic unit, decontamination room for dental instruments, and day ambulatory surgery. Green floor: pantry area for staff only. All staff and patients in the building exit through a centralized door (red arrow).

TABLE 2 | PPE use in different settings in NDCS.

Setting	Personal Protective Equipment (PPE)
Triage Staff	Surgical mask
Performing or assisting in aerosol-generating procedures	Full PPE: N95 mask, gown, gloves, and eyewear protection Powered air purifying respirators were used by healthcare workers where N95 masks were found to be ineffective during mask fitting
Performing or assisting in non-aerosol-generating procedures	Surgical mask, gown, gloves, and eyewear protection
Non-clinical areas with no direct patient contact (e.g., administrative offices, storerooms, and pantry)	Surgical masks and hand hygiene with alcohol-based hand rub if handling items from a patient environment (e.g., forms and patient files) Employees to put on surgical masks immediately after meals, conversations between staff minimized

PERSONAL PROTECTIVE EQUIPMENT (PPE)

A risk-based approach was adopted for the use of personal protective equipment. This depended on the risk areas in NDCS, the exposure risk, and the type of procedure performed.

At the onset of DORSCON orange, nation-wide guidelines did not advise the use of PPE for non-clinical areas with no patient contact, e.g., administrative offices and storerooms. In clinical areas (i.e., triage, reception, and operatories), the same nation-wide guidelines advised that staff members were to wear a surgical mask, and protective eyewear or a face shield for dental procedures. Treatment of suspect cases referred to national specialty centers required the use of gloves, an N95 mask, gown, and eyewear protection. A wider safety margin was adopted as a further precaution in NDCS, with all aerosol-generating procedures requiring the use of at least an N95 mask and eyewear protection, irrespective of patient status (**Table 2**). N95 masks had to be tested for fit prior to use as improper fits may lead to unintentional exposure of aerosols. Facial hair, in particular, may interfere with the mask seal, and in general, hair must not cross the sealing surface (31). These masks were not to be touched once put on, changed once soiled with blood or any other splash contaminants, and worn only for up to 6 h, which were similar to CDC guidelines (49).

These precautions were similar to other national guidelines regarding the use of PPE. In the United Kingdom, when caring for a patient with a suspected or confirmed case of COVID-19, dental procedures such as high-speed drilling required the use of a filtering face piece (class 3) (FFP3) respirator, a long-sleeved disposable gown, gloves, and disposable eye protection. Close patient contact of within 1 m only or in a cohorted area did not require an FFP3 respirator, but at least a fluid resistant (type IIR) surgical face mask (31). In the United States, the Centres for Disease Control and Protection recommended the use of N95 respirators or respirators that provided a higher level of protection when performing or present during aerosol-generating procedures. Furthermore, if reusable respirators such as powered air purifying respirators (PAPRs) are used, they had to be disinfected prior to reusing them (50). The use of PAPRs may provide more reliable protection, but training in putting them on and removing them without contaminating surfaces is necessary, and whether it is necessary for treating COVID-19-positive patients is unknown (51). However, others have recommended its use for other high-risk procedures such as intubation of patients (52).

Besides donning of appropriate PPE, staff members were also reminded to practice the five moments of hand hygiene, i.e., use an alcohol-based hand rub or wash hands with soap and water, (1) before touching a patient; (2) before engaging in clean/aseptic procedures; (3) after body fluid exposure risk; (4) after touching a patient; (5) after touching patient surroundings (53).

When treating suspect cases, the clinicians and dental assistant would don a full PPE consisting of an N95 mask, gown, gloves, and eyewear protection. Staff would then self-monitor for a period of 14 days for any respiratory symptoms, with twice-daily temperature monitoring. As the risk of transmission was deemed to be low due to the appropriate usage of PPE, the staff was not required to stop work.

However, staff could have unknowingly treated COVID-19-positive patients where they were later found to have the infection. If the staff members had donned appropriate PPE during treatment, the same self-monitoring guidelines were followed. However, if there was close contact without appropriate PPE, the staff would then be placed on quarantine for 14 days. If there was only casual contact (<30 min face-to-face interaction without a high risk procedure *i.e.,* consultation, making impressions, and radiographs) the staff was not required to stop work but monitored by a Ministry of Health Staff for 14 days over the phone.

CLINICAL CARE AND PATIENT MANAGEMENT

At the onset of DORSCON orange in February 2020, in order to review PPE supply and the classification of urgent and essential dental procedures, all aerosol generating procedures were rescheduled for 3 days. A centralized patient triage and temperature screening for staff, visitors and patients was created at the ground floor of NDCS where all patients entered through one entrance before going to the waiting areas at their respective levels (**Figure 1**). Queues were kept fast-moving by ensuring that there were adequate staff to carry out the triage. Visitors were limited to one per patient to reduce overcrowding areas, and essential ones such as the patient's caregiver or a pediatric patient's parents took priority.

In NDCS, a wide safety margin was used in patient management. All non-essential dental review appointments were rescheduled for at least 4 months to reduce clinical workload and risk of disease transmission. Patients on active therapy that presented with any of the following were asked to have their dental procedures deferred for 2 weeks or until recovery of their

symptoms if they did not present with a dental emergency: (1) any travel history in the last 14 days; (2) contact history with any known positive cases; (3) respiratory symptoms such as cough and fever. Travel and contact history were confirmed, and patients re-assessed for symptoms by the attending clinician. Suspect cases requiring urgent care were isolated at a designated holding area and managed accordingly by the dentist in an isolation room with appropriate PPE. Patients with pre-existing movement restrictions (stay-home notice, quarantine orders, leave of absence, medical leave) who presented to NDCS but had respiratory symptoms were also referred to the Department of Emergency Medicine at Singapore General Hospital for further assessment. Patients without respiratory symptoms were informed to have their treatment deferred unless they presented with a dental emergency.

On 20 March 2020, Singapore implemented stricter safe distancing measures which included separation of at least a meter between seats at public venues (54). These measures were also similarly employed at NDCS at queues and waiting areas. Patients were also encouraged to use existing self-check-in counters, in order to minimize contact with counter staff. These self-check-in counters were disinfected after every use. Alcohol-based hand rubs and posters that reminded visitors and patients to practice good respiratory and hand hygiene were also placed at these triaging and waiting room areas. This included encouraging frequent hand washing with soap and water or alcohol-based hand rubs, covering one's mouth and nose, keeping a distance of at least 1 m from someone who is coughing, sneezing, or has a fever, and to avoid touching one's eyes, nose and mouth. Precautionary measures were further heightened on 14 April 2020, and anyone leaving their homes were mandated to don a mask (55).

When Singapore entered its "circuit breaker" period, further mitigations were employed. In order to reduce the risk of non-essential commuting by patients and visitors to NDCS, only treatment requiring urgent or emergency care was continued according to specialty-determined guidelines. This included dental clearance for patients referred from other departments in the hospital receiving oncological treatment, general anesthesia, intravenous, or intramuscular antiresorptive medications. Other essential treatment included biopsies for oral pathological cases, treatment for dental trauma, periodontal abscesses, cracked teeth, and irreversible pulpitis. All non-essential cases such as orthodontic therapy, implant therapy, and asymptomatic endodontic lesions and third molars were deferred. A medication delivery system was also set up to minimize patient visits. These were patients who only required a refill of prescription for the management of chronic dental conditions, recurrent oral disorders or orofacial pain. A tele-consultation with the patient was done, and medications would be delivered to patients' homes where necessary. "Last-mile" procedures were also performed to complete ongoing treatment so as to minimize unscheduled returns arising from complications with treatment delay. For cases that required treatment, a high suction evacuator was always used during procedures that were aerosol generating, and a dental assistant was always present to ensure the practice of four-handed dentistry.

New or existing patients who had their treatment canceled or deferred also faced risks in their dental condition and overall prognoses deteriorating, such as malnutrition in frail patients awaiting denture treatment. To mitigate this, clinicians were also informed to scan through their appointment lists to identify patients who required urgent reviews and to prioritize their care concurrent to the gradual easing of restrictions of people movement and reopening of workplaces after the "circuit breaker" period.

It has to be noted that the extended suspension of routine dentistry leaves the risk of an increase in emergency or urgent cases occurring. In events where healthcare supplies (such as PPE) and manpower are strained, decision making in dentistry can be challenging. For example, it has been suggested that extractions of teeth over restorative treatment take priority in cases of acute swelling as a means of early and definitive intervention in order to reduce aerosol generation and for antibiotic stewardship (56).

EDUCATION

Lectures, seminars, and journal clubs usually takes place within the center for dental officers, residents and staff. These are held in seminar rooms or lecture halls. When DORSCON orange started, an online refresher class on infection prevention practices was implemented for all staff. Dental education that involved different team members was conducted through video conferencing. Staff within the same teams could meet but in reduced group sizes with safety distances observed between each other. During the "circuit breaker" period, and with several staff not required to be at work, all meetings were held online.

In Singapore, large classes have been postponed in schools, including universities, due to disease transmission concerns. This has led to teaching interruptions especially for final year students. School closures have coincided with key assessment periods where internal and external assessments have been rescheduled. Medical and dental training has been disrupted in the same regard, with clinical postings for medical students suspended (57). It is crucial that continued education takes place, and amidst a time where many workplaces are closed and social distancing measures are in effect, digitized education or distance learning provides a means to mitigate the loss of learning.

Preparedness has been paramount in containing and mitigating this present pandemic, and this posture should remain so for future disease outbreaks. Singapore had a previous experience with medical and dental school disruptions during the SARS epidemic in 2003. During that period, videotaped vignettes and audiotaped webcasts for medical students were used (58). In what was novel at that time, the first fully online module was also implemented (59). Technological advances have been made since then, and with the past familiarity of the SARS epidemic, and with improved technological infrastructure, it has enabled education to continue as seamlessly as possible within the given limitations of school closures.

DENTAL PRACTICE: QUO VADIS?

There remain challenges to the practice of dentistry during this pandemic. In the absence of pharmaceutical options to treat or prevent COVID-19 cases, the only viable options for the healthcare team at large include thorough contact tracing, postponing non-urgent dental appointments for patients who are suspect cases, reducing the number of patients seen each day, and social distancing.

Implementation of these safety measures in NDCS have largely been adhered to due to strong teamwork and cooperation amongst staff members. However, the protracted nature of the COVID-19 pandemic globally has affected staff morale negatively due to restrictions in social gatherings and the inability to travel abroad to visit family members. Staff fatigue to safety measures are of concern too. Furthermore, some staff members have chosen to remain abroad to be with their families and this poses potential manpower issues in terms of work allocation. Lectures and seminars are still conducted online and its impact on the quality of dental education remains to be seen.

The severity of this pandemic depends on several still-unknown factors such as duration of acquired immunity to the virus, and seasonal variations in transmission. A gradual exit strategy from the "circuit breaker" period with long-term

TABLE 3 | Proposed color-coded framework for dental practice during the COVID-19 pandemic.

Status	Green	Yellow	Orange	Red
Nature of SARS-CoV-2	Virus has mutated into a mild form and/or does not spread easily	Virus spreads easily but: (i) has mutated into a mild form; and/or (ii) is being contained and treated effectively	Virus spreads easily and: (i) infected patients have a high morbidity/mortality rate; and/or (ii) is not being contained or treated effectively	Virus is not being contained with exponential increases of outbreaks in the community, and infected patients have a high morbidity/mortality rate
Healthcare team management	Normal deployment of staff	Normal deployment of staff	Divide staff into teams and segregate to different clinics/levels (if possible) Reduce social contact with other teams with safe distancing observed within the same team	Alternate teams on duty
Personal protective equipment	Surgical masks to be worn in operatories	Surgical masks to be worn at all times in clinical areas (i.e., triage, reception, and operatories)	N95 masks and protective eyewear for aerosol generating procedures (e.g., use of ultrasonic scalers and surgical handpieces) Surgical masks to be worn at all times in clinical areas (i.e., triage, reception, operatories, and pantry except when eating)	N95 masks and protective eyewear for aerosol generating procedures (e.g., use of ultrasonic scalers and surgical handpieces) Surgical masks to be worn at all times in clinical areas (i.e., triage, reception, operatories, and pantry except when eating)
Clinical care and patient management	Normal workload	Normal workload with heightened precautions, i.e., thorough screening at triage, monitoring temperature of patients and staff, maintain good personal hygiene Defer all suspect cases and refer to a medical GP (if medically stable) or hospital via ambulance for further management	Implement centralized patient triage Defer non-emergency cases for patients with a travel history, contact history to a known case, or respiratory symptoms Reduce patient bookings and postpone recalls Isolated holding areas and operatories for suspect cases All suspect cases and high-risk patients requiring urgent/emergency care to be treated at selected tertiary institutions or in-house hospital dental team Defer non-emergency treatment for COVID-19-positive patients	Defer all new/ongoing elective procedures Emergency cases only (e.g., swelling of the face, neck, and mouth; uncontrolled hemorrhage) Treat urgent cases (e.g., abscesses, pericoronitis, and pulpitis) with minimized aerosol generation Defer non-emergency treatment for COVID-19-positive patients Tele-consultation and medication delivery to patients' homes
Education	Normal classroom-/lecture hall-based interactions	Normal classroom-/lecture hall-based interactions	Online conferences/classes and/or classroom-based interactions with reduced group sizes, surgical masks, and social distancing	Online conferences/classes

ASA, American Society of Anesthesiologists physical status classification system; PAPR, powered air-purifying respirator.

safe distancing measures in Singapore has been shown to be effective when compared to an immediate lifting of restrictions using an epidemic simulation model (60). However, reopening the country and its national borders for international travel risks having new community outbreaks of COVID-19. A single episode of a complete lockdown in a state or country to restrict non-essential movement and social interactions that was introduced by many countries may not be sufficient to contain the pandemic, and intermittent lockdowns of varying degrees to limit social interactions may need to continue until 2022 to prevent national critical care capacities from being exceeded, even in high-income countries (61).

With this in mind, **Table 3** outlines a color-coded framework for the practice of dentistry in COVID-19. This framework offers guidelines for each specific color-code and corresponds to different suggested severities of an outbreak. This may be modified further for future similar disease outbreaks.

CONCLUSION

The COVID-19 pandemic is a rapidly evolving situation that is causing great disruption to daily life. Dental practice is no exception and protocols have to be adjusted to continue operation in a way that maximizes safety and reduces disease spread. SARS-CoV-2 can be transmitted through droplets, aerosols, environmental contact and oral-faecally, outlining the importance of upholding hygiene standards and minimizing contact with one another. A risk-based approach to the pandemic that is focussed on staff and patient safety, adopting a wide safety margin, and responding dynamically to the level of risks involved in the workplace is also outlined for areas in healthcare team management, personal protective equipment, clinical work, and dental education. This in turn leads to the safer practice of dentistry in the current climate.

AUTHOR CONTRIBUTIONS

JT and EN contributed to conception, data acquisition and drafted, and critically revised the manuscript. CJS contributed to the conception, drafted and critically revised the manuscript. MO, CS, and KT contributed to the data acquisition and drafted and critically revised the manuscript. All authors gave their final approval and agree to be accountable for all aspects of the work.

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The Impact of Periodontal Disease on Hospital Admission and Mortality During COVID-19 Pandemic

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Introduction: COVID-19 has had a huge impact on society and healthcare and it has been suggested that people with periodontal disease are at risk of having worse outcomes from the disease. The aim of this study was to quantify the impact of periodontal disease on hospital admission and mortality during the COVID-19 pandemic.

Materials and Methods: The study extracted UK Biobank participants who had taken a COVID-19 test between March and June 2020 (n = 13,253), of which 1,616 were COVID-19 positive (12%) and 11,637 were COVID-19 negative (88%). Self-reported oral health indicators of painful or bleeding gums and loose teeth were used as surrogates for periodontal disease, participants who did not report any of the aforementioned indicators were used as controls. Multivariable logistic regressions were used to obtain crude and adjusted odds ratios of COVID-19 infection, subsequent hospital admission and mortality adjusted for demographics, BMI, biomarkers, lifestyle and co-morbidities.

Results: Painful gums, bleeding gums and loose teeth were reported in 2.7, 11.2 and 3.3% of participants with COVID-19 infection, respectively. Risk of COVID-19 infection in participants with painful or bleeding gums and loose teeth compared to controls was not increased (odds ratio [OR]: 1.10, 95% CI: 0.72–1.69; OR: 1.15, 95% CI: 0.84–1.59). COVID-19 positive participants with painful or bleeding gums had a higher risk of mortality (OR: 1.71, 95% CI: 1.05–2.72) but not hospital admission (OR: 0.90, 95% CI: 0.59–1.37). Participants with loose teeth did not show higher risk of hospital admission or mortality compared to the control group (OR = 1.55, 95% CI: 0.87–2.77; OR: 1.85; 95% CI: 0.92–2.72).

Conclusion: There was insufficient evidence to link periodontal disease with an increased risk of COVID-19 infection. However, amongst the COVID-19 positive, there was significantly higher mortality for participants with periodontal disease. Utilization of linked dental and hospital patient records would improve the understanding of the impact of periodontal disease on COVID-19 related outcomes.

Keywords: COVID-19, oral health, periodontal disease, hospital admission, mortality, UK Biobank

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INTRODUCTION

The COVID-19 pandemic has resulted in a huge burden on society and healthcare. Studies have shown that sex, older age and co-morbidities including diabetes, hypertension, cardiovascular disease and cancer may increase risk of COVID-19 associated deaths (1, 2). There are also suggestions that COVID-19 related deaths may be associated with deprivation and ethnicity (3). As yet no study has examined the impact of periodontal disease on COVID-19 infection and associated outcomes.

Over a lifetime, ∼90% of adults will experience oral disease. Periodontal disease is a main cause of tooth loss in adults and the sixth most prevalent disease globally (4), affecting between 10 and 50% of adults (5, 6). Existing evidence suggests that people with periodontitis may have an increased risk in developing subsequent systemic diseases including cardiovascular disease, hypertension, respiratory disease, diabetes and cancer (7–12). It has been suggested that COVID-19 could be linked to periodontal disease given their shared risk factors, which include obesity, age and hypertension (13, 14). Additionally, there is growing evidence of bacterial co-infection in COVID-19 hospitalizations (15), while ventilator associated pneumonia is also a reported complication of patients hospitalized with COVID-19 (16). Oral dysbiosis as a result of increased dental plaque in periodontitis may provide an environment for oral carriage of respiratory pathogens and cause COVID-19 complications. As yet there is insufficient evidence to provide robust conclusions on how periodontal disease may be associated to COVID-19 infection and outcomes.

During the COVID-19 pandemic UK Biobank has provided live-feed information of its participants on COVID-19 testing, subsequent hospital admission and mortality. The UK Biobank dataset provides an extensive resource to aid in understanding the impact of various factors including periodontal disease during the pandemic. The aim of this study was to quantify the impact of periodontal disease on COVID-19 infection and related outcomes utilizing the UK Biobank data.

MATERIALS AND METHODS

Database

Data from the UK Biobank cohort was used in this analysis. UK Biobank is a national, longitudinal cohort study of over 500,000 participants. The dataset includes information from UK Biobank assessment centers; self-reported responses *via* online questionnaires, linked HES data including ICD-10 diagnoses and hospital admissions provided by NHS Digital, and death records extracted from the death register. Since 16th March 2020 COVID-19 test results provided by Public Health England have been linked to UK Biobank core data as a live-feed for the purposes of COVID-19 related research during the pandemic. The COVID-19 test result data reflects the change in national testing capacity, which has moved from mostly inpatient to more community testing. The data is accessible by researchers with an approved UK Biobank application (reference no: 54633) for a prior study and may carry out additional COVID-19 related research without further approval according to UK Biobank guidelines.

Study recruitment was between 2006 and 2010. Linked follow-up information from HES and death records were available until May and June 2020, respectively. COVID-19 test results were available until the date of data extraction (August 2020). All participant information was fully anonymised prior to data acquisition. HES data, death records and COVID-19 test results were linked to the core UK Biobank dataset by a unique study ID therefore we do not anticipate any missing outcome data. Participants are free to remove themselves from the UK Biobank study cohort at any point (17).

Study Sample

For this study we included participants who were tested for COVID-19 ($n = 13{,}502$) with their results linked to the core UK Biobank dataset. The final dataset included information on participant demographics, biomarkers, co-morbidities, COVID-19 test results, hospital admissions and mortality.

Study Outcomes

Hospital admission and mortality following positive COVID-19 test result.

Exposures

The self-reported oral health indicators of bleeding gums, painful gums and loose teeth were utilized as surrogates for periodontal disease as they have demonstrated their validity in the absence of a clinical diagnosis (18). Painful and bleeding gums were associated with mild to moderate periodontal disease, while loose teeth indicated severe periodontal disease. Periodontal disease status was determined by the presence of any of the aforementioned indicators, while no mention of the indicators identified the control group, comprising participants with no self-reported history of periodontal disease.

Covariates

Information on participant demographics (age, sex, ethnicity, household income) and BMI was collated during attendance to UK Biobank assessment centers. Periodontal disease status was also determined from self-reported responses taken from UK Biobank assessment centers. Age at COVID-19 test was derived from age at assessment center attendance and date of test. Information on biomarkers such as blood pressure (systolic and diastolic) and resting heart rate was also acquired from attending UK Biobank assessment centers. Where there were multiple entries for biomarkers the most recent report was extracted. History of smoking was derived according to self-reported current or ex-smoking status. The following conditions were also considered as covariates: cancer, hypertension, angina, cardiac arrest, diabetes, myocardial infarction (MI), stroke, peripheral artery disease (PAD), heart failure, atrial fibrillation and respiratory conditions. Validated ICD-10 code lists within the Cardiovascular Research Using Linked Bespoke Studies and Electronic Health Records (CALIBER) resource were used to classify the aforementioned conditions (19), and the presence of the appropriate ICD-10 code in a participants health records

denoted history of the disease. The code list meanings were also adapted to identify relevant self-reported conditions that were not coded with ICD-10 classification. Participants were considered to have disease history if relevant ICD-10 codes were found in their health records, or if the condition was self-reported at the assessment center. No participants had history of heart failure therefore it was excluded from further analysis. A history of hypertension was determined if ICD-10 code was present in health record data, or if the blood pressure reading from the assessment center exceeded 140/90 mmHg.

Data Analysis

Descriptive statistics for baseline characteristics were presented using frequency (percentage) for categorical data and mean [standard deviation (SD)] or median [interquartile range (IQR)] for continuous variables depending on their distribution. Among participants who had COVID 19 test results available, the risk of COVID-19 infection was investigated for those with periodontal disease (self-reported painful gums, bleeding gums or loose teeth) using logistic regression, and further adjusted for covariates including demographics, BMI,

TABLE 1 | Summary table of UK Biobank participants stratified by oral health indicator and COVID-19 test result.

		No self-reported history of periodontal disease		Painful gums		Bleeding gums		Loose teeth	
		COVID-19 test result		COVID-19 test result		COVID-19 test result		COVID-19 test result	
	Overall	–	+	–	+	–	+	–	+
n	13,253	9,815	1,338	321	44	1,148	181	353	53
Age at test, mean (SD)	68.55 (8.38)	69.10 (8.20)	67.15 (9.19)	67.88 (8.71)	69.27 (9.20)	66.10 (8.22)	63.24 (8.50)	69.82 (7.27)	68.13 (8.28)
Sex, female (%)	6,802 (51.3)	5,026 (51.2)	627 (46.9)	174 (54.2)	18 (40.9)	677 (59.0)	98 (54.1)	150 (42.5)	32 (60.4)
Ethnicity, white (%)	12,268 (92.9)	9,231 (94.3)	1,180 (88.5)	276 (86.5)	34 (77.3)	1,047 (91.4)	148 (82.2)	307 (87.2)	45 (84.9)
Average Total Household Income, £ (%)	3,349 (28.3)	411 (4.7)	34 (2.9)	114 (43.3)	11 (29.7)	263 (27.0)	40 (26.0)	126 (43.4)	21 (51.2)
<18,000									
18,000–30,999	2,836 (24.0)	2,108 (24.1)	279 (23.5)	59 (22.4)	13 (35.1)	256 (26.3)	43 (27.9)	73 (25.2)	5 (12.2)
31,000–51,999	2,578 (21.8)	1,925 (22.0)	258 (21.8)	47 (17.9)	6 (16.2)	235 (24.2)	42 (27.3)	54 (18.6)	11 (26.8)
52,000–100,000	1,871 (15.8)	1,424 (16.3)	180 (15.2)	36 (13.7)	5 (13.5)	171 (17.6)	21 (13.6)	30 (0.3)	4 (9.8)
>100,000	517 (4.4)	481 (5.5)	73 (6.2)	7 (2.7)	2 (5.4)	48 (4.9)	8 (5.2)	7 (2.4)	NA
BMI, mean (SD)	28.24 (5.18)	28.08 (5.06)	28.68 (5.28)	28.83 (6.18)	30.55 (5.13)	28.61 (5.52)	28.27 (4.94)	28.76 (5.42)	30.81 (7.21)
Systolic blood pressure/mmHg, mean (SD)	140.69 (20.11)	141.03 (20.01)	140.78 (20.65)	138.43 (19.33)	143.28 (20.34)	138.44 (20.11)	138.06 (19.09)	141.88 (21.25)	136.21 (19.39)
Diastolic blood pressure/mmHg, mean (SD)	82.27 (10.79)	82.16 (10.74)	82.73 (11.16)	81.42 (9.86)	83.49 (10.76)	82.55 (10.92)	82.65 (10.99)	83.18 (10.77)	81.08 (11.95)
Resting heart rate/BPM, mean (SD)	63.85 (9.87)	64.12 (10.29)	57.67 (5.20)	58.00 (NA)	NA	67.14 (8.91)	65.00 (NA)	74.50 (7.78)	NA
History of smoking (%)	6,731 (51.0)	4,937 (50.5)	677 (51.0)	186 (58.7)	25 (56.8)	538 (47.0)	82 (45.6)	256 (73.1)	30 (56.6)
Cancer (%)	2,334 (17.6)	1,813 (18.50)	179 (13.4)	53 (16.5)	2 (4.5)	190 (16.6)	23 (12.7)	66 (18.7)	8 (15.1)
Hypertension (%)	7,781 (58.7)	5,776 (58.8)	793 (59.3)	197 (61.4)	31 (70.5)	636 (55.4)	90 (49.7)	229 (64.9)	29 (54.7)
Angina (%)	1,711 (12.9)	1,251 (12.7)	159 (11.9)	64 (19.9)	13 (29.5)	135 (11.8)	20 (11.0)	61 (17.3)	8 (15.1)
Cardiac arrest (%)	204 (1.5)	160 (1.6)	20 (1.5)	6 (1.9)	NA	11 (1.0)	1 (0.6)	5 (1.4)	1 (1.9)
Diabetes (%)	551 (4.2)	376 (3.8)	62 (4.6)	26 (8.1)	3 (6.8)	36 (3.1)	10 (5.5)	31 (8.8)	7 (13.2)
Myocardial infarction (%)	1,133 (8.5)	830 (8.5)	114 (8.5)	56 (17.4)	5 (11.4)	74 (6.4)	14 (7.7)	37 (10.5)	3 (5.7)
Stroke (%)	769 (5.8)	547 (5.6)	92 (6.9)	35 (10.9)	5 (11.4)	55 (4.8)	8 (4.4)	22 (6.2)	5 (9.4)
Peripheral artery disease (%)	963 (7.3)	695 (7.1)	110 (8.2)	36 (11.2)	2 (4.5)	67 (5.8)	12 (6.6)	36 (10.2)	5 (9.4)
Atrial fibrillation (%)	1,100 (8.3)	826 (8.4)	116 (8.7)	34 (10.6)	5 (11.4)	74 (6.4)	16 (8.8)	30 (8.5)	1 (1.9)
Respiratory disease (%)	3,056 (23.1)	2,213 (22.5)	335 (25.0)	88 (27.4)	9 (20.5)	255 (22.2)	49 (27.1)	96 (27.2)	11 (20.8)
Hospital admission	4,083 (30.2%)	2,723 (27.7)	665 (49.7)	89 (27.7)	18. (40.9)	297 (25.9)	81 (44.8)	101 (28.6)	26 (49.1)
Mortality	644 (4.8%)	292 (3.0)	247 (18.5)	12 (3.7)	7 (15.9)	25 (2.2)	21 (11.6)	11 (3.1)	16 (30.2)

BMI, body mass index; n, number of participants; SD, standard deviation; NA, not applicable as not enough data; –, negative COVID-19 test result; +, positive COVID-19 test result. Means and percentages are calculated for variables excluding missing data. There was missing data in the following variables: oral health (1.88%), ethnicity (0.3%), household income (15.9%), BMI (3.0%), systolic and diastolic blood pressure readings (3.4%), heart rate (99.4%), history of smoking (0.4%).

biomarkers, lifestyles and comorbidities. Among participants with a positive COVID-19 test result, the risks of hospital admission and mortality were investigated for those with periodontal disease using logistic regression and further adjusted for the relevant covariates mentioned above. Crude and adjusted odds ratios (OR) with 95% confidence interval were reported.

Multiple imputations were used for missing data, and Rubin's rule was used to combine the coefficients (20). To assess the impact of missing data, sensitivity analyses were performed using only the complete cases. Data processing and analyses were performed using R version 4.0.0 (21). Statistical significance level was set as 0.05.

RESULTS

Of the 13,253 participants involved in the final analysis cohort, there were 365 (2.4%) participants with painful gums, 1,329 (8.7%) with bleeding gums, 406 (2.7%) with loose teeth and 11,153 (84.1%) with no self-reported history of periodontal disease. Overall there were 1,616 (10.5%) confirmed COVID-19 cases and 11,637 negative test results in the study sample.

The mean age of all participants was 68.55 ± 8.38 years. There were 51.3% females in the final cohort. 92.9% of participants were of white ethnicity. On average participants were considered overweight with a mean BMI of 28.24 ± 5.18.Mean BMI was higher in COVID-19 positive participants when compared to negative participants across all periodontal disease indicator groups. 58.7% of all participants had a history of hypertension and 23.1% had respiratory disease (**Table 1**).

COVID-19 infection risk was not higher in participants with painful/bleeding gums or loose teeth compared to controls (OR = 1.10, 95% CI = 0.72–1.69; OR = 1.15, 95% CI = 0.84–1.59) (**Table 2**).

Though participants with painful/bleeding gums did not have a higher risk of hospital admission (OR = 0.90, 95% CI = 0.59–1.37), their mortality was almost doubled (OR = 1.71, 95% CI = 1.05–2.72) compared to the control group. Participants with loose teeth did not have significantly increased risk of hospital admission or mortality (OR = 1.55, 95% CI = 0.87–2.77; OR = 1.85; 95% CI = 0.92–2.72) (**Table 3**).

Sensitivity analysis on complete cases showed similar effects of periodontal disease on COVID-19 infection risk, hospital admission and mortality rate, but the effects were not significant due to a smaller sample size.

TABLE 2 | Association between oral health indicators and risk of COVID-19 infection.

	Oral health status, OR (95% CI)		
	Control	**Bleeding or painful gums**	**Loose teeth**
Crude OR (95% CI)	**1 (ref)**	1.07 (0.70-1.63)	0.99 (0.73-1.38)
Adjusted* OR (95% CI)	**1 (ref)**	1.10 (0.72-1.69)	1.15 (0.84-1.59)

CI, confidence interval; OR, odds ratio; ref, reference value.

**Adjusted by age at test, sex, ethnicity, average total household income, BMI, systolic and diastolic blood pressure, history of smoking, history of previous conditions including: cancer, hypertension, angina, cardiac arrest, diabetes, myocardial infarction, stroke, peripheral artery disease, atrial fibrillation, and respiratory disease.*

DISCUSSION

Our study did not find a difference in the risk of COVID-19 infection between participants with periodontal disease and those with no self-reported history of periodontal disease. However, logistic regression showed that participants with painful or bleeding gums were at much higher risk of mortality following COVID-19 infection after adjusting for covariates, though hospital admission risk was not higher in these participants. Loose teeth did not affect COVID-19 infection risk, or hospital admission and mortality following COVID-19 infection.

In this study, risk of mortality was significantly increased in participants with painful or bleeding gums following COVID-19 infection. A recent retrospective study of COVID-19 patients found dominant bacterial, viral and fungi co-infections in ∼94% of cases (22). These pathogens have also been identified in the oral biofilms associated with periodontal disease (23). Our results suggest oral bacterial load in people with periodontal disease may influence prognosis following COVID-19 infection, and supports the suggestion that the oral microbiome could be associated with severe COVID-19 complications (13). Conversely, risk of hospital admission following COVID-19 infection in participants with painful or bleeding gums did not significantly increase. This could be due to a reduction in the number of people attending hospital for acute disease during the social containment mandate ("lockdown") period of the pandemic (24). People with severe COVID-19 may have chosen to avoid hospital which may have impacted the risk estimates for this outcome. The follow up time for mortality outcomes from the UK Biobank cohort was longer than for the HES data available in determining hospital admission (June 2020 and May 2020, respectively). This may also influence the accuracy of estimates for risk of hospital admission.

Risk of hospital admission and mortality was not higher in participants with self-reported loose teeth, due to smaller sample size in this subgroup. Loose teeth is an indicator of severe periodontal disease (25). Participants with this response in the UK Biobank cohort could have since undergone periodontal treatment, had the affected teeth extracted, or in severe cases, the affected teeth may have self-exfoliated. This could result in a change in participant oral health status between the time of self-report and the COVID-19 infection as most of the self-reported information was collected at baseline. A study of a larger sample size with up-to-date dental measures is required to understand this phenomenon.

The results of this study have clinical implications for the management of COVID-19 infections in the general population, and in hospitalized patients. In England, routine dental services were suspended in March 2020 (26) and, at the time of writing, two-thirds of dental practices were operating at or below 25% of

TABLE 3 | Association between oral health indicators and hospital admission and mortality for participants with COVID-19 infection.

	Crude OR (95% CI) for oral health status			Adjusted* OR (95% CI) for oral health status		
	Control	**Painful or bleeding gums**	**Loose teeth**	**Control**	**Painful or bleeding gums**	**Loose teeth**
Hospital admission	**1 (ref)**	0.99 (0.13–3.02)	0.88 (0.16–10.04)	**1 (ref)**	0.91 (0.12–2.94)	0.90 (0.16–10.63)
Mortality	**1 (ref)**	1.60 (1.03–2.42)	1.34 (0.71–2.76)	**1 (ref)**	1.71 (1.05–2.72)	1.85 (0.92–2.72)

CI, confidence interval; OR, odds ratio; ref, reference value.
**Adjusted by age at test, sex, ethnicity, average total household income, BMI, systolic and diastolic blood pressure, history of smoking, history of previous conditions including: cancer, hypertension, angina, cardiac arrest, diabetes, myocardial infarction, stroke, peripheral artery disease, atrial fibrillation, and respiratory disease.*

their pre-COVID-19 activity levels (27). Dental practices are also having difficulties sourcing Personal Protective Equipment (PPE) (28). In the absence of routine dental care, remote consultations are an opportunity to emphasize self-care methods such as thorough brushing and interdental cleaning, both to prevent oral disease and to reduce the risk of COVID-19 mortality. UK government strategy has focused on tackling obesity to reduce the risk of serious illness or death from COVID-19 (29). Our results show that periodontal disease may be another preventable risk factor that the government could target to improve population outcomes before and after COVID-19 infection. The oral health of patients who have been hospitalized with COVID-19 should not be neglected. There is a wealth of evidence establishing an association between good hospital mouth-care and a reduced risk of pneumonia and acute viral respiratory infections (13). Furthermore, simple measures such as chlorhexidine mouth rinses have been shown to reduce the risk of ventilator associated pneumonia in critically ill patients from 24 to 18% (30). Improving the mouth care provided to COVID-19 patients in hospital could be a straightforward method for improving their outcomes, and Public Health England have supported this by publishing mouth care guidance for patients with COVID-19 (31).

This is the first study to quantify the effect of periodontal disease on risk of COVID-19 infection and related outcomes. As such, there are several strengths to our study. First of all, this is the largest study to date to quantify the association between periodontal disease and COVID-19. Secondly, the utilization of UK Biobank, a national resource with high quality measures linked to COVID-19 test results enabled our quantitative analysis of association between periodontal disease and COVID-19 outcomes. Finally, our study demonstrates robust results using both imputed and complete cases.

Our study also has some limitations. Delayed information of hospital admission and mortality (updated until June 2020) limited the number of study cases, and has been recognized as an avenue for further investigation. The use of self-reported oral health indicators as a surrogate for signs of periodontal disease could introduce bias, as research suggests self-reported periodontal disease prevalence is underestimated in populations (32, 33). We are also aware that loose teeth, and painful or bleeding gums could result from trauma or endodontic diseases, however, there is evidence that the validity of a periodontal disease diagnosis is not compromised when self-reported responses of bleeding gums and loose teeth are utilized (18). In addition, the dataset held no information regarding any periodontal treatment that the participants had received in the time between reporting the oral measures and receiving the results of the COVID-19 test. Given that periodontal therapy can reverse or prevent disease activity, participants may have experienced changes to periodontal disease status between self-report at UK Biobank assessment center and undertaking a COVID-19 test. Furthermore, the oral measures (painful gum, bleeding gum and loose teeth) in this study may be due to oral dysbiosis but this causal association was not measurable within the UK Biobank dataset. Lastly, as the pandemic continues to take hold, the study follow up time for hospital admission and mortality was relatively short (until May and June 2020); the numbers of COVID-19 positive cases may have been underreported during the early stages of the pandemic.

Suggestions for future research include: (1) Using updated information of additional COVID-19 test results with longer follow up in order to acquire more precise estimates of the effect of periodontal disease on risk of COVID-19 infection and associated outcomes. (2) Utilization of linked dental and hospital records in future analyses. This could provide more accurate and recent information on oral health status in comparison to the self-reported periodontal disease responses at UK Biobank assessment centers and account for any change in oral health status following dental treatment.

CONCLUSIONS

Our study demonstrated an increased risk of mortality following COVID-19 infection in people with periodontal disease. The findings suggest that while periodontal disease might not increase risk of COVID-19 infection directly, it may be associated with COVID-19 pathology and increase the risk of death. This indicates the importance of good oral hygiene and periodontal disease management, particularly while dental services are working below their pre-COVID-19 capacity levels.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

JW and JK contributed to study design and data acquisition and interpretation of the results. HL contributed to data analysis and interpretation and drafted the manuscript. SW contributed to interpretation of the results. All authors critically revised the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2020.604980/full#supplementary-material

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The Impact of the COVID-19 Epidemic on Orthodontic Patients in China: An Analysis of Posts on Weibo

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Background: During the COVID-19 pandemic, many dental care services including orthodontic practice were suspended. Orthodontic patients turned to social media platforms to communicate, share experiences, and look for solutions. Our study aimed to investigate the attitudes and perspectives of orthodontic patients during the COVID-19 epidemic in China by analyzing orthodontics-related posts on Sina Weibo (a Chinese counterpart of Twitter).

Materials and Methods: Potentially eligible posts on Sina Weibo platform were collected between December 30, 2019, and April 18, 2020. Posts related to both orthodontics and COVID-19 were included and then coded and classified into specific appliances and themes. Geographic and temporal distributions of the included posts were analyzed. In addition, time-lagged cross correlation was performed to explore the association between the number of daily posts and daily new COVID-19 cases/deaths in China. Chi-square tests were employed to compare the differences between fixed appliances and aligners in *problems/difficulties* and *feelings* during the epidemic.

Results: Of the 28,911 posts identified, 4,484 were included in the analysis. The most frequently mentioned themes were *appointments* (n = 2,621, 58.5%), *negative feelings* (n = 2,189, 48.8%), and *problems/difficulties* (n = 1,155, 25.8%). A majority of posts were tweeted in regions with high levels of economic development and population density in eastern China and from February to March. The number of daily posts had a significantly positive correlation with daily new COVID-19 cases/deaths in China ($P < 0.05$). Compared with clear aligners, patients with fixed appliances reported more *problems/difficulties* ($P < 0.001$) and *negative feelings* ($P < 0.001$), but fewer *positive feelings* ($P < 0.001$).

Conclusions: The analysis of Weibo posts provided a timely understanding of the impact of COVID-19 on orthodontic patients. Delayed appointments were their greatest concern, and negative feelings and untreated orthodontic problems increased during the

suspension of dental care services. However, patients with clear aligners reported fewer negative feelings and problems than those with fixed appliances. The findings highlighted the need to consider both treatment- and psychology-related issues of orthodontic patients and how to handle them appropriately during the epidemic.

Keywords: COVID-19, orthodontics, social media, dental care, online health

INTRODUCTION

The coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread rapidly throughout the world and triggered a global pandemic after being discovered in Wuhan, China, in December 2019 (1). The coronavirus showed high contagiousness and rapid spread, and as of June 9, 2020, the World Health Organization (WHO) reported 7,039,918 confirmed COVID-19 cases and 404,396 deaths (2).

The characteristics of dental practices, such as close face-to-face communication, droplet- and aerosol-generating procedures, and contaminated surfaces, expose dental patients and practitioners to high levels of pathogenic microorganisms and high risks of cross infection (3, 4). In addition, standard precautions are insufficient to protect practitioners and patients from the infection of COVID-19, which brings great challenges to dental services in this period (3). Therefore, most epidemic-attacked regions in China enforced strict regulations to dental health services in late January 2020, which only permitted emergent dental services (4). After 2 months of effective anti-epidemic efforts, China moved into a mitigation stage in April (5), and dental facilities began to gradually resume routine services under strict protective measures.

Scheduled orthodontic appointments and most orthodontic problems were deemed nonemergent; thus, most orthodontic departments and clinics were suspended during the epidemic (6). During the time of orthodontic practice suspension and home quarantine, many orthodontists and patients were at home and communicated by smartphones or online telemedicine services (4, 7). Given the failure to attend regular appointments, orthodontic problems such as loosening of brackets and archwires could not be treated timely in this long period of dental service suspension (6), which had a considerable impact on the lives and treatments of orthodontic patients. Therefore, being aware of patients' mental and physical conditions was necessary for orthodontists to give appropriate suggestions to patients during the epidemic and to prioritize the needs of patients after dental service reopening.

Social media have shown unique advantages in the dissemination of information, and the activities on social media platforms have increased sharply in the special period of transportation restriction and home quarantine (8). As a Chinese counterpart of Twitter, Sina Weibo is a popular social media platform that allows users to share their experiences, opinions, and perspectives, as well as to follow and communicate with others (9). The large scale of users, huge volume of information, and availability of free and immediate access have made it possible for researchers to investigate the public perception of public health events such as MERS-CoV and H7N9 through Sina Weibo (10). In addition, Weibo, regarded as an ideal tool to search large-scale, comprehensive information in a short time, was widely adopted in research related to impact of COVID-19 on public opinions, dental service, and psychology (11–13).

Previous studies have indicated that the COVID-19 epidemic had a negative impact on the public (14, 15). However, to our knowledge, its impact on orthodontic patients has not been explored, and Weibo has not been applied in the orthodontic field before. Therefore, this study aimed to investigate attitudes and perspectives of orthodontic patients during the COVID-19 epidemic, by analyzing the geographic location, time, and content of orthodontic-related posts on Weibo during the COVID-19 epidemic in China.

MATERIALS AND METHODS

Ethics

This study was approved by the Ethics Committee of School & Hospital of Stomatology, Wuhan University (no. 2020-B46). As the study utilized open information on the Internet, personal privacy and clinical data of the research subjects were not involved. Therefore, an exemption for informed consent was granted (11).

Data Collection

Potentially eligible posts were searched and collected retrospectively by two authors (F.G. and B.T.) from the Sina Weibo platform between December 30, 2019, and April 18, 2020. We used 9 keywords regarding COVID-19 and 10 keywords about orthodontics (**Table 1**), which were searched in

TABLE 1 | Keywords for searching the posts (translated from Chinese).

COVID-19-related keywords	Orthodontic-related keywords
Pneumonia	Orthodontics
Novel coronavirus	Correction
Virus	Orthodontic treatment
Epidemic	Invisalign®[a]
Anti-epidemic	Angelalign®[b]
Epidemic prevention	Braces
Battle against the epidemic	Brackets
COVID-19	Archwires
NCP (novel coronavirus pneumonia)	Oral myofunction
	Sleep disordered breathing

[a] *Align Technology, Santa Clara, CA, USA.*
[b] *EA Medical Instruments, Shanghai, China.*

TABLE 2 | Main themes and specific appliances for coding with definition and example.

Category[a]	Definition	Example
Main theme[b]		
Problems/difficulties	Problems related to orthodontic treatment	"…epidemic… The rubber bands have been used up. And the wire deformed when I just ate the braised chicken."
Appointments	Able/unable to attend orthodontic appointments	"…I haven't made an appointment of my appliances for 3 months because of the epidemic…."
Negative feelings	Obvious emotional words and/or emoticons expressing negative feelings	"If it wasn't for the epidemic, I would have started orthodontic treatment! I'm mad!!!"
Positive feelings	Obvious emotional words and/or emoticons expressing positive feelings	"…because of this epidemic…Finally I got the new aligners and my treatment will soon come to an end. I can see the dawn of victory!"
Contact with dentists	Able/unable to contact the dentist during the epidemic	"…clinics provided the online follow-up consultation warm-heartedly and professionally, and send new aligners and rubber bands…"
Consultation	Orthodontic consultation with netizens for advice	"I can't see the dentist during the epidemic and found my teeth becoming a little bit irregular. I want to ask what's wrong with my teeth ?"
Orthodontic plans	Plans for orthodontic treatment after the epidemic	"I'm not afraid of tooth extraction, I just want to put on braces after pneumonia"
Others	Other COVID-19- and orthodontic-related posts could not be classified into the above-mentioned themes, e.g., routine records	"Today is my 496th day of wearing Invisalign®. During the epidemic, I persisted in wearing aligners and now I'm wearing the 49th maxillary and 57th mandibular aligner."
Specific appliances[c]		
Fixed appliances	Posts with key words indicating fixed appliances, for example, brackets or archwires	"My brackets are lost! Pain! Please let the epidemic end soon!"
Clear aligners	Posts with key words indicating clear aligners, for example, Invisalign® or Angelalign®	"…This is the 11th week to wear Invisalign®…"
Retainers	Posts with key words indicating retainers	"…My retainer on the table was thrown by others…I can't get another pair during the epidemic"

[a] *A post could be classified into both main theme and specific appliances.*
[b] *A post was classified into more than one main theme if containing miscellaneous information.*
[c] *Only posts that contained key indicating words and could be identified as a specific type of appliances were coded.*

combinations (i.e., one COVID-19 keyword combined with one orthodontic keyword). A Python-based platform Gooseeker was employed to collect all the Weibo posts and extract data from each post, including Weibo number, Weibo username, full-text content, posting date, and location tag (optional when posting). In addition to the location tag, we also extracted geographic location information from full-text posts.

After the collection of posts, duplicate posts were initially removed by Microsoft Excel (2019), and then the remaining posts were screened by two authors (F.G. and D.Q.) to identify eligible posts. As decided *a priori*, only Weibo posts pertaining to both COVID-19 and the users' own orthodontic experience were included. Posts not related to COVID-19 (e.g., other types of pneumonia or other viral infections), irrelevant to orthodontic experience (e.g., prosthodontic treatment or other dental experience), posted by dental professionals, containing advertisements, or having a geographic location outside of China were excluded.

Coding Procedure

The included posts were read iteratively to familiarize two authors (F.G. and D.Q.) with the contents before coding. Inductive and deductive manual coding approaches were used (16). Initial primary coding categories for type of appliances and post contents were developed based on our study objective and previous research (17–19). Each category had several main themes (**Table 2**). A pilot coding on a subset of posts (10% randomly selected posts) was then conducted independently and in duplicate by two authors (F.G. and D.Q.) using the predetermined codes. Posts that could not be categorized with the initial codes were given a new code. Any disagreement was resolved via discussion with two experts (F.H. and H.H.). After coding, data were examined to identify potential subcategories within each primary category.

Prior to the formal coding procedure, 60 randomly selected posts were coded by two authors (F.G. and D.Q.) independently and in duplicate to achieve an agreement on the understanding of themes and subthemes. Thereafter, all posts were coded and sorted into primary categories and/or subcategories by the same two authors. If new codes emerged during this procedure, the temporary coding categories would be revised accordingly. All disagreements in classification and naming of themes and subthemes were resolved by discussion with two experts (F.H. and H.H.).

Data Analysis

Descriptive statistics were performed to summarize the characteristics of the included posts. For geographic distribution analysis, the number of posts with location was compared with the cumulative number of COVID-19 cases in each region of China. Epidemiological data were retrieved from the

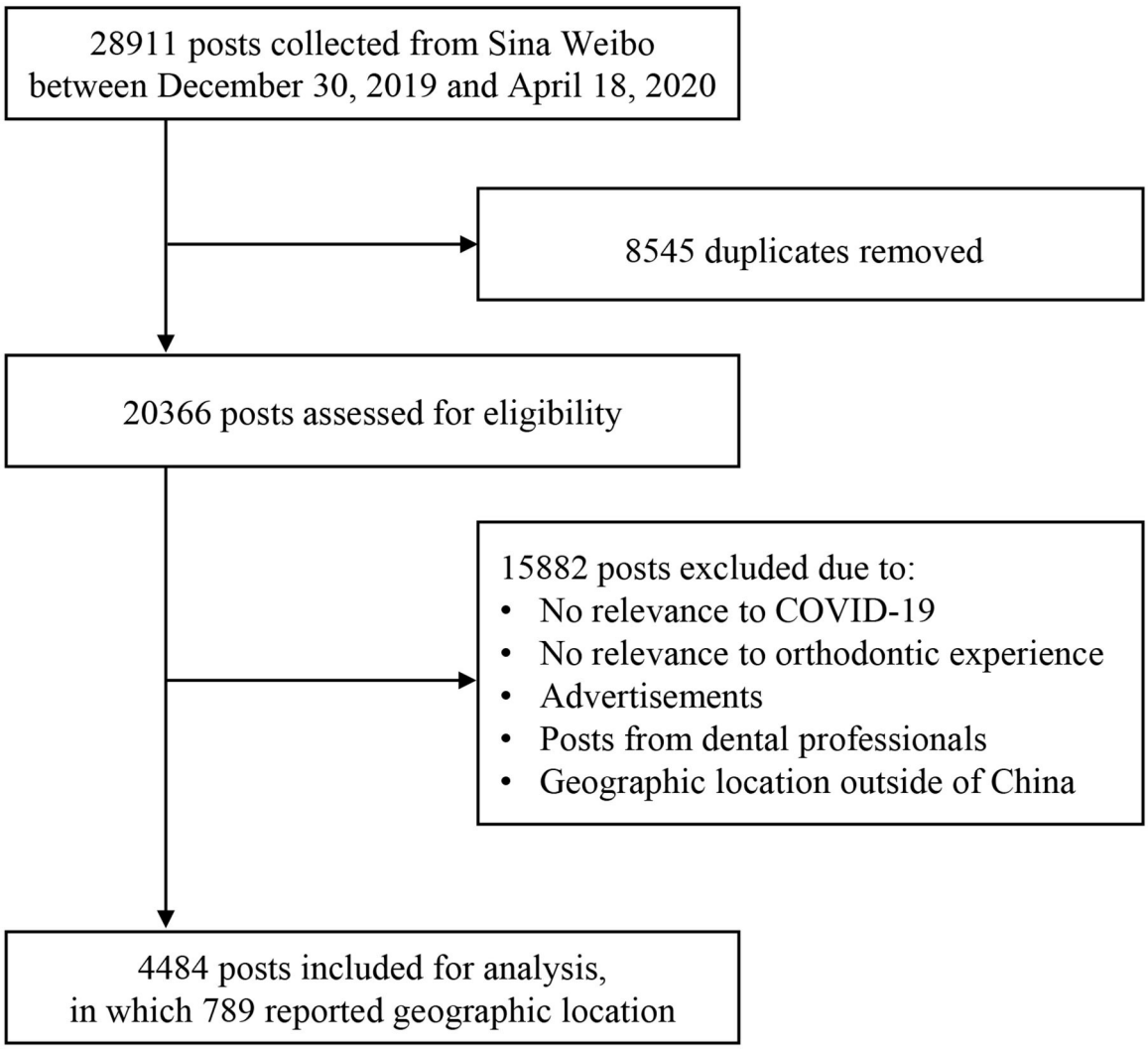

FIGURE 1 | Flow chart of posts selection.

official website of the Chinese Center for Disease Control and Prevention (CCDC) (5).

Temporal distribution analysis was performed to (1) present the change of number of posts and confirmed new COVID-19 cases/deaths each day in China; (2) display the daily number of posts related to orthodontic problems; (3) compare the daily number of posts of *positive feelings* with that of *negative feelings*; and (4) analyze the number of posts each day related to ability (able or unable) to attend an appointment during the epidemic. Time-lagged cross correlation (TLCC) was used to investigate the association between daily number of posts and daily confirmed new COVID-19 cases/deaths in China.

Chi-square tests were employed to compare the differences between fixed appliances and aligners in *problems* and *positive* and *negative feelings*. IBM SPSS Statistics 23.0 was used for statistical analysis, and a two-tailed $P < 0.05$ was considered significant.

RESULTS

Inclusion and Basic Characteristics of Posts

A total of 28,911 Weibo posts were collected, of which 4,484 were finally included in the analysis (**Figure 1**). Although we identified 305 posts regarding oral myofunction or sleep disordered breathing, none of these posts were concerning orthodontics. Among 4,484 included posts, 1,835 could be identified and coded as a specific type of appliances, in which 786 (42.8%) were related to fixed appliances, 985 (53.7%) clear aligners, and 64 (3.5%) retainers (**Table 3**).

Geographic Distribution of Posts

Among the 4,484 included posts, only 789 (17.6%) reported geographic information. The results of geographic distribution analysis are presented in **Figure 2**. In western China with

TABLE 3 | Number of posts for specific appliances (n = 1,835)[a].

Appliances	Number	Percentage (%)
Fixed appliances	786	42.8%
Clear aligners	985	53.7%
Retainers	64	3.5%
Total	1,835	100%

[a]*Among 4,484 included posts, 1,835 could be identified as a specific type of appliances and were coded.*

<100 COVID-19 cases confirmed, posts were less frequently distributed. More than half of the posts containing location information were posted from eastern China, where four provinces (Guangdong, Beijing, Shanghai, and Shandong) had the most posts (>60). However, <40 posts were from Hubei, the original epicenter and worst-affected province of COVID-19 in China.

Frequency of Main Themes and Subthemes

Figure 3 illustrates the percentage of posts in each main theme. The most frequently mentioned themes were *appointments* (n = 2,621, 58.5%), *negative feelings* (n = 2,189, 48.8%), *problems/difficulties* (n = 1,155, 25.8%), and *positive feelings* (n = 750, 16.7%). *Negative feelings* were reported 3 times more frequently than *positive feelings*. Only a few posts mentioned *contact with dentists* (n = 196, 4.4%) and *consultation* (n = 146, 3.3%).

The frequency and distribution of subthemes within each main theme are shown in **Table 4**. Among the 1,155 posts related to *problems/difficulties*, the most commonly listed issue was "loose brackets or archwires" (n = 479, 41.5%), followed by "shortage of subsequent aligners" (n = 268, 23.2%) and "poking archwires or ligatures" (n = 175, 15.2%). In terms of 2,126 Weibo posts regarding *appointments*, three-quarters were regarding "unable to attend an appointment" (n = 1,875, 71.5%). However, only a relatively small proportion of posts mentioned being "able to attend an appointment" (n = 747, 28.5%). In accordance with the *appointments* and *problems/difficulties*, 2,189 posts expressed feelings in a negative tone, in which most of them were related to treatment delay (n = 1,933, 88.3%), followed by "complaint about pain from orthodontic appliances" (n = 132, 6.0%).

In 750 posts related to *positive feelings*, one-third were concerning clear aligners, including "pleased to get new aligners during the epidemic" (n = 149, 19.9%) and "convenience/comfort of clear aligners" (n = 115, 15.3%). "Excellent dental care service," with key words such as "warm-hearted" and "careful," was mentioned 10 times more commonly than "poor dental care service" (217 vs. 20). Other reasons for positive feelings were "looking forward to ending orthodontic treatment" (n = 135, 18.0%) and "pleased to attend an appointment" (n = 131, 17.5%). Moreover, according to 196 posts with respect to *contact with dentists*, most patients could contact their dentists (n = 180, 91.8%) and make online consultation or face-to-face appointments with them, whereas a few lost contacts with their dentists (n = 16, 8.2%).

Temporal Distribution of Weibo Posts and Specific Themes

The temporal distribution of Weibo posts is presented in **Figure 4A**. No posts were identified before January 21. Then the number of posts began to increase from late January to early February, which was in accordance with the trend of daily new COVID-19 cases/deaths. The number of posts maintained a steady high level for 2 months, about 60 to 80 posts per day. In late March, the number of posts started to decline gradually.

The trend of posts related to *problems/difficulties* during this period (**Figure 4B**) was consistent with that of total posts. The number of posts related to orthodontic problems reached a plateau between mid-February and mid-March and then gradually declined. *Positive and negative feelings* showed opposite trends during the epidemic (**Figure 4C**). Posts related to *negative feelings* increased sharply in late January and early February and decreased gradually in late March, while those regarding *positive feelings* rocketed in late February. Similar trends were seen in *appointments* (**Figure 4D**), in which posts related to "unable to attend an appointment" increased quickly in late January and decreased in late March and those regarding "able to attend an appointment" started to increase gradually in early March.

As **Table 5** shows, the total number of daily posts was significantly correlated with the daily new cases (r = 0.323) and deaths (r = 0.555) in lag (−2) ($P < 0.05$), which suggested that the increase in the number of posts happened 2 days before that of new cases or deaths. *Negative feelings* also rose 2 days before the increase of deaths (r = 0.287, $P < 0.05$) but were not significantly associated with daily new cases. In addition, the number of posts regarding positive feelings showed a significant negative correlation with daily new cases (r = −0.331) and deaths (r = −0.272) in lag (5), which indicated that *positive feelings* increased 5 days after the decline of daily new cases or deaths.

Comparison Between Fixed Appliances and Clear Aligners

As shown in **Table 6**, 75.4% of the posts regarding fixed appliances reported problems arising during the epidemic and only 35.4% of those regarding clear aligners. The difference in *problems/difficulties* between the two appliances was significant ($P < 0.001$). For positive feelings, 44.9% of aligners expressed *positive feelings*, which were significantly more than that of fixed appliances (8.8%, $P < 0.001$). On the contrary, the difference between two appliances in *negative feelings* was significant ($P < 0.001$), as more fixed appliances (70.9%) were related to *negative feelings* compared with clear aligners (28.9%). Moreover, posts of fixed appliances expressed more *negative feelings* than *positive feelings*, while clear aligners were in the opposite situation.

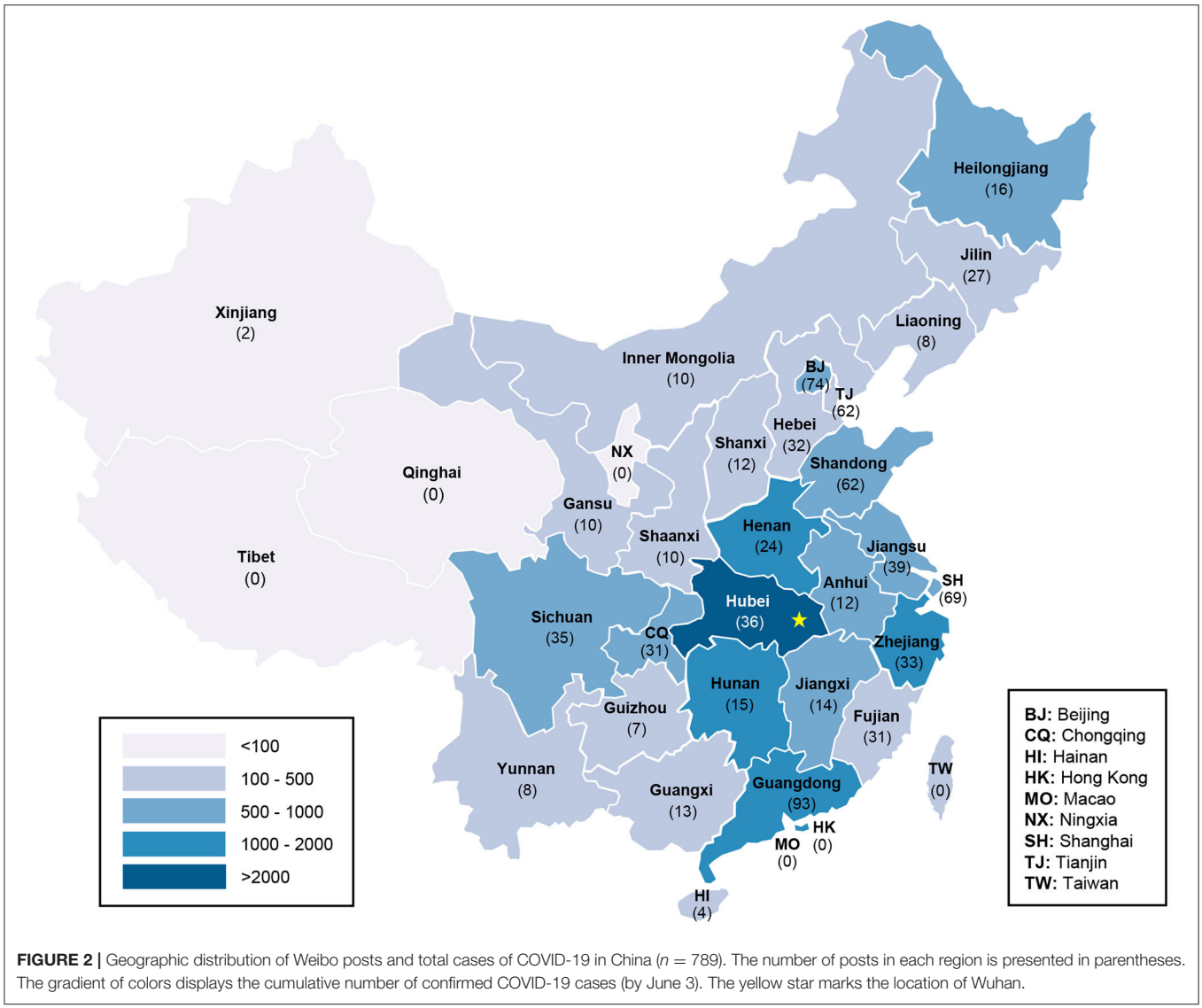

FIGURE 2 | Geographic distribution of Weibo posts and total cases of COVID-19 in China ($n = 789$). The number of posts in each region is presented in parentheses. The gradient of colors displays the cumulative number of confirmed COVID-19 cases (by June 3). The yellow star marks the location of Wuhan.

DISCUSSION

Orthodontic Services and the COVID-19 Pandemic

The outbreak of COVID-19 has brought about considerable changes to people's daily life. To control and prevent the spread of COVID-19, in late January, Chinese authorities imposed traffic restriction and appealed to the public to take a series of actions, including self-isolation and quarantine, social distancing, and mask-wearing in public places (20). The outbreak of disease and changes in life are reported to have a psychological impact on the public, such as panic, anxiety, and depression (21, 22).

For orthodontic patients, except for the above-mentioned situations, orthodontics-related problems were also their main concerns. Relevant governments in most regions in China set regulations on dental care services during the epidemic, and all elective dental treatments were suspended including orthodontic practice (4, 23). As a result of the regulation of dental practice as well as travel restriction, orthodontic patients could not attend an appointment on a routine basis, leaving problems untreated and with consequences for a prolonged duration of treatment.

About 1 month after the outbreak of COVID-19, as the epidemic was controlled in most provinces, the regulations began to relax and dental care services gradually resumed in these regions. To investigate the attitudes and perspectives of orthodontic patients during the COVID-19 epidemic, we have adopted a new data search platform, social media Weibo. The application of Weibo in orthodontic research can fit well with the COVID-19 epidemic, due to its advantages in studying population-level health behaviors, social opinions, and public responses to health issues in a timely and dynamic way. Therefore, 4,484 included posts in Sina Weibo were collected between December 30, 2019, and April 18, 2020, about 1 month

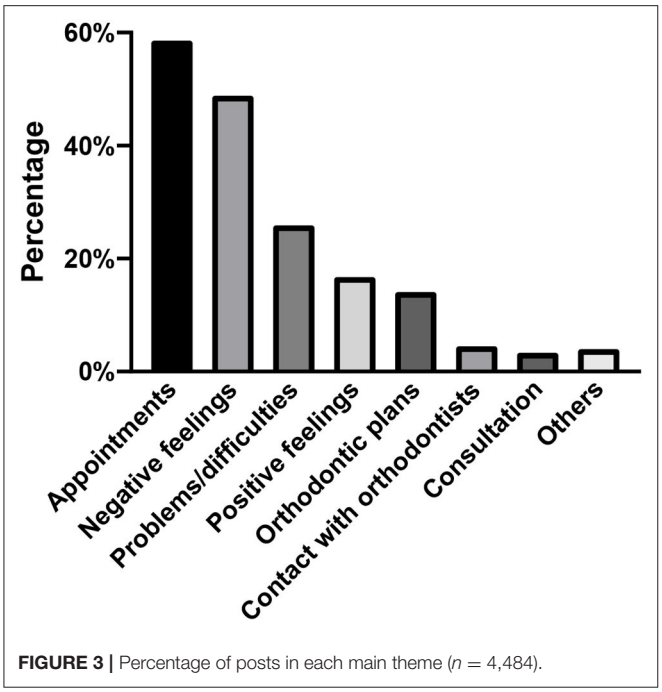

FIGURE 3 | Percentage of posts in each main theme (n = 4,484).

before the outbreak and after the relief of COVID-19, to provide insights into the changes in the influence of COVID-19 on orthodontic patients during the period of the progression and remission of the epidemic.

Distribution of Weibo Posts

In this study, posts were mainly from eastern regions that generally had a high level of economic development and population density in China. Three province-level regions including Guangdong, Beijing, and Shanghai posted 2 to 3 times more posts than did Hubei, the most virus-hit province. A previous study focusing on the Weibo posts with COVID-19-related oral health information showed a similar geographic distribution (12). Guangdong, Beijing, and Shanghai are the most economically developed and densely populated areas in China, and more people used Weibo to express their opinions during the epidemic (11). In addition, since orthodontic treatment is relatively expensive and not covered under health insurance in China, more people in these regions with better economic condition receive orthodontic treatment; economically developed regions also have more dental hospitals and clinics and therefore have more orthodontic patients (23). As people were more sensitive to epidemic and social events in these areas with a large population, convenient transportation, and high network penetration, negative feelings caused by epidemic were more likely to emerge (11, 14). Thereby, attention should be paid to the psychological management of orthodontic patients from developed regions.

The trend of Weibo posting was associated with the pattern of reports of daily new cases and death cases of COVID-19, which can be divided into three main stages: rising, stable, and falling. This trend was similar to a previous study on H7N9-related posts on Weibo (24). After the official confirmation of human-to-human transmission of COVID-19 on January 20 and the steep rise in the number of newly confirmed cases, the number of daily posts increased substantially from late January to early February. Then the number of posts reached a plateau and lasted until mid-March, about half a month after the initial control of the epidemic. During this period, most dental practices were suspended as well as orthodontic treatment, and orthodontic patients could only consult via online services (4). As the daily new COVID-19 cases decreased to a relatively low level and dental services began to resume in less-affected regions, the number of posts gradually declined.

TABLE 4 | Frequency and distribution of subthemes within each main theme (n = 4,484).

Main theme	Total	Subtheme	*N* (%)
Problems/difficulties[a]	1,155	Loose brackets or archwires	479 (41.5%)
		Shortage of subsequent aligners	268 (23.2%)
		Poking archwires or ligatures	175 (15.2%)
		Broken appliances	72 (6.2%)
		Loss of aligners/retainers	55 (4.8%)
		Insufficient rubber bands	34 (2.9%)
		Aligners worn irregularly	32 (2.8%)
		Failed attachments	29 (2.5%)
		Loose temporary anchorage devices	23 (2.0%)
		Unfit aligners	13 (1.1%)
		Others	54 (4.7%)
Appointments	2,621	Unable to attend an appointment	1,875 (71.5%)
		Able to attend an appointment	746 (28.5%)
Negative feelings[a]	2,189	Negative feelings toward treatment delay	1,933 (88.3%)
		Complaint about pain from orthodontic appliances	132 (6.0%)
		Concerns about orthodontic visits during the epidemic	110 (5.0%)
		Fear of the COVID-19 epidemic	23 (1.1%)
		Poor dental care services	20 (0.9%)
		Others	54 (2.5%)
Positive feelings[a]	750	Excellent dental care service	217 (28.9%)
		Pleased to get new aligners during the epidemic	149 (19.9%)
		Looking forward to ending orthodontic treatment	135 (18.0%)
		Pleased to attend an appointment	131 (17.5%)
		Convenience/comfort of clear aligners	115 (15.3%)
		Others	126 (16.8%)
Contact with dentists	196	Able to contact dentists	180 (91.8%)
		Losing contact with dentists	16 (8.2%)

[a]*A post was classified into more than one subtheme if containing miscellaneous information.*

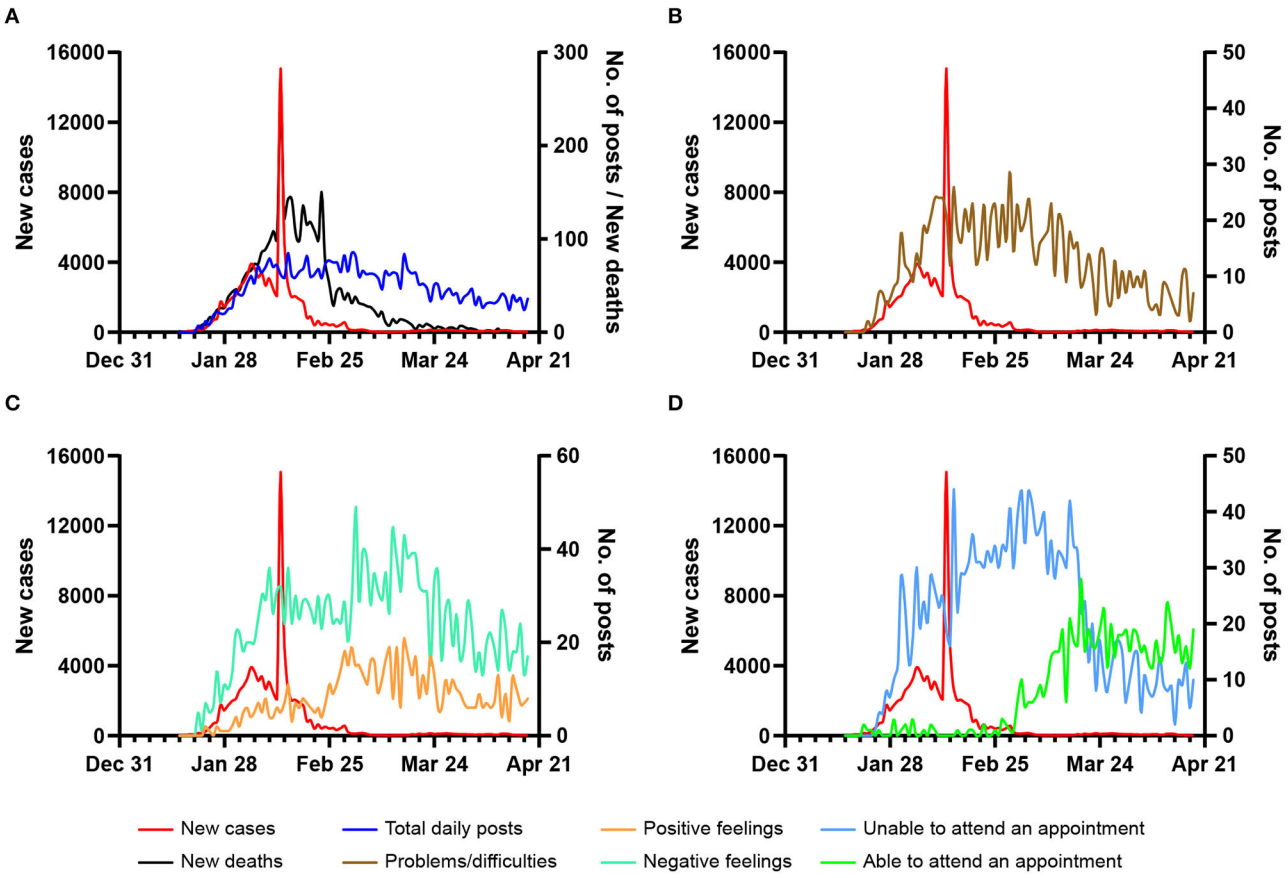

FIGURE 4 | Number of Weibo posts and daily new COVID-19 cases/deaths in China. Total number of posts **(A)**, and number of posts related to problems **(B)**, positive and negative feelings **(C)** and if able to attend an appointment **(D)** are compared with daily new cases/deaths.

TABLE 5 | Time-lag correlation coefficients between the number of posts and daily new confirmed COVID-19 cases or daily new deaths (n = 4,484)[a].

Lag	−5	−4	−3	−2	−1	0	1	2	3	4	5
Daily new cases											
Total number of posts	**0.297**	**0.265**	**0.249**	**0.323**[b]	**0.229**	0.201	0.196	0.149	0.141	0.073	−0.004
Positive feelings	−0.183	−0.174	**−0.238**	−0.141	−0.182	**−0.231**	**−0.241**	**−0.290**	**−0.320**	**−0.275**	**−0.331**[b]
Negative feelings	0.099	0.120	0.074	0.138	0.050	0.079	0.050	−0.019	0.011	−0.052	−0.100
Daily new deaths											
Total number of posts	**0.517**	**0.533**	**0.517**	**0.555**[b]	**0.517**	**0.502**	**0.499**	**0.440**	**0.421**	**0.393**	**0.322**
Positive feelings	−0.013	−0.028	−0.097	−0.063	−0.106	−0.148	−0.157	−0.203	**−0.237**	**−0.228**	**−0.272**[b]
Negative feelings	**0.225**	**0.263**	**0.228**	**0.287**[b]	**0.244**	**0.260**	**0.238**	0.175	0.182	0.130	0.086

[a] *Values in bold are statistically significant (<0.05).*

[b] *The largest correlation between the number of posts and daily new confirmed COVID-19 cases or daily new deaths among different time lags.*

As aforementioned, time of each fluctuation of the number of posts was related to the date of major events, especially regulations about dental practice. Likewise, during the "hepatitis B vaccine crisis," the trend of public reactions on Weibo was also influenced by the number of deaths and the suspension of relevant vaccine (25). In addition, we found a moderate positive correlation between the number of posts and negative feelings and that of new cases or deaths 2 days before and a negative association between positive feelings and number of new cases and deaths 5 days after. Our findings suggest that the popularity of Weibo topics related to COVID-19 and orthodontics was associated with the severity of the COVID-19 epidemic (11), and the implementation of public health interventions could have an impact on patients' reaction to their treatment and feelings in outbreaks of diseases (25).

The Content of Weibo Posts

In our study, the most frequent reasons for tweeting were delayed appointments and expression of negative feelings. Negative feelings were mainly toward treatment delay including worries about missing appointments, annoyance arising from orthodontic problems, and extension of the duration. A recent study has suggested that the COVID-19 epidemic impacted orthodontic appointments and provoked patients' anxiety, and the biggest concern of over half of the patients was also the delay of treatment (26).

Due to the suspension of orthodontic practices during the epidemic, lots of orthodontic problems remained untreated. A previous study showed that the need for orthodontic treatment ranked second in all dental problem-related Weibo posts during the epidemic (12). In our study, a quarter of posts mentioned orthodontic problems, in which loose brackets and archwires were the most common problems. However, some orthodontic procedures that are aerosol generating were still restricted in high-risk regions after the resumption of orthodontic practice. Therefore, to reduce nosocomial infection, orthodontists should give priority to deal with the patients whose treatment would not have aerosol generated after work resumption and avoid appointments with patients whose treatment was restricted (27).

Telemedicine, the approach of online consultation and remote management of patients, developed rapidly and was widely applied during the COVID-19 epidemic (6, 7). However, in this study, a few patients stated that they were unable to contact their dentists, which compromised patients' confidence in treatment (28, 29). Thus, orthodontists should provide patients with correct contact information in case of any emergent situation. In addition, due to the high risk of infection in dental settings, patients may hesitate to attend an appointment after work resumption (26). Therefore, online consultation may still serve as the main communication method at the beginning of work resumption and is also useful in patient triage in this busy time (30).

In summary, our study on the distribution and content of Weibo posts provided an updated understanding of the attitudes and perspectives of orthodontic patients during the COVID-19 epidemic. With accessible resources to acquire timely and large-scale information (13), the social media platform Weibo was recommended to be used by orthodontists to better understand the physical and psychological conditions of orthodontic patients as well as their needs (31). Given the suspension of routine dental practices, more patients with orthodontic problems would seek support and relevant information about treatment through the Internet. However, this online information remains to be doubtful and might be incorrect or unfounded (18). Previous research has indicated that Weibo was more efficient in disseminating information than conventional ways (24). Therefore, orthodontics can use Weibo to spread professional knowledge regarding the management of orthodontic emergencies, such as the use of orthodontic wax for poking archwires for patients, especially for those who lost contact with their orthodontists. Moreover, our findings can provide data based on which patient management during and after the epidemic can be optimized (29). Since adolescents who are a susceptible population of COVID-19 comprise the majority of orthodontic patients and asymptomatic COVID-19 infection may exist after the epidemic, strict infection control measures are necessary for orthodontists (30). Except for the management mentioned above (including restriction on aerosol-generated practices, online consultation, and strict precautions), it is also recommended to schedule patient appointments carefully and reduce the number of patients to avoid crowds gathering/waiting in the consultation area of dental hospitals and clinics.

TABLE 6 | Frequency and distribution in different themes between fixed appliances and aligners (n = 1,771).

Themes	Fixed appliances (n = 786)	Aligners (n = 985)	P
Problems/difficulties	593 (75.4%)	349 (35.4%)	<0.001
Positive feelings	69 (8.8%)	442 (44.9%)	<0.001
Negative feelings	557 (70.9%)	285 (28.9%)	<0.001

Differences Between Fixed Appliances and Clear Aligners

In the present study, clear aligners showed many advantages over fixed appliances during this epidemic; problems with clear aligners were significantly less than those with fixed appliances. Many patients chose fixed appliances due to lower cost and shorter treatment duration (32); however, they experienced high incidence of bracket detachment and poking archwires, which could not be treated timely during the epidemic (27). In contrast, the main concerns of aligners were shortage of aligners and aligner breakage, which were easier to manage during the lockdown period. Patients were required to extend the wearing time of each available aligner and to wear it carefully to avoid breakage, and after work resumption, they could get the remaining aligners on delivery without the need for an appointment (29). As for feelings, there was a significant difference in positive and negative feelings between fixed appliances and aligners, and patients with fixed appliances were more inclined to get anxious. Previous studies also suggested that aligners had less impact on patients' daily life, and patients felt more satisfaction and less discomfort compared to patients with conventional fixed appliances (33, 34). It seems that patients with clear aligners were easier to manage than those with fixed appliances during the COVID-19 epidemic; therefore, more attention should be paid to the management of patients with fixed appliances.

Limitations

The present study has some limitations. First, the inclusion of Weibo users alone may not reflect the overall situation in the whole population. However, samples from social media should be representative of adolescents, which predominate the orthodontic patients (18). Although there are other popular social media platforms such as WeChat in China, Weibo is the largest one with ample public opinions and accessible information. In addition, Weibo is the most often used platform for discussing breaking news and events, with 550 million monthly active users in the first quarter of 2020 (35). Second,

the present study was based only on the Chinese population, which may not reflect populations from other countries. Further research is needed to study the situation in other countries and regions, which may identify cross-cultural differences. Third, data quality issues and privacy issues are frequently mentioned in social media research (36). Since Weibo users can choose to share posts with the public or specific people and only open public data can be searched, some information was inevitably unavailable. However, such selection bias is common in health care-related research using social media (19, 37). So far, there have been no commonly accepted guidelines or consensus about the ethics of user privacy and data use on social media-based studies. In this study, we only collected public information and strictly avoided direct quotations and presentation of any personal information (38).

CONCLUSIONS

The analysis of Weibo posts provided a timely understanding of the impact of COVID-19 on orthodontic patients. Delayed appointments were their greatest concern, and negative feelings and untreated orthodontic problems increased during the suspension of dental care services. However, patients with clear aligners reported fewer negative feelings and problems than those with fixed appliances. The findings highlighted the need to consider both treatment and psychological issues of orthodontic patients and how to handle them appropriately during the epidemic.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of School & Hospital of Stomatology, Wuhan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

FH: study conception. FG, BT, DQ, TZ, FH, and HH: study design. FG, BT, DQ, FH, and HH: data collection. FG, DQ, and FH: data analysis. TZ, Y-xS, CM, and HH: data interpretation. FG, BT, and DQ: manuscript drafting. TZ, Y-xS, CM, FH, and HH: critical revision of the manuscript. All authors: approval of the final version.

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ACE2 and Furin Expressions in Oral Epithelial Cells Possibly Facilitate COVID-19 Infection via Respiratory and Fecal–Oral Routes

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Background: Coronavirus disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that mainly transfers from human to human via respiratory and gastrointestinal routes. The S-glycoprotein in the virus is the key factor for the entry of SARS-CoV-2 into the cell, which contains two functional domains: S1 is an angiotensin-converting enzyme 2 (ACE2) receptor binding domain, and S2 is necessary for fusion of the coronavirus and cell membranes. Moreover, it has been reported that ACE2 is likely to be the receptor for SARS-CoV-2. In addition, mRNA level expression of Furin enzyme and ACE2 receptor had been reported in airway epithelia, cardiac tissue, and enteric canals. However, the expression patterns of ACE2 and Furin in different cell types of oral tissues are still unclear.

Methods: In order to investigate the potential infective channel of the new coronavirus via the oropharyngeal cavity, we analyze the expression of ACE2 and Furin in human oral mucosa using the public single-cell sequence datasets. Furthermore, immunohistochemistry was performed in mucosal tissue from different oral anatomical sites to confirm the expression of ACE2 and Furin at the protein level.

Results: The bioinformatics results indicated the differential expression of ACE2 and Furin on epithelial cells from different oral anatomical sites. Immunohistochemistry results revealed that both the ACE2-positive and Furin-positive cells in the target tissues were mainly positioned in the epithelial layers, partly expressed in fibroblasts, further confirming the bioinformatics results.

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Conclusions: Based on these findings, we speculated that SARS-CoV-2 could invade oral mucosal cells through two possible routes: binding to the ACE2 receptor and fusion with cell membrane activated by Furin protease. Our results indicated that oral mucosa tissues are susceptible to SARS-CoV-2 that could facilitate COVID-19 infection via respiratory and fecal–oral routes.

Keywords: COVID-19, SARS-CoV-2, ACE2 (angiotensin converting enzyme-2), Furin, oral mucosa, single cell RNA seq

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes coronavirus disease 2019 (COVID-19) pandemic and mainly triggers acute respiratory distress syndrome (ARDS) and viral sepsis that bring challenges to the patient's treatment (1, 2). The pandemic infection of COVID-19 confirmed nearly 40,000,000 human cases, including >1,100,000 deaths, and the infection rate is continuously increasing worldwide. The present outbreak of COVID-19 has been labeled as a global pandemic by WHO and has posed critical challenges for public health, research, and medical communities (3). Airborne transmission has been recently reported as a dominant route for COVID-19 infection (4). Similarly, many research groups had reported gastrointestinal manifestation of COVID-19 purposing the fecal–oral route as an alternative route of SARS-CoV-2 transmission (5–8). These findings suggest that the epithelial cells of the oropharyngeal cavity provide the binding site to enter and propagate the SARS-CoV-2. However, the expression of possible receptors of the SARS-CoV-2 in different cell types of the oral cavity has not been investigated yet.

Like patients with SARS and Middle East respiratory syndrome (MERS), the clinical manifestations of COVID-19 at illness onset are fever, dry cough, and myalgia. The patients suffer from dyspnea, shortness of breath, respiratory failure, and even death in later stages (2, 9, 10). Besides, COVID-19 patients show oral manifestations, including oral pain, gingivitis, and ulcers, especially for severe cases (11). Dry mouth and amblygeustia are experienced by a relatively high proportion of COVID-19 patients (12). Also, viral enanthema in the oral mucosa is considered as a possible diagnostic challenge in the COVID-19 pandemic (13). As the oropharyngeal cavity is a route of COVID-19 transmission, it might have adverse impacts on patients' oral health. Since COVID-19 seems to stay longer in our society, the insights in the relationship between oral health and COVID-19 could provide crucial information for decision-making in managing this notorious infectious disease.

SARS-CoV-2 entry into the cell is induced by the binding of viral spike protein to host cellular angiotensin-converting enzyme 2 (ACE2) receptors (14, 15). Previous findings indicated that ACE2 plays an essential role in SARS-CoV-2 entry in the host cells. Thus, ACE2-expressing cells may act as target cells and are susceptible to COVID-19 infection (2, 14–18). Hamming et al. (19) had reported the ACE2 receptor expression in various human tissues, including epithelium of the lung and small intestines. As a co-expressed membrane endopeptidase of the ACE2 receptor, Furin has the potential to cleave the viral envelop glycoprotein, thereby enhancing the viral fusion with host cell membranes (20). Genomic characterization of SARS-CoV-2 has revealed that the Furin enzyme could activate the specific site of its spike protein (21). Meanwhile, Li et al. (22) showed that a putative Furin cleavage site in the spike protein of SARS-CoV-2 facilitates the virus–cell fusion. The Furin cleavage site is absent in SARS-CoV. The presence of the Furin cleavage site in SARS-CoV-2 showed distinct clinical symptoms (23, 24). Furthermore, online single-cell sequence datasets analysis unveiled that Furin was expressed in coronavirus's potential target organs, such as lung, heart, nose, rectum, colon, intestine, and ileum (22). Hence, the expression and distribution of ACE2 and Furin in the epithelium of the oral cavity could be critical for the coronavirus invasion to the host cells. However, information on the expression and distribution of ACE2 and Furin in the human oral cavity is limited.

Single-cell RNA sequencing (scRNA-Seq) technique provides an avenue to understand gene regulation networks and the complexity of cell-to-cell heterogeneity at the single-cell level. scRNA-Seq has diverse applications on bioinformatics, stem cell differentiation, organ development, whole-tissue subtyping, and tumor biology (25–27). scRNA-Seq captures cellular differences underlying tumor biology at a higher resolution than regular bulk RNA-Seq and has revolutionized studies of cancer mechanisms and personalized medicine (28). For a better understanding of the potential COVID-19 infection risk in the oral cavity, we explored whether ACE2 and Furin are expressed and the composition and proportion of their expressing cell in different oral tissues based on the public scRNA-seq profiles from Gene Expression Omnibus (GEO) public databases. Furthermore, we performed immunohistochemistry analysis for ACE2 and Furin in human oral epithelium tissue sections. Oral epithelium showed the expression of ACE2 and Furin in both mRNA and protein levels, indicating the oral cavity as a platform for COVID-19 invasion via the respiratory route and possibly fecal–oral route.

MATERIALS AND METHODS

Public Single-Cell RNA Sequencing Dataset Acquisition

scRNA-Seq datasets (GSE103322), including the gene expression and cell type annotation from human oral squamous cell carcinoma (OSCC) tissue, were downloaded from the GEO database (https://www.ncbi.nlm.nih.gov/geo/). Patient

characteristics and demographics for the dataset used are listed in **Supplementary Table 1**.

Single-Cell Sequencing Analysis

scRNA-Seq datasets (GSE103322) were downloaded from the GEO database. Datasets of five patients, which have the closest histological features with normal tissue, were selected for further analysis. The scRNA-Seq datasets of GSE103322_HN_UMI_table.txt were used to subsequently analyze based on R package Seurat (Version 3.6.2). For quality control, we removed cells with <50 genes, as well as the cells with mitochondrial content higher than 5%. Besides, the genes detected in <3 cells were filtered out in the function Create Seurat Object. Subsequently, the data were log-normalized using the function Normalize Data with the default parameters. The Find Variable Genes function was used to determine the highly expressed variable genes, followed by principal component analysis (PCA) dimensionality reduction by RunPCA function. PCA components, which $P < 0.05$, were selected to analyze further using two-dimensional t-distributed stochastic neighbor embedding (tSNE). The setting of k.param was 20 in the function Find Neighbors, and the setting of the resolution was 0.5 in the function Find Clusters. Finally, the cell types were assigned based on their canonical markers. The functions of DotPlot and VlnPlot displayed the gene expression of different cell types. The significant level was set as 0.05.

Human Oral Tissue Specimens

Twelve normal tissues of the oral mucosa (three buccal and gingival tissues, two lip, tongue, and palatal tissues, respectively) were taken from 12 different patients with clinically diagnosed fibrous epithelial polyp or benign tumor (19, 29), whose average age was 53 years. The healthy oral mucosa tissue was collected from a 2-cm distance of the tumor edge. Patient exclusion criteria of this study were patients with a history of smoking, periodontitis, uncompensated diabetes mellitus, immunocompromised status, under radiotherapy and/or chemotherapy, and systemic diseases. Vulnerable populations such as pregnant women, minors (i.e., under 18 years old), and seniors (i.e., over 60 years old) were also excluded. Written informed consent was obtained for each participant, and the study was in accordance with the Declaration of Helsinki and the guidelines and approved by the Clinical Ethics Committee of Affiliated Stomatology Hospital of Guangzhou Medical University (Approval no. KY2020002). Tissue morphology was evaluated in hematoxylin and eosin-stained sections by a qualified pathologist.

Immunohistochemical Staining

The selected tissues were fixed in 10% neutral formalin solution and embedded in paraffin. The paraffin sections (4 μm in thickness) were deparaffinized in xylene, rehydrated in a graded series of alcohol. Human lung bronchi tissue sections were used as positive control of ACE2 and Furin expression. The tissue sections were then incubated in citrate buffer (pH 6.0) for 5 min at 120°C, and the endogenous peroxidase was blocked by 0.3% H_2O_2 for 10 min. Subsequently, the tissue sections were dried and incubated with Rabbit Anti-ACE2 antibody (cat. no. ab15348, Abcam, Cambridge, CB, UK) antibody, Anti-Furin antibody (cat. no. bs-13228R) overnight at 4°C. The negative control sections were incubated with 1% rabbit serum containing phosphate buffered saline (PBS) instead of the primary antibody. The next day, the tissue sections were incubated with the horseradish peroxidase (HRP) (Goat Anti-Rabbit IgG H&L)-conjugated secondary antibody for 1 h at room temperature. Peroxidase activity was developed by using 3,3′-diaminobenzidine (DAB) for 8 min and counterstained with hematoxylin. A qualified pathologist analyzed the staining. The ACE2 and Furin staining intensities were semiquantitatively graded according to the previously described method (30).

RESULTS

Identification of Cell Types in the Oral Mucosal Tissues

We detected the ACE2-expressing cell types in oral tissue by analyzing the scRNA-Seq data. A total of 1,843 individual cells from the oral mucosa of five patients were analyzed. Using the unsupervised graph-based clustering, we found that at least 13 distinct cell clusters existed in the oral tissues (**Figure 1A**), including epithelial cells (clusters 1, 4, 5), fibroblasts (clusters 0, 2, 7), T-cells (clusters 8, 9), and B cells (cluster 12). The heatmap of the main corresponding cell marker gene expression profiles across the cell types can be found in **Figure 1B**. The marker gene of epithelial cells included KRT6B, GJB2, SFN, and KRT14; fibroblasts included THY1, COL1A1, DCN, and ACTA2; B cells included SLAMF7, CD19, CD20, and CD79A; T cells included CD2, CD3, and CD45.

Identification of Angiotensin-Converting Enzyme 2-Expressing Cells in the Oral Mucosa

We explored the online datasets to find out the expression level of ACE2 in the oral mucosa. A single-cell atlas from analysis of scRNA-Seq data of the human oral mucosa identified 13 cell subclusters in the oral mucosal cells, including epithelial cells, fibroblasts, T cells, and B cells (**Figure 1**). The clusters 1, 4, 5, and 6 are epithelial cell clusters. The red dots in the scatter plot (**Figures 2C,D**) showed the expression profiles of ACE2 and Furin in the 13 distinct cell clusters identified from **Figure 1A**. As expected, data from GEO indicated that ACE2 receptor expression level was relatively higher in epithelial cells (clusters 1, 4, 5) (**Figures 2A,C**), while very little cellular expression of ACE2 was found in fibroblasts (cluster 2). Then, we calculated the percentage of ACE2-expressing cells in the dataset (**Figure 2E**). We find that, in oral tissue, the percentage of ACE2-positive cells was 2.2%. Among them, 92% were epithelial cells. The negative control of oral tissue immunohistochemistry (IHC) is listed is **Supplementary Figure 1**.

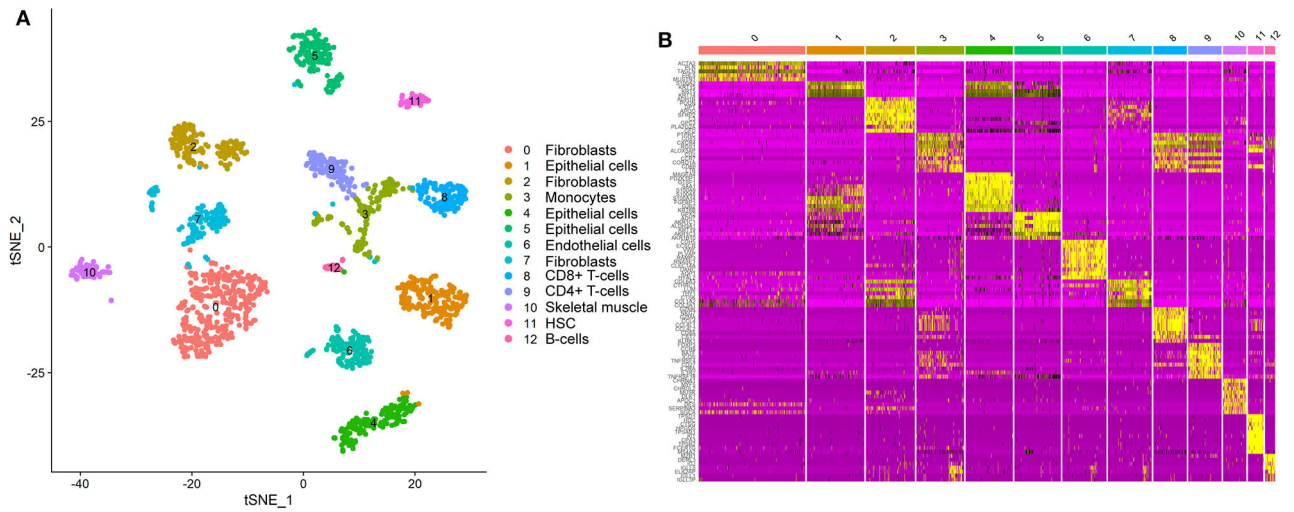

FIGURE 1 | Single-cell atlas of the human oral mucosa. **(A,B)** Analysis of single-cell sequencing data identified 13 cell subclusters in the oral mucosal cells. Thirteen distinct cell clusters existed in the oral tissues **(A)**, including epithelial cells, fibroblasts, T cells, and B cells. The heatmap of the main corresponding cell marker gene expression profiles across the cell types is plotted in **(B)**. The marker gene of epithelial cells included KRT6B, GJB2, SFN, and KRT14.

Identification of Furin-Expressing Cells in the Oral Mucosa

To determine the cell types of expressing Furin, we analyzed the Furin mRNA expression using tSNE method. Violin and scatter plot showed that Furin was highly expressed in epithelial cells, followed by fibroblasts, T cells, and endothelial cells of the oral mucosal tissues, but hardly expressed in B cells (**Figures 2B,D**). Meanwhile, the proportion of Furin expressing cells was ∼10%. Among them, epithelial cells make up more than 55% (**Figure 2F**).

Angiotensin-Converting Enzyme 2 Protein Is Highly Expressed in the Epithelial Layer of the Buccal Mucosa, Lip, Palate, Tongue, and Gingiva

IHC analysis further determined the protein level expression of ACE2 in the oral mucosa. ACE2 and Furin were highly expressed in human lung bronchi tissue sections, indicating the specificity of the primary antibodies used in this study. The first remarkable finding was that ACE2 was expressed in epithelial cells in all the tissues studied (**Figure 3**). Results indicated that the expression level of ACE2 protein was significantly higher in the lip, tongue, and buccal mucosa, especially the epithelial cells in the basal layer, although the mRNA expression level is not as high (**Figure 2**). The ACE2-positive cells in the gingival and palatal tissues were limited. The corresponding gingiva and palate epithelial cells showed weak positive ACE2 staining. Systematic ACE2 expression levels in different oral sites are shown in **Figure 5**. Also, we found that ACE2 was expressed in fibroblasts and endothelial cells. These results indicate oral epithelial cells as the potential targets of SARS-CoV-2.

Furin Protein Was Highly Expressed in the Normal Oral Mucosa

Furin mRNA expression has been described mainly in oral epithelial cells through scRNA-Seq technique. To determine whether this differential expression of Furin was maintained at the protein level, oral tissues from different sites were screened. As shown in **Figure 4**, moderate to mild immunostaining in the cytoplasm of epithelial cells was observed in five normal oral tissues. Surprisingly, except for the positive cells in the basal layer of the oral epithelium, the spinous layer in all examined tissues also turned out with large numbers of Furin-positive cells. In addition, the percentage of Furin-positive cells in the lip, tongue, and gingiva was higher than that of buccal and palatal mucosa. Systematic Furin expression levels in different oral sites are shown in **Figure 5**.

DISCUSSION

Highly infectious nature and pandemic spreading of COVID-19 overwhelmed the public health services in the world and have become a global public health problem (31). Studies had reported both the respiratory and gastrointestinal tract manifestations of COVID-19 (4, 32). As mentioned before, the ACE2 receptor in the host cell membrane and Furin cleavage site of SARS-CoV-2 are the key factors that allowed the virus to invade the host cells (22, 23). In this study, we found the expression of ACE2 and Furin in oral epithelial cells in both mRNA and protein levels. Since the oral cavity is connected to both the respiratory and gastrointestinal tract, the ACE2 and Furin in oral mucosal cells could be the possible facilitators of COVID-19 infection *via* respiratory and fecal–oral routes.

Many studies have shown that the ACE2 receptor was highly expressed in respiratory epithelium, kidney, testis, digestive

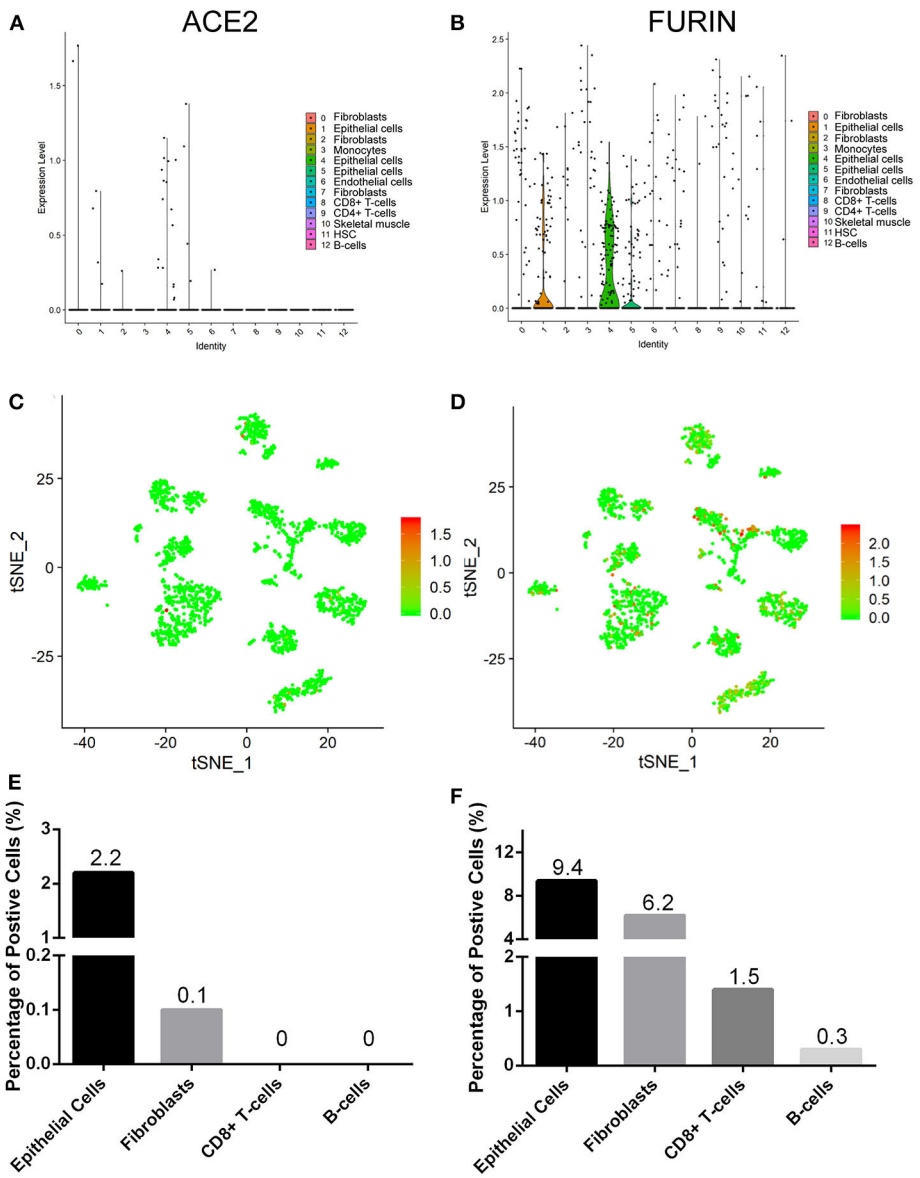

FIGURE 2 | The expression profiles of angiotensin-converting enzyme 2 (ACE2) **(A,C,E)** and Furin **(B,D,F)** in the oral mucosal cells. Violin and scatter plot showed the expression profile of the ACE2 receptor **(A,C)** and Furin **(B,D)** in oral mucosal cells. ACE2 and Furin were mainly expressed in epithelial cells. **(E,F)** The percentage of ACE2- and Furin-positive cells in the oral mucosa.

system, and cardiovascular system (6, 18, 33). Pieces of literature using bulk RNA sequencing data found that ACE2 is expressed in oral tissues, which could not accurately reflect the expression of ACE2 in the single-cell level (29, 34). Chen et al. benefited from the single-cell sequencing data to further prove the expression of ACE2 receptor in the tongue, buccal mucosa, and gingiva (14, 19, 34). However, these studies were based on public databases and did not further analyze the protein level expression. In the current study, we firstly analyzed the ACE2 expression in different cell types present in various oral anatomical sites using the scRNA-Seq public data from five human subjects. We further confirmed the protein level expression of ACE2 in histological tissue sections from different anatomical sites of 12 human subjects by IHC. Results indicated that ACE2 is mainly expressed in epithelial cells in all included oral tissues, especially in the buccal mucosa, lip, and tongue. Our results demonstrated that compared with other oral anatomical sites, buccal mucosa, lip, and tongue showed a higher expression of ACE2, suggesting that these sites are more susceptible to SARS-CoV-2-invasion.

Team of virologists from Cornell University reported another structural analysis of the coronavirus S protein, suggesting that the Furin cutting site allows the SARS-CoV-2 virus to enter cells in a very different way than SARS, and this may regulate the virus stability and infection (35). Other

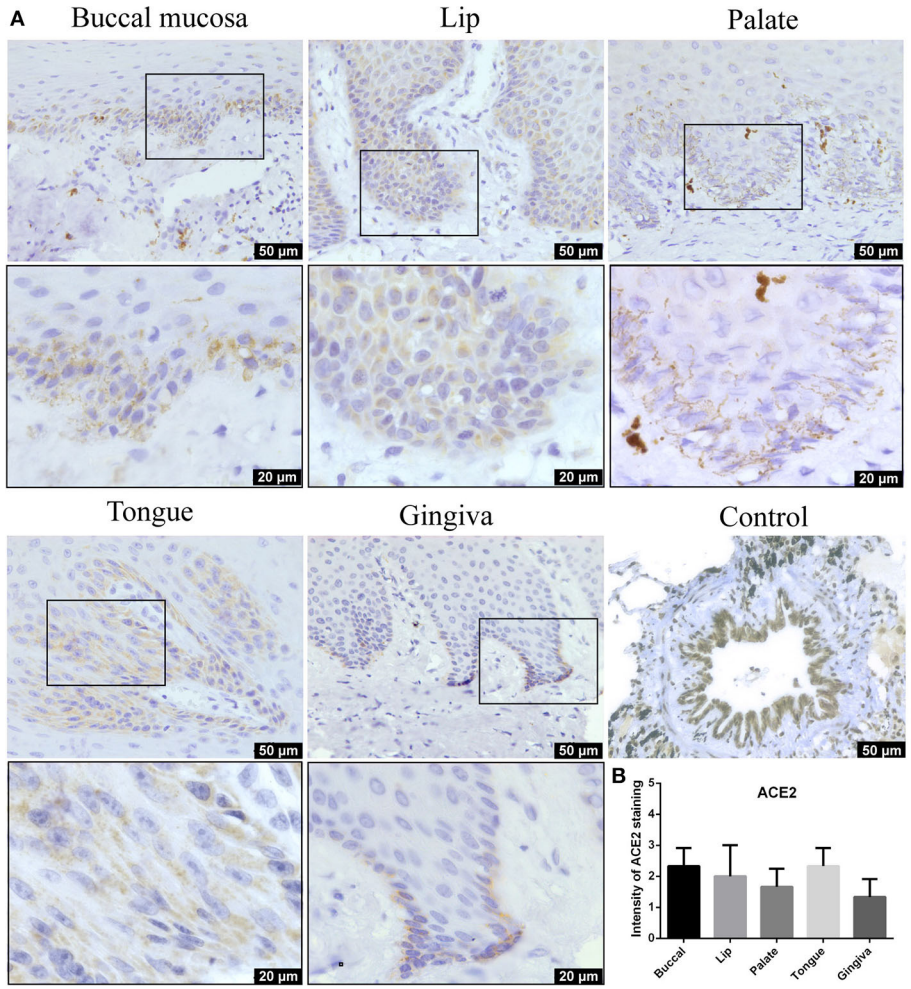

FIGURE 3 | (A) Representative immunohistochemistry (IHC) images of oral tissue showing the expression of angiotensin-converting enzyme 2 (ACE2) protein in buccal, lip, palate, tongue, and gingival mucosa and lung bronchi (positive control). **(B)** Semiquantitative analysis of IHC intensity of ACE2 staining for various oral tissues. Data are presented as mean ± standard deviation (SD).

research teams have also identified this activation site, suggesting that it may enable the virus to spread effectively between humans (21). It has been demonstrated that SARS-CoV-2 could fuse with the cell membrane and then gain entry into the target cells (36, 37). Researchers have found Furin proteases in many tissues, including the lungs, liver, and small intestine (23). However, limited reports were seen regarding the expression of Furin in the oral cavity, and whether the novel coronavirus could spread by the oral cavity is not fully understood. Thus, we reported both gene and protein level expression patterns of Furin enzyme in epithelial cells of five different oral anatomical sites. As expected, Furin was found abundantly enriched in oral mucosa cells, particularly in epithelial cells, and the proportion of Furin-positive cells was higher than that of ACE2-positive cells. Our results would be valuable for the prevention and management of the COVID-19.

Previous reports had demonstrated that Furin protein was expressed in metastasizing OSCCs (38). Besides, Furin was expressed in normal epithelium and upregulated in SCCs from three different organs (30). But the reports of Furin protein expression in the healthy oral cavity are limited. For further validating the results in the gene level, Furin IHC was therefore performed on conventional sections for the first time to assess its expression in oral mucosa obtained from five different sites. It is noteworthy that moderate positive expression of Furin protein was observed in tongue, gingiva, and lip, while weakly positive in the buccal and palatal tissues. Shreds of data from the literature indicate that SARS-CoV-2 enters host cells by binding to ACE2, and the viral S protein is cleaved by transmembrane protease serine 2 (TMPRSS2) (39). Furin cleaves S1/S2 site during the process of S protein transport and virus assembly (40). As a result, we speculated that SARS-CoV-2 could attach to the cell membrane of the oral mucosal cells, then enter into the host

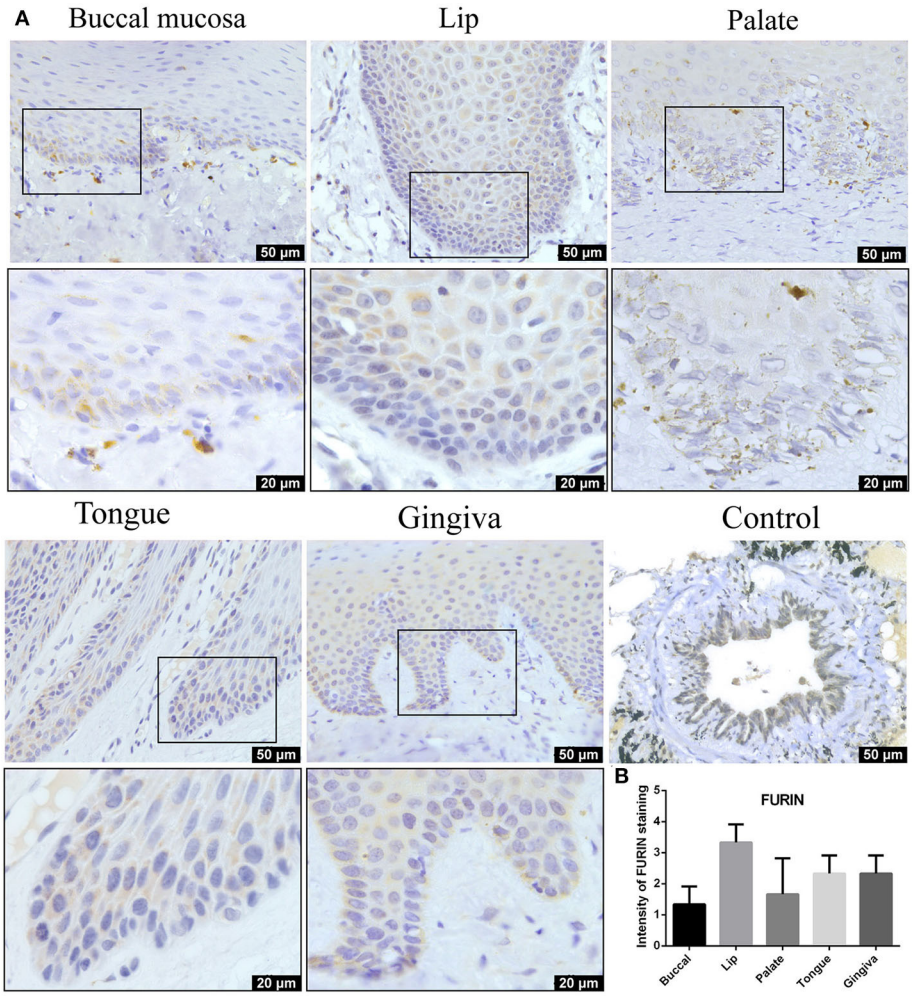

FIGURE 4 | (A) Representative immunohistochemistry (IHC) images of oral tissue showing the expression of Furin protein in buccal, lip, palate, tongue, and gingival mucosa and lung bronchi (positive control). **(B)** Semiquantitative analysis of IHC intensity of Furin staining for various oral tissues. Data are presented as mean ± SD.

cells via the ACE2 and Furin activity. Therefore, Furin could be a possible target to reduce COVID-19 infection.

For entry of SARS-CoV-2 to host cell, viral surface glycoprotein spike (S) must be cleaved at two different sites (S1/S2 and S2) by host cell proteases (41). The S can be cleaved by the Furin at the S1/S2 site and TMPRSS2 at the S2′ site (42). The spread of SARS-CoV-2 also depends on TMPRSS2 activity (43). The Furin-mediated precleavage at the S1/S2 site in infected cells might promote subsequent TMPRSS2-dependent entry into target cells. TMPRSS2 is essential for SARS-CoV-2 activation and multiplication in airway epithelial cells. A combination of TMPRSS2 inhibitor and Furin inhibitor more potently inhibits SARS-CoV-2 replication in human airway epithelial cells compared to any single inhibitor (42). This indicates the important role of Furin and TMPRSS2 proteases in facilitating the entry of SARS-CoV-2 in host cells. The expression of TMPRSS2 in oral tissues should be further investigated.

Strikingly, the scRNA-Seq data analysis and IHC results indicated that ACE2 and Furin were both abundantly expressed in oral mucosa, especially on oral epithelial cells. In other words, two key proteins of SARS-CoV-2 entering the target cell in different routes are both present in oral mucosa, which implied the potential attack and spread of SARS-CoV-2 in the oral tissues. Moreover, the live SARS-CoV-2 was consistently detected in the self-collected saliva of 91.7% (11/12) COVID-19 patients (44). It could be transmitted via saliva, directly or indirectly, even among asymptomatic infected patients. The existence of SARS-CoV-2 in nasal and throats swab samples suggests the strong spreadability of COVID-19 via the oral cavity (45). Thus, it is suggested that all healthcare workers should focus on taking effective measures to prevent the virus from spreading via the oral cavity, and potential impairment of oral tissues should be evaluated after infection with SARS-CoV-2, giving more evidence to the prevention and treatment of COVID-19. Strict precautions

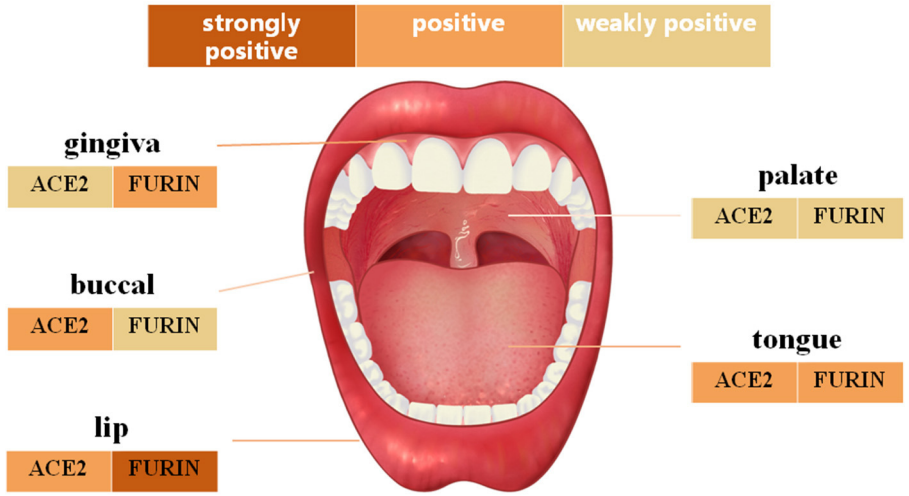

FIGURE 5 | The schematic diagram of angiotensin-converting enzyme 2 (ACE2) and Furin protein expression in different oral anatomical sites.

should be taken to protect from direct exposure of oral tissues to SARS-CoV-2 contamination.

CONCLUSIONS

Our results systematically investigated the expression profiles of Furin enzyme and ACE2 receptor in the oral cavity at the gene and protein levels for the first time. Furthermore, significant expression of Furin and ACE2 was discovered in oral epithelial cells, implying the possibility of COVID-19 transmission through the oral mucosa, which provides new insight into the future prevention strategy and clinical care. More evidence is still needed to reinforce the current findings.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of Stomatology Hospital of Guangzhou Medical University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BL, MZ, JP, HG, LW, and LG contributed to the study design. BL, MZ, and HG contributed to the sample collection. XW, CL, KW, and ML contributed to the IHC and analysis. L-HL, C-lQ, JH, and J-mC contributed to the data collection, analysis, and interpretation. MZ, L-HL, and JP contributed to the manuscript preparation. All authors approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2020.580796/full#supplementary-material

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Anxiety, Practice Modification, and Economic Impact Among Iraqi Dentists During the COVID-19 Outbreak

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Objectives: As health care workers on the front line during the coronavirus (COVID-19) pandemic, dental practitioners are amongst those at risk due to their close contact with potentially infected individuals. The aim of the current study was to assess the anxiety, awareness practice modification, and economic impact amongst Iraqi dentists whilst working during the outbreak.

Methods: This study was performed using an online survey questionnaire with aid of Google forms from 2nd to 23rd July 2020. A total of 484 clinicians responded. The questionnaire was composed of open end, closed end, and Likert five-point scale questions to assess anxiety, awareness and financial impact of COVID-19 on dentists. Mann–Whitney test was used to compare two groups, whilst Kruskal–Wallis was performed by *post-hoc* test for multigroup comparisons.

Results: The mean age of participants was 36.51 ± 9.164 years and the majority (75.2%) of these were graduate dentists only. More than 80% of participants reported anxiety of catching COVID-19. The recorded anxiety level was higher amongst younger dentists and females. Awareness and practice levels among these dentists of precautions and infection-control measures associated with COVID-19 (94%) was found to be high and to be statistically significantly affected by age, qualification and designation (except GP vs. Specialist). With respect to the economic impact, about 75% of practitioners, regardless of demographical variables, reported that their income had declined by about 50%.

Conclusions: The investigation provides clear insights into the anxiety, practice modifications and economic impact on dentists working in Iraq. Although there is a high level of knowledge and awareness of required practice regarding the COVID-19 outbreak among Iraqi dentists, they also reported a high level of anxiety.

Keywords: anxiety, coronavirus, Iraqi dentists, economic, practice management

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INTRODUCTION

Since the emergence of the novel coronavirus disease (COVID-19) in Wuhan, China, all aspects of life have been influenced worldwide. The COVID-19 pandemic has spread in an exponential manner (1, 2), affecting millions of people worldwide and causing hundreds of thousands of deaths (3). Many countries have shut down their teaching institutes, industries, sport activities, social gatherings, public events, and airports. Drastic measures such as individual self-quarantine and social distancing rules have been introduced in an attempt to control the spread of the infection (4). The condition in Iraq has been no better than in many other countries. Since the first registered case of COVID-19 was recorded on the 24th of February 2020 in an Iranian student attending the city of Najaf in the south of Iraq, the spread of the virus has been escalating and as of 1st of July there were 51,524 confirmed cases and 2,050 deaths.

COVID-19 belongs to the Coronaviridae virus family, which is characterized by a single strand RNA structure (5). This virus has potential to cause severe respiratory tract infection and pneumonia among infected individuals, and can be easily transmitted via hand contact, saliva, nasal droplets and contaminated surfaces (2, 6). Health care workers and dentists in particular are categorized as at high risk of catching this infection (7). This could be because their close contact with patients during routine dental procedures increases the possibility of infection transmission (8, 9). Droplets and aerosols that are generated during dental procedures by such as high speed handpieces, air-water syringes, and ultrasonic scaling could produce a contaminated pathogenic environment within the dental working field during treatment of an infected person (6, 9, 10). Therefore, the risk of infection transmission within the dental team cannot be controlled through the standard protective measures of daily dental practice (8). This categorization as high-risk professionals could increase fear within the dental community (11, 12).

Regarding the rapid spread of the infection, the World Health Organization (WHO) and American Dental Association (ADA) published specific precaution guidelines to be implemented by dentists during treatment of urgent and emergency cases only. Otherwise, they stipulated that dental offices should be kept closed during the outbreak (13, 14). These guidelines emphasized the use of the appropriate precautions including wearing personal protective equipment (PPE) during dental procedures (13, 14). In addition, the use of antibacterial mouth washes, rubber dam, and high-volume section during treatment procedures with frequent cleaning and disinfecting of surfaces of chairs, door handles and floors was highly recommended (8, 15). Providing a secure environment is of paramount importance for dentists and dental staff to conduct dental work in a safe working environment. The high infection rate of COVID-19 and lack of PPE might affect the anxiety of the dentist. The levels anxiety of dentists have shown a negative impact on decision making, quality of work, and burnout (16).

On the other hand, in dental practice the demand arose for more expensive aerosol controlling equipment such as the high efficiency particulate arrestor (HEPA) during the outbreak period (10). The expense of these precautionary measures and limitations in the treatment of patients may have had serious economic impact on the dentistry field. Hence, the future careers of dentists could be affected if the outbreak continues for an indefinite period.

Meanwhile, no study has assessed the levels of anxiety among Iraqi dentists in the wake of the COVID-19 outbreak, their awareness about this illness and the infection control guidelines to prevent its spread, or the financial impact on their current practice. Therefore, the aim of this study was to use a specially designed online-based questionnaire to assess the impact of the COVID-19 outbreak on Iraqi dentists in terms of their anxiety, awareness and practice modification, and the financial implications for their dental practice.

METHODS

Survey Administration

A cross-sectional survey was conducted using an online questionnaire that was electronically sent to Iraqi dentists by Iraqi Dental Association (IDA). Administration of the questionnaire started on 02/07/2020 for a period of 2 weeks, which was extended for another week after a reminder was sent, and ended on 23/07/2020. The study was approved by the ethics committee of the College of Dentistry, University of Baghdad in compliance with the Helsinki declaration (Ref No. 579/06/2020).

Study Population and Sample Size

The survey was exclusively sent to registered Iraqi dentists and only completed forms were included in the final analysis. All incomplete forms and those returned outside the required timeframe were excluded.

The total number of registered Iraqi dentists, as officially provided by the IDA, was 6,463. Sample size was determined according to the following formulas (17, 18):

$$\begin{aligned}\text{Sample size} &= (\text{distribution of } 50\%)/[(\text{margin of error}\%/\\ &\quad \text{confidence level score})^2]\\ \text{Confidence level} &= 1.96 \text{ (for confidence level of } 95\%),\\ &\quad \text{margin of error } = 0.05.\\ \text{True sample} &= (\text{sample size} \times \text{population})/\\ &\quad (\text{sample size} + \text{population} - 1)\end{aligned}$$

The calculated sample size was equal to 363 which was further adjusted to take account of the dropout risk, previously estimated from a pilot study, by using the following formula:

$$N = n/[1 - (z/100)]$$

Where N is the adjusted sample size, n is the calculated sample size, z represents the hypothesized attrition rate (25%). The final sample size was equal to 484 dentists. Accordingly, the questionnaire link was distributed via emails to corresponding number of randomly selected dentists.

TABLE 1 | The study questionnaire.

Age			
Country			
Sex	A-Male	B-Female	
Qualification	A-Graduate	B-Postgraduate	
Designation	A-General practitioner	B-Specialist	C-Consultant
Working place	A-Clinic	B-Hospital	C-Both
Working type	A-Private	B-Government	C-Both

1- Do you have a anxiety of being infected with COVID-19 by a patient or co-worker?				Yes	No
2- Are you afraid of providing treatment for any patient?				Yes	No
3- If a patient is coughing or suspected to be infected with COVID-19, are you afraid to provide treatment for him/her?				Yes	No
4- Do you anxious talking to the patients in close proximity?				Yes	No
5- Are you afraid that you could carry the infection from your practice back to your family?				Yes	No
6- Do you feel anxious when you hear that one of your co-workers or colleagues has been infected with COVID-19?				Yes	No
7- Do you know the illness problems associated with COVID-19 virus?				Yes	No
8- Do you know the mode of transmission of COVID-19 virus?				Yes	No
9- Are you updated with the current WHO guidelines for cross-infection control for COVID-19 virus?				Yes	No
10- Are you currently asking every patient if he/she has recently been in contact with an infected COVID-19 person?				Yes	No
11- Are you or your staff members taking every patient's body temperature before performing dental treatment?				Yes	No
12- Are you deferring dental treatment for patients with suspicious symptoms?				Yes	No
13- Do you think the routine surgical mask is effective to prevent COVID-19 cross infection?				Yes	No
14- Do you think that N-95 masks should be used routinely in dental practice because of the current COVID-19 outbreak?				Yes	No
15- Do you routinely follow universal infection control protocol for every patient?				Yes	No
16- Do you currently use rubber dam isolation for every patient as a part of your infection control?				Yes	No
17- Do you routinely use high volume section for every patient as part of droplets and airborne isolation precautions?				Yes	No
18- Do you routinely prepare antimicrobial mouth rinse for every patient to be used before starting treatment?				Yes	No
19- Have you changed or increased the procedure of infection control during the COVID-19 pandemic?				Yes	No
20- Has the schedule of your practice been changed to make it safer for you and the patient?				Yes	No
21- Do you routinely wash your hands with soap and water/ use sanitizer before and after treatment of every patient?				Yes	No
22- Do you and your staff members get tested for COVID-19 as a precautionary measure?				Yes	No
23- Do you know which authority to contact if you come across a patient with suspected COVID-19 infection?				Yes	No
25- What is the average drop in the number of patients visiting your practice as compared to the period before the COVID-19 pandemic?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
26- How many appointments for non-urgent cases have you canceled recently as a part of COVID-19 precaution protocol?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
27- Because of the COVID-19 pandemic, how much have the prices for your dental services been reduced, if at all?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
28- If any, how much financial compensation (governmental and non-governmental) are you receiving for your losses in your practice?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
29- To what extent have you reduced the staff numbers in your clinic?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
30- By how much has the practice's income been reduced due to the COVID 19 pandemic?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
31- What percentage of your stored dental materials have expired during the COVID-19 pandemic?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	
32- If applicable, what has been the average reduction of working days during the COVID-19 outbreak?					
A- N/A	B- <25%	C- 25–50%	D- 50–75%	E- >75%	

Questionnaire Design

Google forms was used to create the link for the questionnaire (illustrated in **Table 1**) that was distributed to the targeted population electronically via IDA to ensure uniform and validated distribution across all groups of dentists, including general practitioners, specialists, and consultants, throughout the country. Before distributing the questionnaire, a pilot study was conducted which included 36 dentists (about 10% of the sample size). Then data were entered on spreadsheet and double-checked by two authors which was followed pre-launch analysis was performed to check the internal consistency of all questionnaire's components.

The questionnaire was adapted and modified from previously published surveys (19, 20). The questionnaire used for this study was composed of demographic/practice-related, closed end, and Likert five-point scale questions. These questions were divided into four sections:

Section 1 was designed to collect demographic/practice-related variables of the respondents.
Section 2, questions #1 to #6, was intended to assess the anxiety among dentists deriving from the COVID-19 infection.
Section 3, questions #7 to #23, was designed to evaluate the dentists' awareness and practice modification about the precautions and infection-control measures for COVID-19 infection.
Section 4, questions #24 to #32, consisted of questions that explored the economic impact of COVID-19 on dental practice.

For closed end questions, each positive response "Yes" was marked as "1" while "No" was marked with "0." The frequency of the positive/negative responses was used to assess the dentists' anxiety (section 2) and awareness (section 3) regarding the COVID-19 infection. For section 4, the responses "N/A," "<25%," "25–50%," "50–75%," ">75%" received sequential scores of "1," "2," "3," "4," "5," respectively. The scores for each section were summed together to calculate the mean of the answers to evaluate the response according to the different independent variables.

Statistical Analysis

Demographic data and total responses for each question were analyzed by descriptive statistics expressed by mean, standard deviation, and frequency/percentage. Inferential analysis for sections 2, 3, and 4 was performed by using Mann–Whitney test for comparing two groups while Kruskal–Wallis followed by *post-hoc* test was used for multiple groups comparisons. The statistically significant value was set at $p < 0.05$. All analyses were performed by using GraphPad Prism (Version 8.4.3, GraphPad Software, San Diego, CA, USA).

RESULTS

A total of 435 dentists (218 male and 217 female) with mean age of 36.51 ± 9.164 years (ranging from 23 to 70 years) participated in the study (**Table 2**). The number of respondents represented 89.9% of the calculated sample size (484) after excluding 49 dentists who did not response to the questionnaire within the specified time. The number of the respondents (435) was considered as a satisfactory response rate (89.8%). The majority of respondents (327, 75.2%) were graduate dentists, in comparison to 108 (24.8%) who had postgraduate degrees. The proportions of general practitioners, specialists and consultants were 47.8% (208), 47.4% (206), and 4.8% (20), respectively. Furthermore, 202 (46%) of respondents working in clinics worked in both the private and governmental sector (**Table 2**).

Responses to section 2 questions relating to dentists' feelings about the COVID-19 pandemic indicated that the majority of respondents (386, > 80%) (**Figure 1A**) were anxious of catching the COVID-19 infection (Q1). Over 60% (274) of the dentists were afraid of treating any patients (Q2). This anxiety was further aggravated (397, 91%) if a patient was showing a sign of suspected infection such as coughing (Q3). Moreover, about 72% (316) of the respondents were not comfortable with being in close contact with their patients (Q4). The highest scoring response among the participants (413, 94%) was associated with the anxiety of carrying infection home to their family (Q5), whilst the second highest response (395, 90%) related to hearing that a co-worker had been infected with COVID-19 (Q6).

Regarding responses to section 3 questions, the dentists' highest scores related to their knowledge about the COVID-19 illness (Q7, 413, 94%) (**Figure 1B**) and its modes of transmission (Q8, 424, 97%), modification in infection control procedure (Q19, 410, 94%) re-scheduling patients' appointments (Q20, 404, 93%), and washing hands before and after treatment (Q21, 416, 95%). Additionally, three questions achieved (>80%) positive responses including: the dentist had updated information about the current WHO guidelines for infection control (Q9), deferring treatment of patients with suspicious symptoms (12), and following universal infection control protocol (Q15). Whereas, the lowest awareness score (138, 31.7%) related to the effectiveness of surgical masks to prevent cross infection (Q13), in comparison to nearly 80% of respondents who thought that N95 masks should be used routinely in dental practice (Q14). The response to (Q16) about the use of rubber dam as an infection control measure was equally low at 31.7% (138), but a higher

TABLE 2 | Demographic characteristics of the study population.

AGE (YEARS)	
(mean± SD)	36.51 ± 9.16
Age range	23–70
AGE GROUPS (YEARS)	
≤35	222 (51)[§]
>35	213 (49)[§]
Gender	
Male	218 (50.1) [§]
Female	217 (49.9)[§]
QUALIFICATION	
Graduate	327 (75.2)[§]
Postgraduate	108 (24.8)[§]
DESIGNATION	
General practitioner	208 (47.8)[§]
Specialist	206 (47.4)[§]
Consultant	21 (4.8)[§]
WORKPLACE	
Clinic	202 (46.4)[§]
Hospital	70 (16.1)[§]
Both	163 (37.5)[§]
EMPLOYMENT TYPE	
Private	135 (31.1)[§]
Governmental	98 (22.5)[§]
Both	202 (46.4)[§]
Total	435 (100)[§]

[§]*Frequency, percentage.*

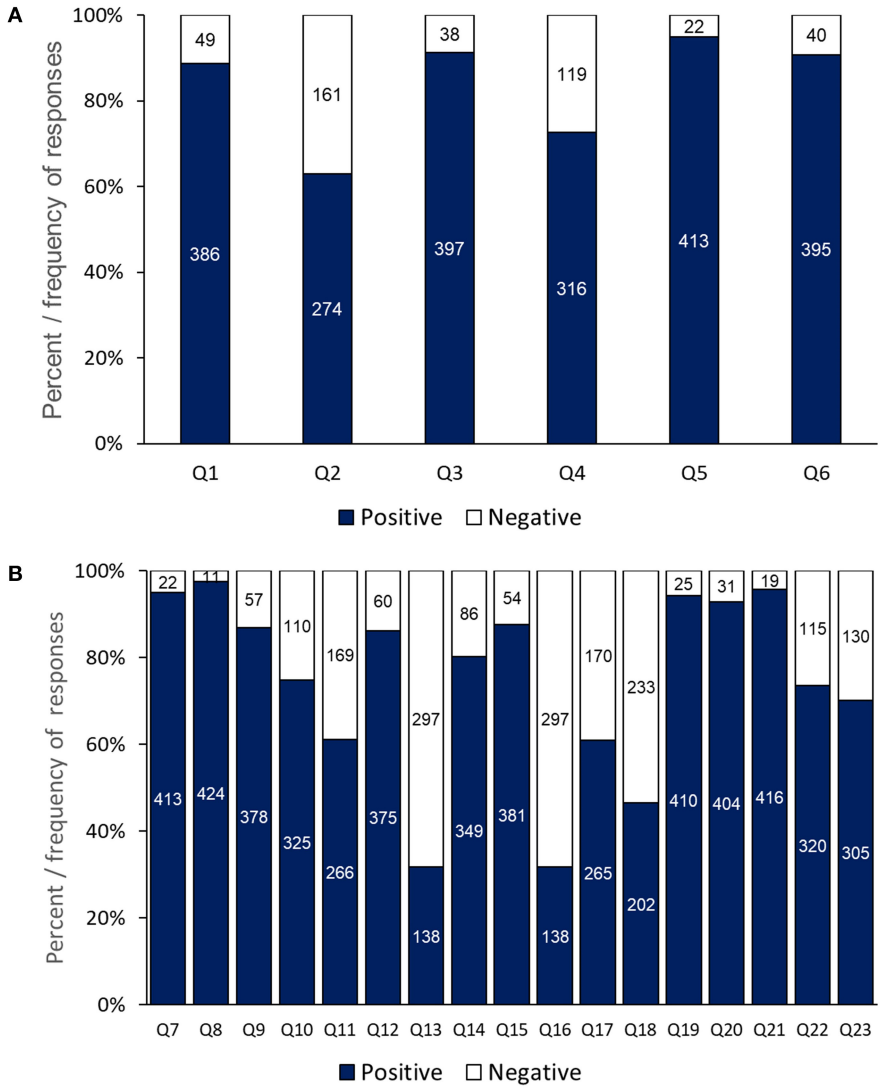

FIGURE 1 | Dentists' responses to anxiety and awareness questions: **(A)** responses to individual questions on anxiety of COVID-19 and **(B)** awareness of precaution and infection control-measures.

percentage of respondents (265, >60%) confirmed that they used high volume section as a droplets precaution measure (Q17).

The economic impact of COVID-19 was investigated in this study via the section 4 questions (**Figure 2**). About 27% of the respondents suggested that the price of personal protection equipment had increased by >75% of the original price (Q24). Meanwhile, 32% of the dentists indicated that the number of patients had declined by 25–50% (Q25). The influence of COVID-19 on income was very apparent as >75% of the dentists reported that their income had dropped by 25–50% (Q30), with a similar response regarding the reduction in their working days (Q32). The level of financial compensation received by the dentists was unsatisfactory as more than half of the respondents were not eligible for any support programmes (Q28). However, the majority of the respondent dentists had not decreased their staff numbers (Q29) (**Figure 2**).

Inferential analysis of the questionnaire sections showed that older (>35 years old) and male respondents exhibited a statistically significant lower degree of anxiety of COVID-19 compared to younger (≤35 years old, $p = 0.018$) and female ($p = 0.003$) respondents, respectively (**Table 3**). Furthermore, the respondents who worked only in a hospital or in a clinic and hospital showed a statistically significantly higher anxiety than those working only in a clinic. Similarly, those working only in the government sector or in the government and private sector showed statistically significantly higher anxiety from COVID-19 than those working only in private clinics. However, respondents' qualifications and designation did not show a statistically significant impact on anxiety of COVID-19 (**Table 3**). Generally, the mean of responses showed a high level of anxiety of COVID-19 infection (5.01 ± 1.37; **Table 3**).

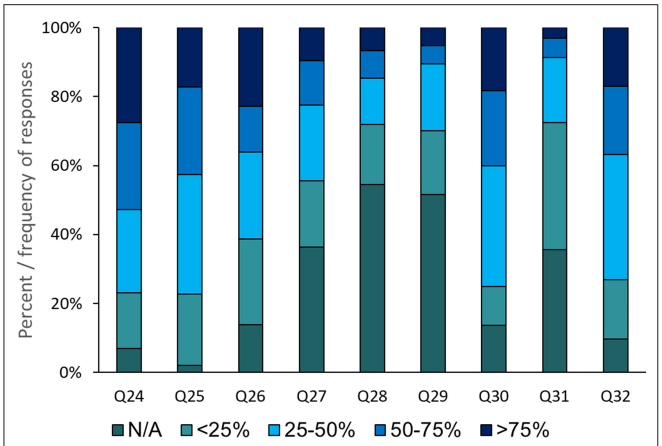

FIGURE 2 | Dentists' responses on the economic impact of COVID-19 outbreak on their practice.

TABLE 3 | Respondents' anxiety of the COVID-19 infection.

Variables	Mean ± SD	Comparison	*p*-value
AGE			
≤35	5.14 ± 1.27	≤ 35 vs. > 35	0.018*
>35	4.87 ± 1.45		
GENDER			
Male	4.78 ± 1.57	Male vs. female	0.003*
Female	5.24 ± 1.08		
QUALIFICATION			
Graduate	4.9 ± 1.39	Postgraduate vs. Graduate	0.363*
Postgraduate	5.04 ± 1.36		
DESIGNATION			
General practitioner (GP)	4.89 ± 1.43	GP vs. Specialist	0.377†
Specialist	5.11 ± 1.34	GP vs. Consultant	>0.999†
Consultant	5.23 ± 0.88	Consultant vs. Specialist	>0.999†
WORKPLACE			
Clinic	4.76 ± 1.45	Clinic vs. Both	0.003†
Hospital	5.31 ± 1.08	Clinic vs. Hospital	0.015†
Both	5.19 ± 1.33	Hospital vs. Both	>0.999†
EMPLOYMENT TYPE			
Private	4.71 ± 1.51	Private vs. Governmental	0.046†
Governmental	5.12 ± 1.09	Private vs. Both	0.015†
Both	5.2 ± 1.36	Governmental vs. Both	0.064†
Total	5.01 ± 1.37		

Mann–Whitney test, †Kruskal–Wallis test.

The mean awareness of respondents (section 3) was 12.65 ± 2.36 (**Table 4**). Age of the study participants have shown a statistically significant impact on respondents' awareness, whereas, this is not the case when male and female compared. Furthermore, qualification and designation (except for GP vs. Specialist) were found to have a statistically significant effect on respondents' awareness ($P < 0.05$, **Table 4**). Meanwhile, no statistically significant differences in respondents' awareness were identified according to workplace and employment type (**Table 4**).

Regarding the economic impact, no demographic variables emerged as having a statistically significant economic effect (**Table 5**). However, the mean economic effect was recorded as equal to 2.72 ± 0.71 out of 5 (**Table 5**), i.e., the economic losses incurred by the dental community amounted to more than 50%.

DISCUSSION

The present cross-sectional study reported a high level of anxiety among Iraqi dentists as a result of the COVID-19 outbreak and high awareness about preventing its transmission and avoiding infection; in addition, they and their practices have been economically affected due to this pandemic situation. These findings are understandable because dentists fall within the highest risk category, since their practice is associated with generation of droplets and aerosols which is considered as a main route of virus transmission (6). The high levels of anxiety recorded among these Iraqi dentists can be considered as natural human feelings during the pandemic situation, especially in light of the increasing infection and mortality rates. In Iraq the mortality rate is considered to be higher (about 3.9%) in comparison to other regional countries, such as the UAE with only a (0.5%) mortality rate (3). This could possibly be due to differences in available health resources between these two countries (21). The general weakness in the medical foundations and care system in Iraq after four decades of military conflicts (22), and the exaggerated pressure on the health care system due to the quick spread of the virus, general feelings of stress and fear among healthcare workers for their own safety and that of their families (23). Additionally, the nature of this disease, with its prolonged incubation period (as long as 14 days), its spectrum that ranged from asymptomatic to death, and the absence of a vaccine or treatment, are all factors potentially exacerbating stressful feelings among healthcare workers, especially dentists. This confirms findings from studies about COVID-19 (11), or previous outbreaks of similar infectious respiratory diseases such as SARS, which demonstrated severe and sustained psychological trauma, especially among the front line healthcare workers (24, 25).

Another interesting finding within the present study was that the recorded anxiety level was higher among younger than older dentists and females than males. This goes against the reports that among infected individuals there are higher risk groups, including older and male adults, who are more likely to develop severe respiratory symptoms and die than younger individuals and females (26). It may be that older dentists are more experienced than younger dentists in dealing with similar pandemic situations. This may make them more confident and less prone to anxiety. This was also reflected in the finding by this study of a statistically significant higher level of awareness about the virus and its mode of transmission among dentists aged above 35 years in comparison to those aged below 35 years. Moreover, since females, as mothers, tend to have closer contact with their

TABLE 4 | Respondents' awareness of COVID-19 infection-control measures.

Variables	Mean ± SD	Comparison	p-value
AGE			
≤35	11.14 ± 2.41	≤35 vs. >35	<0.001*
>35	12.99 ± 2.24		
GENDER			
Male	12.32 ± 2.58	Male vs. female	0.121*
Female	12.8 ± 2.09		
QUALIFICATION			
Graduate	11.98 ± 2.49	Postgraduate vs. Graduate	0.003*
Postgraduate	12.75 ± 2.28		
DESIGNATION			
General practitioner (GP)	12.48 ± 2.24	GP vs. Specialist	>0.999†
Specialist	12.53 ± 2.48	GP vs. Consultant	0.016†
Consultant	13.91 ± 1.92	Consultant vs. Specialist	0.027†
WORKPLACE			
Clinic	12.76 ± 2.07	Clinic vs. Both	0.569†
Hospital	12.44 ± 2.58	Clinic vs. Hospital	0.963†
Both	12.36 ± 2.58	Hospital vs. Both	>0.999†
EMPLOYMENT TYPE			
Private	12.82 ± 2.09	Private vs. Governmental	0.196†
Governmental	12.26 ± 2.38	Private vs. Both	>0.999†
Both	12.53 ± 2.52	Governmental vs. Both	0.674†
Total	12.65 ± 2.36		

Mann–Whitney test, †Kruskal–Wallis test.

TABLE 5 | Economic impact of the COVID-19 outbreak.

Variables	Mean ± SD	Comparison	*p*-value
AGE			
≤35	2.71 ± 0.69	≤ 35 vs. > 35	0.955*
>35	2.72 ± 0.72		
GENDER			
Male	2.67 ± 0.72	Male vs. female	0.109*
Female	2.77 ± 0.69		
QUALIFICATION			
Graduate	2.66 ± 0.8	Postgraduate vs. Graduate	0.468*
Postgraduate	2.73 ± 0.67		
DESIGNATION			
General practitioner (GP)	2.71 ± 0.73	GP vs. Specialist	0.463†
Specialist	2.74 ± 0.65	GP vs. Consultant	0.463†
Consultant	2.54 ± 0.94	Consultant vs. Specialist	0.353†
WORKPLACE			
Clinic	2.73 ± 0.73	Clinic vs. Both	>0.999†
Hospital	2.68 ± 0.67	Clinic vs. Hospital	>0.999†
Both	2.71 ± 0.69	Hospital vs. Both	>0.999†
EMPLOYMENT TYPE			
Private	2.63 ± 0.74	Private vs. Governmental	>0.999†
Governmental	2.69 ± 0.67	Private vs. Both	0.077†
Both	2.79 ± 0.69	Governmental vs. Both	0.877†
Total	2.72 ± 0.71		

Mann–Whitney test, †Kruskal–Wallis test.

children than other family members, the anxiety of transferring infection to family members, especially their children, could increase feelings of stress among female in comparison to male dentists. In the same way, dentists who were working in the public sector, in clinics or hospitals, reported higher anxiety levels than others. This could be attributed to the large number of dental patients visiting the public centers per day in comparison to private clinics (27). Consequently, this may increase dentists' concerns and anxiety of being infected compared to those working only in private clinics, who have more control over their appointments, case selection and cancellation of non-emergency cases. Finally, consultant dentists and those with postgraduate degree have higher levels awareness than their counterparts and this can be explained by the fact the majority of these dentists work in academic field, thus more update about the new developments in their field including the COVID-19 outbreak.

Almost all of the responding dentists were aware of the nature of the COVID-19 illness and its mode of transmission. This information is considered to be crucial in terms of applying infection control measures while carrying out dental treatment. In the same way, over 80% of the dentists responded that they were up to date about the current WHO guidelines for cross-infection control measures within dental practice (14). This was reflected through over 70% of the respondents asking their patients if they had been in contact with an infected COVID-19 individual, and above 60% recording patients' body temperature. Logically, this is basic information required during the routine examination to identify potentially infectious conditions among patients and the necessary precautionary management. Indeed, under such pandemic circumstances, the conventional precautions already recommended by WHO and any other infectious control authority worldwide should be rigorously applied to prevent cross-infection within dental practice. But unfortunately, more than 60% of the respondents were not using rubber dam for every patient as a cross-infection control. Rubber dam effectively limits the spread of aerosols during use of rotary instruments, decreases the hazard of fine instrument swallowing, gives excellent isolation of the working field and increases patients' acceptance of dental procedures (28). Therefore, training courses and workshops are suggested for Iraqi dentists, especially new graduates, to increase their awareness about the effectiveness of rubber dam in controlling the spread of infection. This could improve their hand skills and increase their willingness to consider rubber dam as part of their routine practice. The usage of high volume suction should also be considered as an essential method during routine dental practice to control aerosols and droplets evacuation (10).

The use of antimicrobial mouth washes before starting dental procedure is also recommended in the WHO guidelines for the current pandemic. Interestingly, over 40% of the respondents were complying with this recommendation. Mouthwashes such as chlorhexidine (29), 1% hydrogen peroxide (6), or povidone iodine (30) can be employed to decrease microbial loading inside

the oral cavity. The latter has virucidal activity against SARS-CoV and MERS-CoV coronaviruses and is recommended to be used at 0.5% concentration as a mouthwash for patients before initiating a clinical procedure. Additionally, the operator is also advised to use povidone iodine as a nasal spray (0.4%) and mouthwash (0.5%) before and after suspected patient contact (31).

A positive finding by the current study was that the majority of Iraqi dentists were routinely focusing on hand hygiene before and after treating each patient, which is considered as an essential infection control measure for dental practitioners. Frequent hand washing with water and soap or using alcohol containing sanitizer is included in the WHO infection control guidelines for the current pandemic (14). The spread of respiratory viruses can be effectively avoided by proper hand washing and cleaning with alcohol-based sanitizers (8, 32). Furthermore, the majority of the study respondents agreed with the routine use of N-95 respirators rather than surgical masks in dental practice during the COVID-19 outbreak. The use of such personal protection equipment (PPE) is also recommended by the WHO and ADA guidelines when performing aerosols generating procedures (33).

Carefulness in selecting cases, controlling appointments, and receiving only emergency cases were also recommended by the ADA and WHO guidelines (13, 14). Almost all of the respondents in the current study stated that they had altered their appointment schedules to control the spread of the virus. This process could be started by initially calling patients or having video conferences to identify their need and decide if their condition requires clinical intervention (34). This could help in limiting face-to-face contact, making diagnoses through remote dental screening, deterring any COVID-19 susceptible patients, delaying nonemergency work, and planning effectively for the emergency cases (8, 34).

According to the findings of the present study, the economic losses caused by the COVID-19 outbreak to the dental community in Iraq amounted to about 50%. This is understandable during such a pandemic situation. The whole country has been affected by quarantines and lockdowns in an attempt to control the spread of the infection. The lockdowns consisted of intermittent periods of complete closure for all sectors followed by partial lockdown for specific sectors including schools, universities, tourism, and others. This has had severe economic impact on almost all activities, including dentistry (4). Additionally, the majority of respondents in the current study reported reduction of their working days, rescheduling of their appointments to see emergency cases only, absence of governmental support, and reduction in their total income. On the other hand, as some of the study participants received financial compensation, the degree of economic impact has shown to be varied from one to another dentist. However, none of demographical variables have shown an impact on income. This can be explained by the fact that during the national lockdown, working in private dental clinics was stopped by government and the only source of income were their monthly salary by the government. According to a recent investigation conducted in the U.S., this economic impact on dental services could be extended to 2022 because of financial hardship among dental patients (35). These financial impacts on dentistry as a profession may have serious implications for the future of this career.

The limitations of this study that should be considered is the rapid changes in respondents' psychology and practice in accordance with the progression of the current outbreak, the attitudes and awareness of dentists will certainly be altered by future alteration in the scientific knowledge about COVID-19. Additionally, although the distribution of the questionnaire for the present study was done through the IDA, fewer responses were obtained from consultants in comparison to the other designations. This possibly because of the general panic situation during the COVID-19 outbreak altered the priorities for potential respondents. Thus, the findings of the current study should be carefully interpreted to avoid generalization of the data.

CONCLUSIONS

The emergence of the novel coronavirus has increased concern among healthcare workers, especially dentists, regarding aerosols borne microbes rather than the conventional blood borne microbes. This has dramatically increased the anxiety among dentists about getting the infection and has altered their awareness toward a new era. Although, Iraqi dentists have gained a high level of knowledge and practice to address the COVID-19 outbreak, their anxiety was high. It is important in the current scenario to modify the conventional dental practice to deal with emergencies only or close down practices until the outbreak recedes. However, this situation may last for an indefinite period, which would have a dramatic impact not only on the economy which have shown to affect the majority of responders by reducing their income by 50% but also on the future of the dental profession such as increasing levels of anxiety amongst dentist and adapting to practice modification.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

ETHICS STATEMENT

The study was approved by the ethics committee of the College of Dentistry, University of Baghdad in compliance with the Helsinki declaration.

AUTHOR CONTRIBUTIONS

AM: study conception. AA and SG: study design. AM, AA, SG, and SQ: data collection. AA and SG: data analysis and manuscript drafting. AA and SG: data interpretation. SG and SQ: critical revision of the manuscript. All authors: approval of the final version. All authors contributed to the article and approved the submitted version.

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REVIEW
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Association of Viral Infections With Oral Cavity Lesions: Role of SARS-CoV-2 Infection

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Different viral agents, such as herpesviruses, human papillomavirus, and Coxsackie virus, are responsible for primary oral lesions, while other viruses, such as human immunodeficiency virus, affect the oral cavity due to immune system weakness. Interestingly, it has been reported that coronavirus disease 2019 (COVID-19) patients can show cutaneous manifestations, including the oral cavity. However, the association between oral injuries and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection is still unclear. This narrative review aimed to summarize the available literature and provide an overview of oral lesions associated with COVID-19. An online literature search was conducted to select relevant studies published up to November 2020. The results of 17 studies showed variability in oral lesions associated with COVID-19, including ulcerations, aphthous-like lesions, and macules. The tongue, lips, and palate were the most frequent anatomical locations. According to current knowledge, the etiopathogenesis of multiple COVID-19-associated lesions seems to be multifactorial. The appearance of such lesions could be related to the direct or indirect action of SARS-CoV-2 over the oral mucosa cells, coinfections, immunity impairment, and adverse drug reactions. Nevertheless, COVID-19-associated oral lesions may be underreported, mainly due to lockdown periods and the lack of mandatory dispositive protection. Consequently, further research is necessary to determine the diagnostic and pathological significance of oral manifestations of COVID-19. All medical doctors, dentists, and dermatologists are encouraged to perform an accurate and thorough oral examination of all suspected and confirmed COVID-19 cases to recognize the disease's possible early manifestations.

Keywords: COVID-19, novel coronavirus, oral health, oral lesions, oral mucosa, SARS-CoV-2, viral infection

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INTRODUCTION

The oral cavity is particularly susceptible to viral infections because of its conformation, particularly its soft tissue and salivary glands. Several viruses, including herpes simplex virus (HSV) and human papillomavirus (HPV), are associated with oral disease-causing primary lesions. Furthermore, oral mucosa can be affected by the secondary pathological processes of a bacterial or fungal nature due to viral immunosuppression, such as the human immunodeficiency virus (HIV).

Consequently, the oral cavity could be considered a "biological barometer" of the viral immunosuppression advancement. Moreover, an implication of certain viral agents has been seen in dysplastic and neoplastic transformations of squamous epithelium (i.e., HPV) (1, 2). General and specialist dentists play a crucial role in evaluating, diagnosing, and managing such lesions, particularly considering the impacts of oral diseases on overall health and quality of life.

A new coronavirus, known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), responsible for coronavirus disease 2019 (COVID-19), was identified in Wuhan, Hubei Province, China, at the end of 2019. It then spread worldwide, becoming a global pandemic (3).

The main transmission route is via large respiratory droplets, even though the virus has also been identified in the stool and urine of affected individuals. It presents great variability in the severity of clinical manifestations, such as dry cough, shortness of breath, and fever (4, 5), passing from a mild flu-like illness to severe respiratory syndrome. Mortality rates vary according to region and change as the number of affected individuals is updated (6). Angiotensin-converting enzyme 2 (ACE2) receptor is considered the main functional receptor through which SARS-CoV-2 infects cells. The wide expression of ACE2 receptors in different anatomical sites, including the respiratory and gastrointestinal tracts, could explain the variability of reported clinical manifestations (7).

Interestingly, dermatological manifestations have also been observed in some patients affected by COVID-19. The most common skin lesions in these subjects include erythematous rash, urticaria, and vesicle formation, especially localized on the trunk, which seems to be the anatomic region most involved (5, 8). Oral lesions, such as unspecific ulceration, desquamative gingivitis, petechiae, and coinfections, such as candidiasis (9–13), have also been reported. Moreover, Xu et al. (14) reported a high level of expression of ACE2 receptors in epithelial cells of the oral mucosa, particularly tongue epithelial cells. These results suggest that oral mucosa could be a target of SARS-CoV-2 infection. Nevertheless, it is still unclear whether these manifestations are a specific clinical pattern derived from direct SARS-CoV-2 infection or a consequence of systemic involvement because of the possibility of coinfections, a compromised immune system, and adverse reactions to medical treatment (13, 15, 16). Because the prevalence of clinical oral manifestations is still unknown, the range of COVID-19 manifestations in the oral mucosa is of broad and current interest.

Therefore, after a brief excursus into the main viral agents associated with oral mucosa lesions, this review aims to summarize the updated literature on oral lesions in patients with COVID-19 and emphasize their clinical implications.

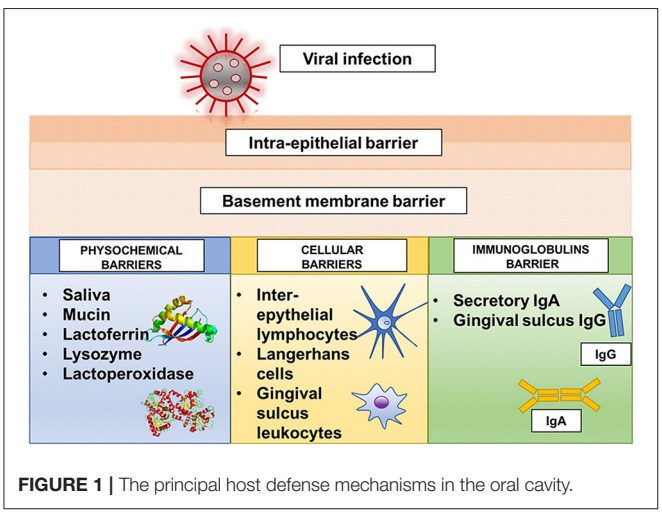

FIGURE 1 | The principal host defense mechanisms in the oral cavity.

The Host Defense of Mouth and Viral Diseases

The oral cavity possesses a series of physicochemical, cellular, and immunoglobulin barriers that prevent the entrance of harmful substances and microorganisms (2) (**Figure 1**). However, physicochemical barriers within the oral mucosa, including saliva and oral epithelium, are not absolute. The saliva secreted by the major and minor salivary glands contains many non-specifically protective agents, such as mucin, lysozyme, lactoperoxidase, and lactoferrin. In particular, lactoferrin, an iron-binding glycoprotein of the transferrin family, can inactivate many deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) viruses, including cytomegalovirus, HSV, and rotavirus (17, 18). Cellular barriers involve the cells of the gingival sulcus, inter-epithelial lymphocytes, and Langerhans cells. In particular, Langerhans cells, which are dendritic inter-epithelial cells and act as mucosa "sentinels," are localized in the mouth inverse to the degree of oral mucosa keratinization and are primarily implicated in immune reactions (2, 19, 20). Despite these defense mechanisms, the oral mucosa is particularly subjected to viral infections (**Figure 2**). A virus is a sub-microscopic entity formed by a protein shell (known as a capsid) surrounding a single nucleic acid, DNA or RNA, only able to replicate in bacterial, animal, and vegetal cells (21). Viral genetic material is distinguishable from human genetic material due to its unique chemical and/or physical features. Also, a lipid envelope derived from the host cell membrane can be identified in some viruses (22, 23). Even though viral infection can involve any human cell, the oral cavity offers an ideal entry into a new host (24). Some of the most well-known viral agents associated with oral lesions are HSVs and HPVs. HSVs contain a double-stranded linear DNA molecule enveloped by an icosahedral capsid and a lipid casing (25). Initially involved in primary infections, they then remain dormant but can later cause secondary or recurrent infections. Eight types of HSV have been identified as human pathogens, and most are responsible for oral diseases (1, 23, 25–35). HPVs are non-enveloped viruses containing double-stranded DNA (36). Over 100 subtypes of HPV have been identified, with at least 13 correlated to an insurgence of oral lesions (37–42). The oral wart is a generic term used to identify all papillary and verrucal proliferations. Squamous papilloma is one of the most represented papillary lesions in the oral cavity (1, 36). Oral lesions can also be secondary due to an immunosuppression state, such as occurs in HIV

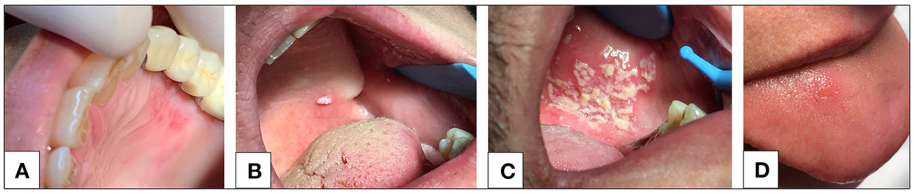

FIGURE 2 | (A) Herpetic-like oral lesion. **(B)** Oral mucosal verruca lesion. **(C)** Opportunistic infection (candidiasis) in patient affected by HIV. **(D)** Unspecific ulcerous lesion in a SARS-CoV-2 infected patient. Image 2D is a case courtesy of Chaux-Bodard et al. (9).

infection (43, 44). HIV is part of the *Lentivirus* genus, part of the *Orthoretroviridae* subfamily of the *Retroviridae* family. Two identical single-stranded RNA molecules form the HIV genome. The most frequent oral manifestations of HIV infection are opportunistic infections, such as candidiasis (45, 46), and malignancies, such as Kaposi's sarcoma (47, 48). The other most important viral agents associated with oral lesions are reported in **Table 1**. The association between oral lesions and SARS-CoV-2 remains controversial.

MATERIALS AND METHODS

An electronic search was conducted in PubMed, Scopus, and Web of Science for literature updated to November 20, 2020. A combination of the following keywords was used: "oral mucosal lesions" OR "oral lesions" AND "COVID-19" OR "SARS-CoV-2" OR "novel coronavirus disease." The full-text articles of all potential studies were evaluated, and the references cited by the relevant studies were manually searched for further studies. Given the lack of available data, all types of studies reporting oral mucosal lesions in patients with laboratory-confirmed COVID-19 were included; only literature reviews were excluded. However, we decided to include only those with laboratory-confirmed COVID-19 when evaluating the reported cases; suspected COVID-19 were excluded. Other exclusion criteria were articles for which the full text was not accessible or not available in English. Duplicate articles were removed, and a first screening was performed by reading only the titles and abstracts of the studies.

RESULTS

From the 86 studies retrieved, only 17 satisfied the inclusion criteria, of which 11 were letters to the editor, 3 were case reports, 2 were case series, and 1 was a short communication. **Table 2** provides a detailed description of the cases included. Given that the studies were published between April and November 2020, the results were listed in the table in alphabetical order of the first author's surname. Excluding the only study in which the gender and age of the participants were not reported (58), 33 cases were female and 24 cases were male. The mean age of reported cases was 42.92 ± 18.05.

The documented manifestations of oral mucosa were quite heterogeneous, varying in the kind of lesion and the location. The most frequent findings were ulcerations (9, 50, 60–62), sometimes associated with necrotic areas (50, 51), aphthous-like lesions (51, 55, 56, 58), and petechiae (51, 52, 54). Maculae (53, 60), blisters (10, 57), lingual papillitis or depapillation (58), and erythema or red plaques (52, 63) were also among the described oral lesions. Besides, a case of dark brown hyperpigmentation was documented by Corchuelo and Ulloa (63).

Tongue (9, 51, 54, 55, 58–62), lips (10, 50, 51, 57, 59, 60, 63) and palate (52, 54, 60) were the most frequently described anatomical locations.

DISCUSSION

An increasing number of atypical clinical presentations have been reported during SARS-CoV-2 infection, including dermatological and oral manifestations (16, 64–67). The pathogenesis of skin damage during COVID-19 is not well known, but some hypotheses have been formulated. For example, the presence of viral particles in cutaneous blood vessels could induce lymphocytic vasculitis through cytokine production, i.e., interleukin-1 (IL-1), interferon gamma (IFN-γ), and tumor necrosis factor alfa (TNF-α) by CD4+ T helper lymphocytes and the migration of eosinophils, CD8+ cytotoxic T cells, B cells, and natural killer (NK) cells (68, 69). Another possible explanation of cutaneous disturbances correlated to SARS-CoV-2 is the formation and accumulation of microthromboses, which could reduce the blood flow to the cutaneous microvasculature (70), and the presence of deoxygenated blood in venous plexi could further contribute to these cutaneous lesions. Moreover, the deposition of complement components C5b-9 and C4d in pauci-inflammatory thrombogenic vasculopathy and their co-localization with COVID-19 spike glycoproteins were shown by Magro et al. (71). It is reasonable to hypothesize that skin involvement is due to a combination of these mechanisms rather than a single one (5). Taste disorders were the most common oral symptom in patients with COVID-19, probably due to a local inflammatory response resulting from rhinitis triggers, which can hamper taste buds' normal function (15, 72). Additionally, oral mucosa involvement was described during SARS-CoV-2 infection. Since the first description of oral lesions in SARS-CoV-2 positive patients, reported by Martín Carreras-Presas et al. (10), several more recent studies have also reported oral mucosa lesions in COVID-19, such as ulcers (50, 60–62),

TABLE 1 | Viruses associated with oral lesions.

Viral family	Virus	Oral disease	Oral lesion
Herpesvirus (HSV)	HSV-1	Primary herpetic gingivostomatitis Herpes labialis (recurrent infection)	Vesicles Erosions Ulcers
	HSV-2	Similar to HSV-1 but rare	
	HSV-3 (Varicella zoster)	Primary infection (rare) Recurrent infection	
	HSV-4 (Epstein Barr)	Mononucleosis Burkitt's lymphoma Nasopharyngeal carcinoma	
	HSV-5 (Citomegalovirus)	Sialadenopathy Aphthae	
	HSV-6	-	
	HSV-7	-	
	HSV-8	Kaposi's sarcoma	
Papillomavirus (HPV)	More than 100 subtypes: HPV-2,−6,−11,−57 HPV-6 and−11	Squamous papillomas Verruca vulgaris Condyloma acuminatum	Exophytic papillary lesions Multiple, pink, soft tissue masses
	HPV-13 and−32	Focal epithelial hyperplasia (Heck's disease)	
	HPV-16 and−18	Dysplastic and neoplastic transformations of squamous epithelium	
Poxvirus	Variola Molluscum contagiosum (MCV)	Smallpox Molluscum contagiosum	Maculopapular lesions Erythematous papules
Picornavirus	Coxsackie virus: A16, A6 A1-A6, A8, A10, A22	Hand, foot, and mouth disease Herpangina	Vesicles Ulcers
Paramyxovirus	Measles virus (MV) Mumps virus	Rubeola Mumps	Small erythematous macules with white necrotic center (Koplik's spots) Ulcers
Retrovirus	Human immunodeficiency virus (HIV)	Opportunistic infections (viral, bacterial, fungal) Malignancies	Not typical lesions but dependent on the secondary lesion

aphthae (51, 55), and maculae (53, 60). The clinical significance of oral mucosa involvement during SARS-CoV-2 infection remains controversial.

As previously reported (14), the high expression of ACE2 on oral epithelial cells, especially on the tongue, suggests that the oral cavity might be an anatomical site particularly susceptible to SARS-CoV-2 infection. Consequently, as suggested by Brandão et al. (51), the interaction between SARS-CoV-2 and ACE2 might disrupt the oral keratinocytes' function, resulting in painful oral ulcers. Furthermore, oral mucosa lesions during COVID-19 could be justified by the variable inflammatory reaction, which can induce vascular inflammation, as observed for cutaneous manifestations (5, 73). The most recent publications on oral mucosa lesions in patients affected by COVID-19 support an association with organic damage and/or complications for thrombocytopenia, anticoagulant therapy, disseminated intravascular coagulation, and systemic inflammation (60, 62, 63). According to Cruz Tapia et al. (54), clinical manifestations and histological findings suggest the possibility that the oral cavity presents the primary or secondary alterations of vascular-hematologic damage associated with COVID-19. Nevertheless, as reported by Martín Carreras-Presas et al. (10) and Hedou et al. (74), ulcers or vesiculobullous lesions can occur as in other viral infections. It is largely documented that high levels of fatigue and stress can increase the risk of the reactivation of HSV (75).

Moreover, oral damage could also be a manifestation of an immunosuppression state and microbiome dysbiosis caused by a viral infection (76). According to Bezerra et al. (50), it is reasonable to think that COVID-19 systemic immune deregulation may cause a more prolonged immune imbalance, which could predispose these late, secondary oral lesions. In addition, as stated by de Sousa et al. (13), most patients developed oral mucosal injury during the hospitalization period, which supports the hypothesis of coinfections, immunity impairment, and adverse reactions to COVID-19 treatment medications.

Interestingly, Martín Carreras-Presas et al. (10) suggested that oral lesions, such as ulcers, could be an inaugural symptom of COVID-19. According to Amorim Dos Santos et al. (15), in mild cases, oral mucosal lesions occurred before or at the same time as the initial respiratory symptoms; however, in those who required medication and hospitalization, the lesions developed approximately 7–24 days after the onset of symptoms. Limited to the cases reported, the time to onset was variable, ranging from 4 to 90 days; however, the time on onset was unavailable in several reported studies, confirming the necessity to verify this data in larger patients' cohorts.

Regarding the age of patients presenting with oral injuries, Brandão et al. (51) reported two distinct oral lesions patterns. One was represented by aphthous-like ulcers in young patients with mild cases of COVID-19, and the other resembled HSV-1 necrotic ulcers in more severe cases of immunosuppressed older patients. Again, the lack of data available from a large sample of participants makes further investigations necessary to support these hypotheses.

Another interesting fact emerging from the reported cases is how online professional consultation using photography (telemedicine) could be a very useful, additional tool to support clinicians in the early diagnosis of oral lesions, especially when direct observation is not possible (57, 63). Indeed, an early clinical diagnosis and the development of sensitive diagnostic tools are essential for a correct management of the disease (77, 78).

There are some limitations to underline in this study. First, almost all the reports were published as letters to the editor, thus imposing editorial limitations that reduce reporting

TABLE 2 | General aspects of the included studies.

Study	Design	Sample (n)	Age and gender	Oral lesion	Localization	Time on onset (days)[a]
Amorim Dos Santos et al. (62)	Case report	1	67 (M)	White plaque; pinpoint yellowish ulcers	Tongue dorsum	24
Ansari et al. (49)	Letter to the Editor	2	75 (M) and 56 (F)	Ulcer	Hard palate and tongue	6 ± 1.41
Bezerra et al. (50)	Letter to the Editor	1	33 (M)	Ulceration; ulcer with necrotic background	Floor of mouth; retromolar region and lip mucosa	70 (first appearance) and 90 (second)
Brandão et al. (51)	Case series	8	53.87 ± 24.86; 5 (M) and 3 (F)	Aphthous-like + necrosis; hemorrhagic ulceration with necrotic areas; aphthous-like; petechia	Upper and lower lip mucosa; anterior dorsal tongue; lateral borders of the tongue; ventral portion of tongue; upper and lower labial mucosa; tonsillar pilar	6 ± 2.56
Carreras-Presas et al. (10)	Short communication	1	65 (F)	Blisters; desquamative gingivitis	Internal lip mucosa	22
Cebeci Kahraman et al. (52)	Letter to the Editor	1	51 (M)	Erythema; petechia; pustular enanthema	Hard palate; soft palate border	10
Chaux-Bodard et al. (9)	Letter to the Editor	1	45 (F)	Erythematous macula evolved into ulcer	Tongue	8 days before the laboratory-confirmed COVID-19
Ciccarese et al. (53)	Letter to the Editor	1	19 (F)	Erosion; ulceration and petechia	Palate and lips	7
Corchuelo and Ulloa (63)	Case report	1	40 (F)	Reddish plaque; dark brown hyperpigmentation	Lower lip; gum	21
Cruz Tapia et al. (54)	Case series	4	47 ± 7.11; 1 (M) and 3 (F)	Bulla; macula; papule-plaque	Hard palate; tongue	N.A.
Díaz Rodríguez et al. (55)	Letter to the Editor	3	58 ± 18.02; 1 (M) and 2 (F)	Aphthous-like; tongue depapillation; fissures; red plate	Dorsum of the tongue; labial commissure; palate	N.A.
Dominguez-Santas et al. (56)	Letter to the Editor	4	33 ± 10.19; 3 (M) and 1 (F)	Minor aphthae	Buccal and labial mucosa; tongue	3 ± 2.16
Kitakawa et al. (57)	Case report	1	20 (F)	Vesicle	Median lower lip semimucosa	7
Nuno-Gonzalez et al. (58)	Research letter	78	N.A.	Lingual papillitis; glossitis; aphthous-like	Tongue; oral mucosa	N.A.
Riad et al. (61)	Letter to the Editor	26	36.81 ± 15.65; 9 (M) and 17 (F)	Ulcer	Tongue	4.12 ± 1.39
Sakaida et al. (59)	Letter to the Editor	1	52 (F)	Erosion	Lips; buccal mucosa	N.A.
Soares et al. (60)	Letter to the Editor	1	42 (M)	Ulceration and reddish macula	Hard palate, tongue and lips	N.A.

n = 17. M, Male; F, Female; N.A., Not available.

[a] *The time on onset refers to days passed after the laboratory-confirmed diagnosis of COVID-19.*

comprehensibility (12). Moreover, the oral manifestations' real incidence could have been underestimated due to exposure and contamination risk while conducting photographic imaging (15) and the limited data available on oral lesion injuries in asymptomatic patients. Another important aspect to consider is the limited availability of microscopic and histological data of oral mucosa lesions in COVID-19. The only accessible data referred to histological characterizations performed by Soares et al. (60) and Ansari et al. (49), which confirmed the presence of an inflammatory infiltrate, suggesting that the patients' lesions could be associated with COVID-19 disease. It is auspicious that the characterization of the oral lesions of COVID-19 infected patients should include incisional biopsies, followed by direct viral testing for SARS-CoV-2, as suggested by Brandão et al. (51).

Further research is necessary to determine the diagnostic and pathological significance of oral manifestations during COVID-19. Indeed, oral mucosa involvement during viral infection may assume differing clinical significance: it could represent either the first sign of viral disease or coexist as a co-symptom or represent a unique sign of the viral infection (26). In this context, the importance of the clinical oral examination of patients with confirmed or suspicious COVID-19 infection should be emphasized, given the need for support, pain control, and quality of life. In addition, dental operators are potentially exposed to a high degree of contamination with SARS-CoV-2

because of dental procedures that produce aerosols (79, 80). Consequently, an accurate inspection of the oral cavity, always with the mandatory dispositive protection (79), could be crucial in the dental setting to perform a more accurate triage of patients and improve safety operator, avoiding underestimation and misdiagnoses of oral signs and symptoms.

CONCLUSIONS

The new SARS-CoV-2 responsible for the global COVID-19 pandemic has become a sanitary emergency of primary importance. Although the typical symptoms include fever, shortness of breath, and a dry cough, cutaneous manifestations have also been reported, including some oral lesions. An association between oral diseases and SARS-CoV-2 infection is still unclear and currently poorly investigated. The appearance of such lesions could be related to the direct or indirect action of SARS-CoV-2 over the oral mucosa cells, coinfections, immunity impairment, and adverse drug reactions. Nevertheless, oral manifestations of this disease seem to be underreported, especially due to lockdown periods and the lack of mandatory dispositive protection. Consequently, based on these outcomes, we can conclude that (1) further studies are necessary to establish the diagnostic and pathological significance of oral manifestations during COVID-19; (2) the oral examination in patients with COVID-19 should not be unattended but rather promote a specialist multidisciplinary approach, including especially dental practitioners; (3) early recognition of oral lesions associated to COVID-19 could be crucial in the dental setting to perform a more accurate triage of patients and improve operator safety, avoiding underestimation and misdiagnosis of oral manifestations.

AUTHOR CONTRIBUTIONS

GL, ML, and EP contributed to all steps of manuscript preparation. RD and SF participated in editing and critical revision of article. All authors contributed to the article and approved the submitted version.

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Systemic Management of Pandemic Risks in Dental Practice: A Consolidated Framework for COVID-19 Control in Dentistry

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Dental teams and their workplaces are among the most exposed to airborne and bloodborne infectious agents, and therefore at the forefront of pandemic-related changes to how dental care is organized and provided to patients. The increasing complexity of guidelines makes is challenging for clinicians to navigate the multitude of COVID-19 guidelines issued by different agencies. A comparative analysis of guidance issued for managing COVID-19 in dental settings leading U.S. agencies was conducted, including documents of the Occupational Safety and Health Administration (OSHA), an agency of the U.S. Secretary of Labor, and of the U.S. Centers for Disease Prevention and Control (CDC), an agency of the U.S. Secretary of Health and Human Services. Details of infection control and other risk mitigation measures were reviewed for consistency, overlaps and similarities, then clustered according to thematic areas covering all domains of managing a dental healthcare setting. The analysis revealed five distinct areas of pandemic control, comprising (1) planning and protocols, (2) patient screening, (3) preparation of facilities, (4) PPE and infection control, and (5) procedures and aerosol control; thereby covering systematically all aspects requiring adaptation in a pandemic context. The "Pandemic-5 Framework for COVID-19 Control in Dentistry" provides an opportunity to simplify comprehensive decision-making from a clinical practitioner perspective. The framework supports a comprehensive systems-driven approach by using dental clinics as a setting to integrate pandemic clinical responses with the implementation of appropriate infection control protocols. Traditionally these two aspects are addressed independently from each other in separate concepts.

Keywords: infection control, workplace safety and health, hierarchy of risk control, airborne transmission of pathogens, dental procedure, systems thinking, dentistry, practice management dental

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SAFETY OF DENTAL CARE UNDER COVID-19

The COVID-19 pandemic has pushed safety precautions and infection control to the limelight, forcing the entire healthcare sector to review protocols and practices to ensure continued safety of care for patients and healthcare workers in an evolving context. Recognizing, understanding and managing the risks of emerging, previously unknown infections, while continuing to provide care, are complex processes. They require a systematic and systemic adaptation of multiple interlinked aspects, such as population protection and risk containment measures, healthcare service practices including infection control; and workplace health and safety for providers and patients, including surveillance of workplace-related adverse events (1–8).

Dental teams and their clinical work places are among the most affected by exposure to airborne and bloodborne infectious agents and therefore at the forefront of pandemic-related changes how dental care is organized and provided to patients (9–12). Early reports from China highlighted the risks of droplet and aerosol transmission in dental care, which led to service limitations or shut-downs in many countries worldwide, following governmental restrictions (13–15). Subsequently, numerous national recommendations for dental services have been rapidly developed, detailing adaptations of practice management, use of personal protective equipment (PPE) and other aspects of clinical dental care (15–17). In the U.S., like in many other countries, different agencies and organizations with different scopes of work are guiding infection control, workplace health and safety, and other related matters. In addition, federal and state regulations may be requiring pandemic changes to oral healthcare services.

For dental teams managing a clinical dental workplace it becomes increasingly complex to navigate this patchwork of COVID-19 guidelines issued by different agencies, also because they address different aspects of pandemic response and often reflect the organizational remit of the issuing organization. This puts a high burden on individual practitioners and practice owners. Clinicians are expected to keep themselves updated with the latest information so that they can take responsible managerial and clinical decisions to provide the safest possible healthcare environment.

This paper presents a new and consolidated framework for managing the COVID-19 pandemic risks in dental settings using five distinct areas of control. By combining approaches of different and overlapping guideline concepts of two leading U.S. public health agencies, the framework aims at simplifying decision-making and adaptations in the dental setting to mitigate the risks of COVID-19 transmission.

CURRENT FRAMEWORKS ADDRESSING OCCUPATIONAL RISKS AND INFECTION CONTROL IN DENTAL SETTINGS

In the U.S., two agencies provide public health and workplace guidance to address COVID-19: The Occupational Safety and Health Administration (OSHA), an agency of the U.S. Secretary of Labor, and the U.S. Centers for Disease Prevention and Control (CDC), an agency of the U.S. Secretary of Health and Human Services. Both have developed recommendations throughout the course of the pandemic with repeated updates accounting for the constantly evolving context. In developing these recommendations, both organizations built on their existing frameworks for risks to occupational health and infection control in healthcare and dentistry.

OSHA's "Hierarchy of Controls" addresses workplace health and safety, including healthcare settings. The concept identifies four areas of intervention with decreasing efficiency of protection for staff: Risk elimination, engineering controls, administrative practices and PPE (18). This approach has been used to issue guidance on preparing workplaces for COVID-19, as well as develop specific recommendations for "Dentistry Workers and Employers" (19, 20). OSHA places dental health care providers in the "very high" or "high" risk category because of their exposure to aerosols during dental care. For aspects of PPE and specific infection control the guidance refers to the relevant CDC recommendations.

In 2016, the CDC defined "basic expectations for safe care" in dental settings (21). The set of standard precautions comprises hand hygiene, PPE, respiratory etiquette, safe injection practice, storage and handling of instruments, and the disinfection of instruments and practice environment. In addition, a set of transmission-based precautions cover the identification of infectious patients, contact precautions, droplet and aerosol precautions. These fundamental principles are taking a clinical service provision perspective, thereby complementing OSHA's health and safety approach. The CDC's COVID-19-related recommendations for dental settings build on these standard and transmission-based precautions, but also incorporate elements of engineering controls from OSHA's framework and reference additional guidance from the American Dental Association (22, 23).

In addition, U.S. state agencies, the American Dental Association, and several dental professional associations provided further guidance, which may or may not be aligned with the advice of OSHA or the CDC. The multitude of guideline-generating agencies places dentists and their teams in a dilemma where they need to actively search for, obtain, read and compare several sources of practice recommendations. They need to appraise the quality of information provided and the relevance for their own context in order to make appropriate decisions in the best interest of patient, staff and the wider public's safety. In the current highly dynamic pandemic context this is a challenging task.

A comparative analysis of the CDC and OSHA guidance was undertaken in order to identify areas of overlap and complementarity. Clustering of thematic areas of infection control and measures for health and safety at the workplace resulted in a consolidated framework comprising five areas of intervention. **Figure 1** shows the areas of intervention of CDC's and OSHA's guidance and their respective links to the proposed new framework with five areas of control.

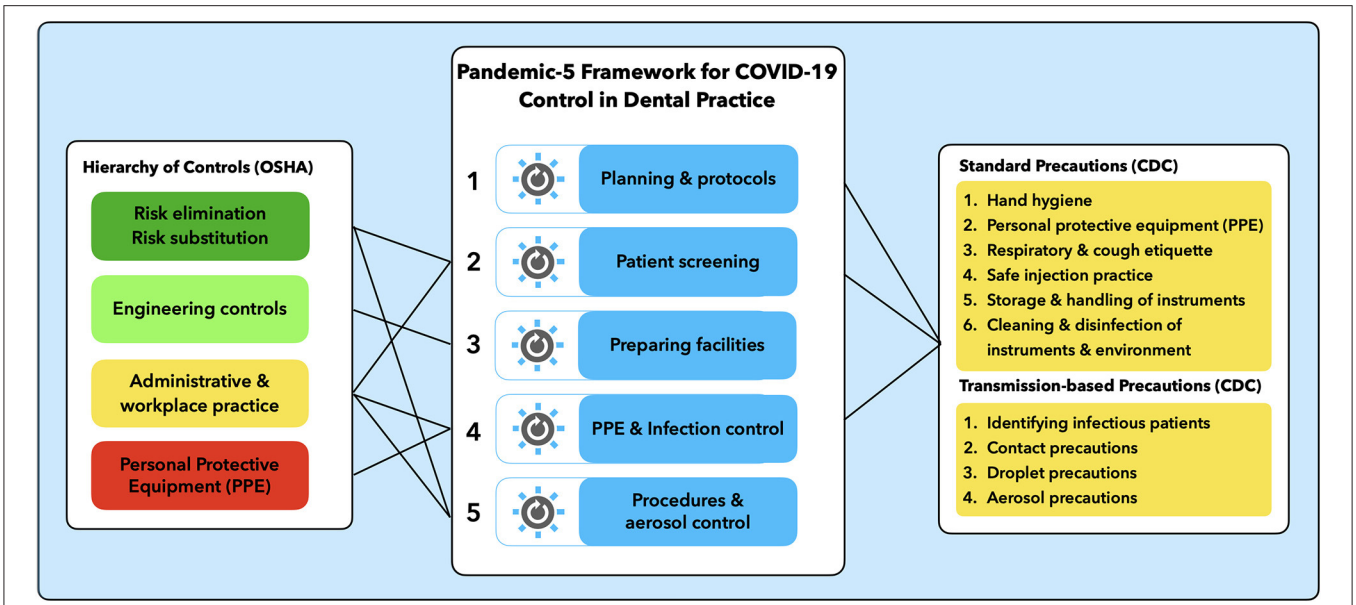

FIGURE 1 | Pandemic-5 framework for COVID-19 control in dental practice.

A SYSTEMS-THINKING APPROACH TO MANAGING RISKS OF COVID-19

Systems-thinking is increasingly applied to public health (24), hospital infections and infectious disease control (25, 26). Using the dental workplace as a system to analyze challenges and solutions in several interconnected and pandemic-related domains allows for a more holistic and comprehensive adaptation and response to COVID-19 in the dental practice.

The "Pandemic-5 Framework for COVID-19 Control in Dental Practice" synthesizes the elements of OSHA's "Hierarchy of Controls" and CDC's "Standard and Transmission-based Precautions" into a new, consolidated and simplified model (**Figure 1**).

The framework is inspired by the model for health system reform developed by Roberts et al. (27), which uses the metaphor of "control knobs" to describe core areas of intervention or change in a complex health system setting. The Pandemic-5 Framework uses the control-knob principle to systematically identify the five areas of possible interventions to manage and control the risk of COVID-19 in dental settings. The five areas and selected control interventions for each area comprise:

1. Planning and protocols
   Pandemic preparedness and response require planning and anticipation, risk assessments, thinking through different scenarios, and putting control and mitigation measures in place. Preparedness also includes communication and participation of the entire dental team and communication with patients. Staff training, rehearsing of protocols and monitoring compliance should be planned and formalized as well. Some aspects of planning and documentation may even be required as part of legal and licensing regulations. Ideally, all control measures are covered by a written plan including protocols, checklists and practical control measures.
2. Patient screening
   This area of control relates to simple assessments of the patient's health status and oral health care need. The objective is to limit or select who has access to the clinical setting. Pre-screening *via* phone or online using questionnaires and/or software are used to determine whether the patient is currently ill, has any particular risks of being infected, or is at part of a high-risk group for infection. Tele-consultations may already address the patient's problem. Through this screening process, patients with urgent problems may receive palliative care while being scheduled treatment at the dental clinic, where additional COVID-19 screening may be performed prior to providing care. Depending on the pandemic situation and infection risks, patient visits for elective procedures may be either post-poned or performed (17).
3. Preparing facilities
   The preparation of facilities comprises a range of measures to ensure physical distancing in waiting and reception areas, signage and patient flow, separation of operatories, ventilation and air filtration, enabling regular hand hygiene for patient and staff through additional disinfection dispensers. Depending on official guidance and context, additional measures to reduce aerosols and surface contamination may be taken such as spacing waiting rooms, opening windows, negative pressure rooms, or touchless doors and faucets. The area of engineering controls from OHSA's "Guidance for workplace health and safety" provides further details.

4. PPE and infection control
   Personal protective equipment is a key aspect for dental teams working in close proximity to the patient's face. A range of measures, including different types and protective levels of face masks, face shields, disposable gowns, head caps, gloves, eye protection or goggles are available and should be selected depending on the nature and length of patient contact, as well as the type of procedure performed. All of the CDC's "Standard and Transmission-based Precautions" for infection control remain in place, and additional measures for surface decontamination and operatory cleaning between patients may be recommended.
5. Procedures and aerosol control
   With the remaining uncertainty around the risk of aerosol transmission of SARS-CoV-2, dental procedures must be selected and delivered carefully. Clinicians have the choice between aerosol-generating procedures involving water-air cooled rotary instruments, ultrasonic scalers and other technology for which maximum suction methods and rubber dam should be used as much as possible. Alternatively, procedure with minimal or no aerosol potential may be chosen, such as the approach of the Safe, Aerosol-free, Emergent (SAFE) Dentistry concept (28). New measures of aerosol control might be considered such as innovative suction technology, once their efficiency and evidence have been demonstrated.

The description of possible activities and risk mitigation measures under each control area is merely illustrative and not meant to be comprehensive, nor is the aim to provide specific guidance on actual measures that need to be taken in a specific setting or situation. Organizations and professional associations are encouraged to structure their guidance according to the five areas of control, thereby making it easier for clinicians to systematically follow and implement. Dental teams may also use the framework to review available information from different sources and to collate them to the five control areas, which simplifies staying updated and taking informed decisions about increasing, maintaining or loosening control measures.

Whatever the choices in the five control areas are, it is important to keep three fundamental principles in mind: consider every patient to be potentially infectious, focus on precautions to prevent droplet/aerosol transmission, and use the best possible PPE for protection of patients and staff (5). In contrast to OSHA's hierarchy of controls, all five control areas are equally important and need to be considered in order to provide the best possible occupational safety and infection control. The combination of measures in all five areas provides best possible safety and protection.

THE CONTINUUM OF UNCERTAINTY AND RISK UNDER COVID-19

Knowing the characteristics of a new infectious agent and its transmission mode, infectivity, disease patterns and many other aspects are part of the foundational determinants for an effective pandemic response, including appropriate infection control measures (29). Only when these aspects are known, the risks of certain events and outcomes can be fully assessed. This empirical analysis of observations, epidemiological surveillance, laboratory and virologic insights is highly complex and dynamic. It resembles a giant puzzle where over time different pieces are coming together toward a more complete picture. Less than a year after the first identification a lot is already known about SARS-Cov-2 and the clinical features of COVID-19 infections. Even though uncertainty is decreasing, and knowledge is increasing on a daily basis, reaching full understanding of the pandemic will take more time. Uncertainties about fundamental properties of the disease and the resulting risks will remain and impact on clinical decisions.

The role of airborne transmission *via* droplets and aerosols is one of the major areas of uncertainty for dentistry, since many of the frequently-used interventions are classified as aerosol-generating procedures (30, 31). Consequently, the current situation limits managerial control in dental settings and leaves a probability for failure (**Figure 2**). So far there have been no reports of major SARS-CoV-2 transmission events in dental settings, but several factors are limiting knowledge and reporting of such incidents; it is likely that more details will emerge over time (5, 32).

Understanding the dynamic nature of the situation, where progress toward full certainty and knowledge of risks may not be a linear process; and where new unexpected challenges may appear at any time, is important when deciding on adapting control and risk management in dental services to the COVID-19 pandemic. Ideally, such measures would need to be equally dynamic and adaptive in order to provide effective protection.

SCENARIO PLANNING USING THE PANDEMIC-5 FRAMEWORK FOR COVID-19 CONTROL IN DENTISTRY

Systems thinking opens the door to a number of analysis and modeling approaches that help understand the relationships and interlinkages between different elements of the system (24). Scenario planning is among the tools that link problem-driven analysis with goal-oriented solutions (33). The principle of a "control knob" to step up or decrease precautions allows for flexible adaptation in the COVID-19 or other novel infectious agent contexts. External factors beyond control of the dental team, such as the level of community spread, availability of PPE or availability of a vaccine, are determining the adaptive measures within the control framework. The overall goal of the adaptations is to maintain and provide safe care for patients and clinicians, without the risk of infection or disease transmission.

SHIFTING RESPONSIBILITY FOR PANDEMIC CONTROL AND RESPONSE REQUIRES HIGH COMPLIANCE

When the first peak of the pandemic subsided, governments or states were allowing the gradual re-opening of dental

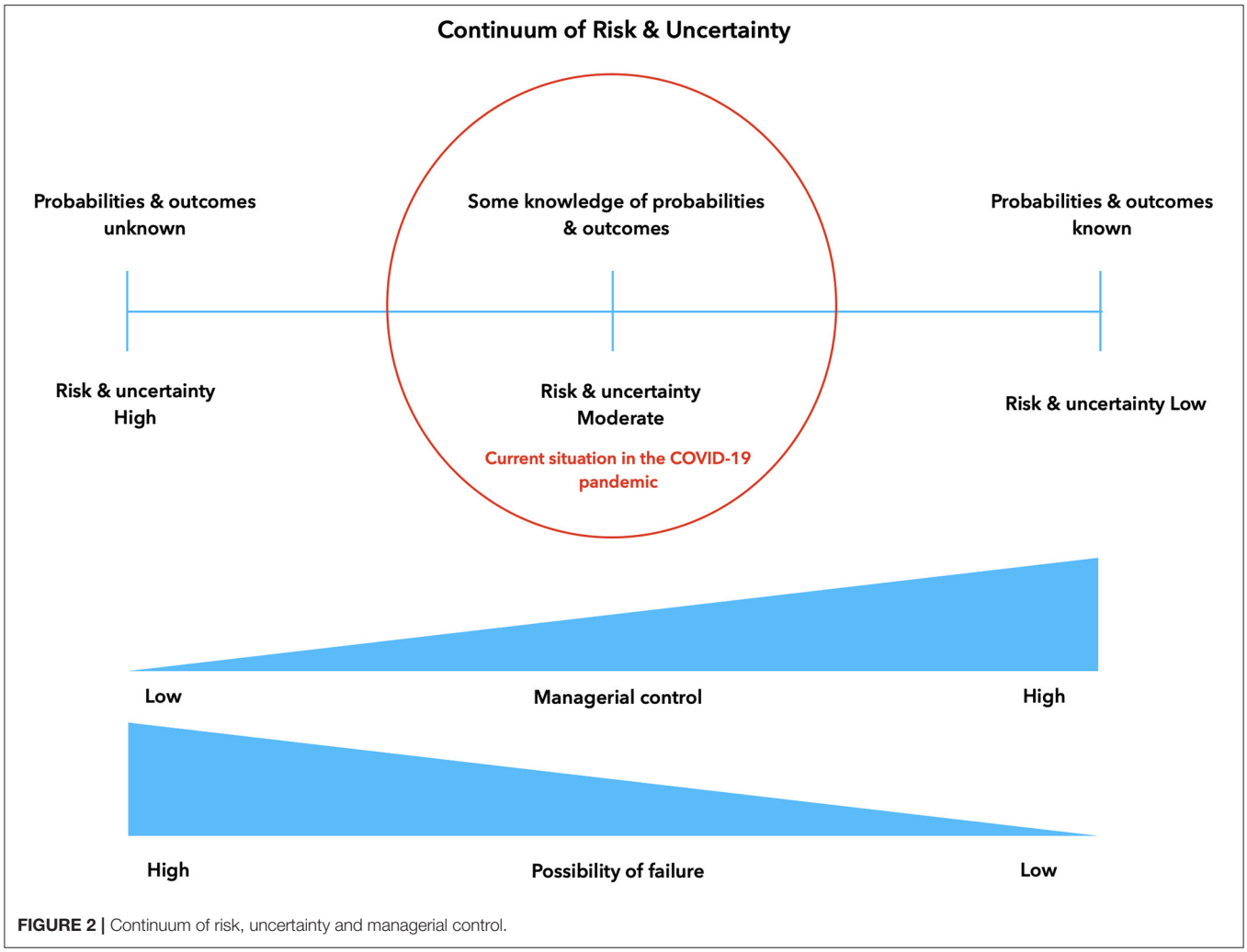

FIGURE 2 | Continuum of risk, uncertainty and managerial control.

services. This process implied shifting aspects of population-wide containment measures to clinic-level measures. By implication, individual practitioners and dental teams had to make the required clinical COVID-19 control decisions based on the most current guidance and their best professional judgment. This is a crucial step in devolving elements of the COVID-19 (or any future airborne infectious disease) preparedness and response, and one which requires confidence that appropriate measures will be uniformly followed.

However, dental teams express concerns over a multitude of uncertainties. These uncertainties include the understanding of community transmission, shortages of PPE, and safety of care without full PPE (34). On the other hand, previous studies show that dentists frequently tend to downplay risks and display a degree of over-confidence with their infection control measures, which may contribute to potentially lower compliance with new recommendations (35, 36). Others may even consider external guidance as an intrusion of their professional autonomy (37–39).

The Pandemic-5 Framework for COVID-19 Control in Dentistry provides an opportunity to simplify and systematize decisions from a clinical setting and practitioner perspective. The framework supports a comprehensive systems-driven approach by using dental clinics as a setting to integrate pandemic clinical responses with the implementation of appropriate infection control protocols. Traditionally these two aspects are addressed independently from each other in separate concepts.

The proposed framework shifts the locus of control back to the clinical setting and the provider's decision realm. Decisions are made based on rational assessments of uncertainty and risk, taking into account external uncontrollable factors. A clinician who feels in control, has decision autonomy and confidence, is more likely to adapt to change and to comply responsibly with service recommendations (40). The knowledge of the five control areas and options to fine-tune the pandemic response empowers and facilitates active management of the pandemic risk.

The concept also facilitates system adaptations in resource-poor settings where governmental or robust epidemiological guidance may not be available. Validation of the concept of the five pandemic control areas, using other international guidelines is encouraged and should not be too complex. Other areas

of healthcare are facing similar challenges related to aerosols and proximity to patients, such as anesthesiology, maxillo-facial or ear-nose-throat surgery. Future research may show to what extent the Pandemic-5 Model might also be applicable to these clinical disciplines.

DATA AVAILABILITY STATEMENT

The original contributions generated for the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors contributed equally to conceptualizing, drafting, and finalizing the manuscript.

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OPINION
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Public Oral Health Care During COVID-19: Time for Reflection and Action

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INTRODUCTION

About 2.3 billion people (mainly from upper and lower middle income countries) suffer from untreated dental caries (affecting permanent teeth) while 530 million children have caries involving primary teeth, according to the Global Burden of Disease 2017. This makes dental caries one of the most common global public health concerns (1, 2). Data from the Global Burden of Disease 2017 further suggest a skewed distribution of reported oral diseases across the global platform. Countries with better economic development have a higher burden of tooth loss yet lower rates of untreated caries and severe periodontitis (3). Changes in dietary intake, increased sugar consumption, and limited access to health care could further be attributed to the reported rates of diabetes, obesity, and dental caries (3). Similarly, increasing rates in periodontal disease, oral cancers, oral manifestations of HIV, and oro-dental trauma demand a more committed public health response (1). Oral diseases are considered a major burden on scarce resources, especially from a public health perspective, due to their impact on pain, discomfort, and compromised quality of life (4, 5). Treatment for oral conditions are generally unaffordable and universal health coverage remains a challenge in most parts of the world. Even in high income countries, oral health related care amounts to almost 5% of the total health expenditure and 20% out-of-pocket health expenditure (1).

The COVID-19 pandemic has sharply brought into focus the need to re-examine oral health systems given that virtually every aspect of healthcare delivery has been impacted by the outbreak including oral health care delivery. It can be argued that COVID-19 has completely altered the care landscape with not only new challenges and threats, but also new opportunities. Likewise dentistry and oral care delivery should not be left behind as the entire health delivery systems morphs and evolves along with the times. This paper advocates a review of public oral health systems (both in developed and developing countries) with a renewed focus on improving oral health related outcomes, as a response to the COVID-19 pandemic. A SWOT analysis framework is used to examine strengths, weaknesses, opportunities, and threats related to the current delivery of oral health services. The strengths and weaknesses of oral health systems will first be examined, followed by opportunities to improve oral health care delivery. Possible threats to achieving improved service delivery will also be explored. This analysis is intended to create greater awareness among oral health and health practitioners, oral health planners, policy makers, health decision-makers, researchers, and academics on the value of oral health within general health care. Additionally, this analysis could be used to guide oral health related "decision-making as it is crucial during the current pandemic to work on weaknesses, avoid threats, and utilize all future opportunities" [(6), p.1343].

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STRENGTHS AND WEAKNESSES OF ORAL HEALTH SYSTEMS

Oral health systems (both public and private) have been in existence but the challenges of delivering effective oral health care remains a challenge in many parts of the world (4), especially in underserved populations. Given the dependency on the public oral health system, especially in economically challenged countries and in under-served populations (7), it is imperative that the health system is able to respond adequately to unmet oral health needs. While the link between oral health and general health has been widely documented, the challenges of implementing an integrated response to health care also continue to persist in several health settings (8). One of the main shortcomings of oral health care is that it is generally assessed independently of general health outcomes while measures of overall health status tend to exclude oral health determinants (9). Another shortcoming would be a dependency on the formal health system to deliver optimal oral health care, without taking into account other key platforms such as community or facility-based care. This divide between oral health and general health continues to permeate through health policy planning and implementation.

Other weaknesses of the health system became more apparent during COVID-19. The pre-COVID inequities in access to optimal health care have been exacerbated during the pandemic where underserved populations and uninsured as those in the US, have been disproportionately affected by the disease (10). Similarly in Africa and other in developing countries, the rhetoric between saving lives and livelihoods becomes more pronounced as people struggle between disease prevention and earning an income (11). Concurrently, oral health systems appeared to use a "knee jerk" approach in dealing with the pandemic. While oral health authorities in some countries called for a suspension of clinical service delivery while others promoted a more cautious approach with emphasis on increased infection control (12). This sadly suggests that current country specific policies and guidelines on oral health care have failed to plan adequately for a public health emergency.

THE NEED FOR COMMITTED FOCUS ON ORAL HEALTH CARE

A review and re-organization of oral health systems is thus overdue. There is need to ensure equitable and improved access to oral health care with a focus on improving population health outcomes (13). There is need for increased policy discussions on oral health care, research and innovation, monitoring, and surveillance. The primary health care model could provide a viable vehicle (8) to facilitate political commitment from planning to implementation through local legislative efforts.

While there is currently no natural immunity against SARS-CoV-2 infection, studies show that people more at risk of developing COVID-19 related complications include those with diabetes and obesity (14, 15). While vaccines are now available, vaccine nationalism and allegations of stockpiling among high income countries have fuelled global discussions on addressing COVID-19 challenges and low income countries are largely left with little bargaining power (16). The emergence of new variants in COVID-19 has made the disease far more transmissible, thereby placing a greater strain on the health system (17). At the same time, diet and obesity are linked to acquisitions of unhealthy lifestyle practices that are deeply rooted in social and economic circumstances (18–20), that could limit the selection of healthier choices. These determinants could thus impact on oral health status as well (21). Concurrently, access to oral care for people afflicted with COVID-19 disease could be compromised due to ongoing restrictions in social movement during state imposed lockdowns.

Hence a more committed focus is needed on prevention of commonly occurring oral diseases and the promotion of healthier behavioral practices. Isolated individual interventions directed toward modifying specific oral health-related behaviors have not been successful in achieving long-term changes in behavioral practices (5). A population based strategy could include a multi-disciplinary approach for the reduction of risk factors associated with tobacco and alcohol use, healthier dietary intake, and exposure to additional topical fluoride within wider integrated health action. The availability and cost of healthier foods as well as providing information on food labels could influence food choices (22).

OPPORTUNITIES FOR IMPROVED ORAL HEALTH CARE DELIVER

Despite the highlighted challenges, several opportunities exist to optimize a more seamless delivery of oral health services, as outlined below:

Oral Health Promotion

Promotion of oral health care should not be the responsibility of just the health system. From an organizational perspective this requires a shift from health practitioner focus to oral health promotion within a social setting (21, 23). It is known that oral health self-care emanates from the primary socialization period, that is, children engage in activities such general hygiene and taking care of one's oral cavity starts through influences within the family and social setting (22). Oral health self-care can be reinforced at multiple settings such as crèches, schools, workplaces, etc. Oral health action could include efforts to modify oral health behaviors through oral health education, dietary counseling, individual skills development (such as proper toothbrushing and flossing) and access to additional fluoride uptake. In addition, awareness programmes to control risks to oral health such as nutrition intake, tobacco cessation, reduction in alcohol consumption, and avoidance of dental trauma should be considered. Other initiatives could include access to clean water and a safe and supportive environment to develop personal skills for positive oral health outcomes (4, 5, 8, 21, 22). These activities should be integrated into COVID-19 public health measures such as regular handwashing, social distancing, and wearing of face masks. Policy development at the

facility or health promotion setting level could assist in ensuing commitments in implementing these initiatives. Oral health promotion delivery needs to occur at multiple levels such as macro level (policy development and agenda setting), meso level (community-based approach), and micro level (interpersonal and intrapersonal). A macro level engagement could also include mass media communications and foster political support for creating supportive environments to address unhealthy behavioral practices (21). Mass media provides opportunities to advocate for integrated health and social messages during COVID-19 that include elements of oral health care (24). However, caution should also be applied to prevent spread of fake news and health-related mis-information (25).

Further investments in oral health could include engagement with technologies to improve the digital interface in health communication (26). Modalities such as tele-dentistry could support the delivery of oral health services, specifically when physical contact or travel to the local clinic is difficult. Tele-dentistry also has potential to link service providers across geographical spaces and ensure continuity in the delivery of expertise in oral health care (26–28). Health or oral health care workers could use these technologies to facilitate support and engagement with service providers in care homes, correctional service facilities and other such settings where public access during COVID-19 is limited. This could ensure that integrated oral health messages and support can still reach these very vulnerable populations. Similarly, remote engagement provides another viable platform for the dissemination of preventive messages. Mobile devices such as smartphones create a personalized platform for the delivery of oral health messages. Although issues such as internet connectivity and availability of data bundles remain a challenge in resource-constrained settings, it is nevertheless valuable to invest in such technologies.

Likewise, stronger collaboration is required between the health system and community based settings for the safe delivery of oral health promotion services (29). These settings provide further opportunities for integrated oral health messages and policy planning (30) such as good oral health habits, positive oral health behaviors, and developing personal oral health skills. Oral health care should be embraced by all stakeholders involved in care provision, and not just the health or oral health worker. Partnerships in health care could also be developed with the private sector and all other stakeholders in community development (29, 30). Thus, the prevention of disease and promotion of healthier lifestyles are integrated into overall community and social development.

Oral health interventions directed at the intrapersonal and interpersonal level should focus on unhealthy behavioral practices such as diet, smoking and alcohol consumption. Smoking has been shown to be linked to a number of health complications such as diminished lung capacity, cardiac complications, and periodontal disease (31). Further complications can linked with COVID-19 (32) given that this a respiratory related disease. Integrated oral health messages could thus be directly beneficial at an individual level. Public health emergency strategies such as isolation and quarantine during COVID-19 places additional strain on the individual's ability to cope with the pandemic (33). Strategies could be developed at the micro-level to help individuals cope with COVID-19, and make healthier behavioral choices. Oral health care workers have a role to play in early recognition of signs of depression in patients and to make the necessary referrals for appropriate care.

Studies have shown that early clinical signs of COVID-19 include a loss of taste and smell (34, 35). COVID-19 provides unique opportunities for oral health care workers to engage in screening services. Thus, oral health workers could play key roles in screening (36) and identifying asymptomatic clients or those presenting with early symptoms; and conduct saliva testing for COVID-19 (37). Oral health care workers could provide integrated health messages such as handwashing, cough etiquette, proper wearing of facial masks/coverings, and oral health related care. Other activities could include infection prevention education and training, reinforcing health and safety measures in client/patient contact, risk management, and program evaluation (12).

Threats

Despite these opportunities some of the possible threats to implementing these strategies could include lack of practitioner skills. There is thus a need for continuing professional and skills development for the oral health care worker as well as a review of undergraduate dental curricula so that appropriate training can provided to better equip the individual practitioner.

Although the notion of integrated oral health care through a multi-disciplinary team approach has been touted as a key strategy to broaden the delivery of oral health promotion services (38), this seemingly uncomplicated patient/client centered initiative continues to face challenges in many parts of the world, as indicated earlier (39, 40). The question begs: why is this so? Perhaps we as dental public health practitioners, academics, health planners, and researchers need to reflect further. Has there been widespread stakeholder engagement to ensure buy-in for these innovative approaches in oral health service delivery? To successfully influence the processes of oral health promotion requires more than simple, document-based policy reforms that are strong on rhetoric, and good ideas, but have not achieved the widespread stakeholder support necessary to carry them through to funding and implementation [(41), p.23]. Simultaneously, we as oral health care workers need to re-examine our roles within a multi-disciplinary team. How can we make more meaningful contribution to overall health outcomes during COVID-19 (42)?

This highlights the need for greater dialogue both within and outside of the health system to explore ways of integrating oral health messages and care within a broader scope of overall community health. This should be supported by ongoing opportunities for health workers to develop skills in oral health promotion activities through training programmes. Further research is required to unpack the barriers and delays in integrated health action.

CONCLUSION

The COVID-19 pandemic has provided opportunities for renewed interest in the oral health agenda. A re-organization of oral health systems with a focus on social orientation of oral health self-care, could see improved oral health gains in the long term. Concurrently, the role of oral health care workers and their preparedness for a public health emergency should be reviewed and addressed through appropriate training platforms.

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The author confirms being the sole contributor of this work and has approved it for publication.

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Dentistry Amidst the COVID-19 Pandemic: Knowledge, Attitude, and Practices Among the Saudi Arabian Dental Students

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Background: The recent pandemic outbreak has created a huge impact on dentistry. Dental students and dental professionals are at a higher risk because dental practice comprises close communication and widespread exposure to blood, saliva, and other body fluids. It is imperative to evaluate the knowledge and perceptions regarding Coronavirus (COVID-19) among budding dentists.

Aim: To assess the knowledge, attitude, and practices of dental students regarding dental practices during COVID-19.

Materials and methods: A cross-sectional questionnaire-based study was conducted among undergraduate students in Riyadh, Saudi Arabia. An online questionnaire consisting of demographic, knowledge, and attitude-based questions were circulated among the study population, and the responses for the knowledge and attitude were scored. Their mean scores were then calculated. Chi-square test and nonparametric tests were computed using SPSS version 21 software, and p-values < 0.05 were considered statistically significant.

Results: 388 undergraduate dental students have participated in the study from Saudi Arabia. 68% of the respondents believed that they had sufficient knowledge regarding COVID-19. The mean score for knowledge was 5.84 out of 7. Females (6.24) scored statistically significantly higher than males (5.55, $p <= 0.001$). The mean attitude score was 6.34 out of 9. 93% were using PPE models, while 95% maintained social distancing. Out of all the participating dental students, only 16% were willing to treat patients during the pandemic, and 28% did not want to treat patients, 28% preferred teledentistry. The majority (44%) of dental undergraduates were willing to handle only emergency cases.

Conclusion: Accurate knowledge and attitude regarding COVID-19 and diversified opinion on preventive practices during the pandemic period among budding dental

professionals evident from Saudi Arabia. Mixed opinions were witnessed among them in seeking help from professional societies. The majority of dental undergraduates were willing to handle only emergency cases.

Keywords: coronavirus, dentistry, dental students, practice, Saudi Arabia

INTRODUCTION

Shutters of dental offices were pulled down with dentistry flagged as a high-risk profession on the unforeseen advent of the highly contagious viral infection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as COVID-19, in early 2020. The pandemic was declared by the World Health Organization (WHO) on Mar 11, 2020, following which, overnight, curfews and lockdowns had been implemented worldwide (1). It was identified that this highly infective virus is transmitted through direct and indirect modes. The natural mode of transmission took place via aerosols generated during surgical and dental procedures, in the form of respiratory droplet nuclei or other bodily secretions and fluids or mother-to-child. This increased the chances of a person getting infected if present in the proximity of 1m of the host. Indirectly, the transmission occurred on touching surfaces in the infected people's immediate environment or objects used by them (2).

The first dentist reported to have fallen prey to this virus was on January 23rd, 2020 the hospital at Wuhan University in China, a country where the infection is said to be originated from, and eventually other health professionals were tested COVID posted (3, 4). In context with this, the civic authorities urged delay of dental sittings unless there being an emergency, and thus, dentistry as a profession came to a standstill (5). The dental profession demands the patients violate the recommended one-meter safe distance and dental procedures generating aerosols. it was no surprise that all non-essential dental procedures were suspended as a part of the interim guidance (6). The oral health providers may accidentally provide direct care for infected or suspected yet not diagnosed COVID-19 patients. There have also been cases of asymptomatic infections wherein transmission may occur even before symptoms appeared (7, 8).

The pandemic took a toll on dental practices. A recent study by Wang et al. (9) reported that 138 hospitals admitted COVID positive patients in Wuhan and identified 29% of these hospitalized patients as healthcare workers. In contrast, Meng et al. reported nine COVID positive cases among dentists and students at Wuhan University, raising the alarm regarding healthcare professionals' safety, especially dentists (5). As much as 38% reduction in patients seeking dental treatment was observed by Guo et al. (10) during the Wuhan outbreak. Consequently, the authorities across the globe were jolted into formulating an action plan for dental services to be carried out post the initial interim suspension.

Several protocols have been set up to ensure minimum human-to-human contact during the pandemic. There is an overall consensus of screening patients prior to initiation of any dental procedures and triage. The dentists are advised to don personal protective equipment (PPE) kits, facemasks, preferably N-95, and face shields. Minimization of aerosol generation, adequately ventilated operatory, and strict compliance with infection control measures and bio-waste management are reinforced (11). Practices of "teledentistry" or web/ telephonic consultation are also being encouraged (12). The face of dentistry is changing, with COVID-19 presenting an unprecedented challenge to the dental industry. The future and sustenance of practicing and emerging dental professionals depend on their adherence to these new norms and protocols and adapting to post-COVID dentistry 2.0. Dentistry has been forced to evolve right from how dental education is imparted to how dental procedures are carried out. Upon identifying the scarcity of such studies conducted to date, this study aims at evaluating the knowledge, attitudes, and practices of undergraduate students in Saudi Arabia to assist in preparing the dental workforce in responding better to such pandemics.

METHODS

This cross-sectional questionnaire-based study has been carried out following the STROBE guidelines (13) specified for this type of study upon approval was obtained from the Institution Ethical Committee, Majmaah University under IRB No. MUREC-June,03/COM-202-/31-2. The study was conducted in Saudi Arabia among undergraduate dental students to investigate their knowledge, attitude, and preventive practices toward COVID-19 from 01-06-2020 to 25-09-2020. Only dental undergraduate students and included both genders. Only those who were willing to sign a written informed consent participated in the study. Postgraduates, Faculty, Private practitioners, those working outside Saudi Arabia, and other health care professionals were excluded from the study. The sample size was calculated using the Raosoft online sample size calculator (14). Based on the survey by Althomairy et al. (15) in an assumption of 3,000 active Saudi dental society members, a response distribution of 50%, while the margin of error and confidence intervals of 5 and 95%, respectively, were made to reach a sample size of 341 dental students (15).

A structured online self-administered questionnaire was administered for this cross-sectional survey to evaluate knowledge, attitudes, and practices regarding COVID-19 among dental undergraduate students. The questionnaire was divided into five main parts. The first constituted the study participants' demographic information (age and gender). The second part explored (i) Information about Coronavirus in your professional society sufficient, (ii) Government institutions able to control the pandemic, and (iii) Obtaining sufficient knowledge regarding COVID-19 information. The third part elicited knowledge of oral health professionals toward COVID-19 by giving correct or

incorrect options for every question. The fourth part assessed attitudes toward COVID-19 infection. The fifth part was considered for preventive practice. Each response was scored as "1" (correct) and "0" (wrong), with knowledge scores ranging from 0 to 7 and attitude scores ranging from 0 to 9. Comparisons of knowledge and attitude scores based on gender and practice questions were evaluated. The correlation of knowledge and attitude scores was established based on practice questions. The questionnaire was circulated among the target population in the form of an online Google form, and the recruitment was done through various social media platforms and contact information obtained from the database. The data assimilated was analyzed using Statistical Package for Social Sciences (SPSS) version 21.0 software NY, USA (16). One–way-ANOVA with Bonferroni corrections was used to analyze more than three groups. A Chi-square test was computed to determine the association between study variables. All the tests were assessed at a 5% level of significance.

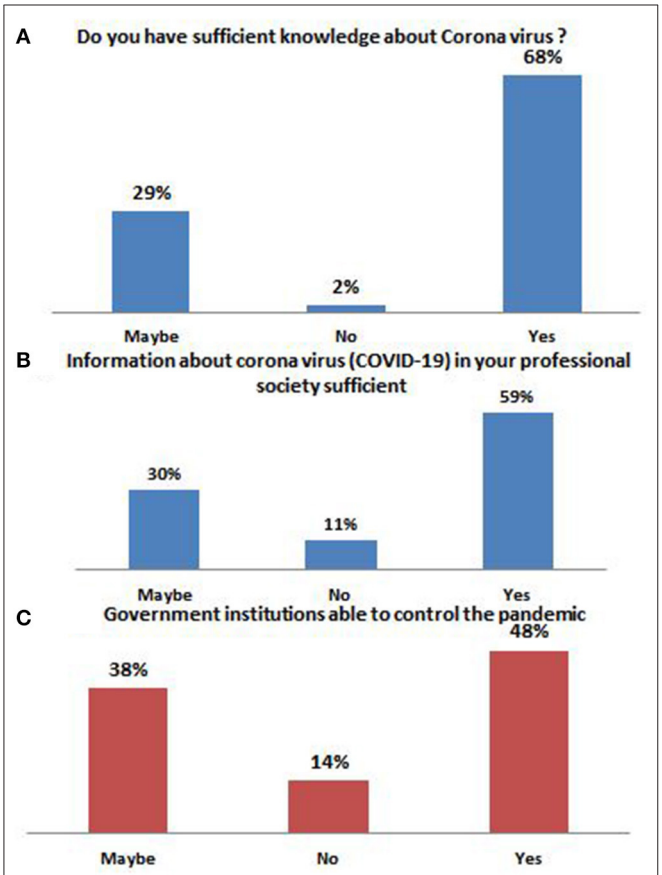

FIGURE 1 | Arabian undergraduate dental students opinions **(A)** sufficient knowledge about Corona virus (COVID-19) **(B)** available information about COVID-19 in your professional society sufficient and **(C)** the role government societies during COVID-19.

RESULTS

A total of 388 responses were received from undergraduate dental students, out of which 223 respondents were male while the remaining 165 were females with a mean age of 22 years. Amongst the participants, Saudis were 91%, and non-Saudis were 9%. When questioned about the knowledge regarding COVID-19, most of the participants (68%) believed that they had sufficient knowledge, while 29% were unsure, only 2% felt they didn't have the required knowledge (**Figure 1**). 48% thought that adequate information was available in their professional society, 38% were unsure, and 14% found the available information insufficient. Government institutions' ability to control the on-going pandemic was found satisfactory by the majority (59%) of the students, but 30% and 11% were unsure and found it insufficient, respectively (**Figure 1**). The mean score for knowledge was observed to be 5.84, where the maximum score was 7 (**Table 1**). Females (6.24) scored statistically significantly higher than males (5.55, $p < 0.001$). The mean attitude score was 6.34, where the maximum score was 9, and here too, females (6.53) managed to secure a higher mean score than males (6.19) (**Table 2**). Surprisingly, only 16% were treating patients during the pandemic, and 28% did not want to treat patients; 28% preferred teledentistry while a majority of 44% were willing to handle only emergency cases (**Table 3**). A 93% of the dental

TABLE 1 | Overall knowledge and attitude scores on COVID-19 among Arabian undergraduate dental students.

Overall total score	Mean	Standard deviation	Median	Mode	Percentile 25	Percentile 75
Knowledge (max = 7)	5.84	1.31	6.00	7.00	5.00	7.00
Attitude score (max = 9)	6.34	1.83	7.00	7.00	5.00	8.00

TABLE 2 | Comparison of knowledge and attitude scores on COVID-19 among Arabian undergraduate students based on gender.

Details	Female (n = 165)		Male (n = 223)		Mean Difference 95% Confidence Interval	p-value
	Mean	Standard deviation	Mean	Standard deviation		
Knowledge	6.24	0.83	5.54	1.50	0.69 (0.44 to 0.95)	0.00*
Attitude	6.52	1.47	6.19	2.038	0.33 (−0.03 to 0.70)	0.07

*$p < 0.05$ is considered statistically significant.

TABLE 3 | Responses of undergraduate students on practice-based questions during COVID-19.

Question	Response	*N* (%)
Are you using the personal protection equipment for safety?	No	29 (7)
	Yes	359 (93)
Are you maintaining social distancing?	No	20 (5)
	Yes	368 (95)
Are you treating your patients now?	No	327 (84)
	Yes	61 (16)
Do you want to treat patients during this lockdown?	I prefer online (tele dentistry) consultation	109 (28)
	No	108 (28)
	Only Emergency patients	171 (44)

TABLE 4 | Comparison of knowledge and attitudes scores based on use of personal protection equipment.

Using personal protection equipment	No ($n = 29$)		Yes ($n = 359$)		Mean Difference 95% Confidence Interval	*p*-value
	Mean	Standard deviation	Mean	Standard deviation		
Knowledge	5.34	1.31	5.88	1.30	−0.53 (−1.03 to −0.04)	0.03*
Attitude	5.72	1.19	6.38	1.86	−0.66 (−1.3 to 0.03)	0.06

*$p < 0.05$ is considered statistically significant.

TABLE 5 | Comparison of knowledge and attitudes scores based on social distancing.

Social distancing	No ($n = 20$)		Yes ($n = 368$)		Mean Difference 95% Confidence Interval	*p*-value
	Mean	Standard deviation	Mean	Standard deviation		
Knowledge	5.8	0.89	5.84	1.32	−0.04 (−0.63 to 0.54)	0.88
Attitude	4.3	1.62	6.44	1.77	−2.14 (−2.94 to −1.34)	0.00*

*$p < 0.05$ is considered statistically significant.

TABLE 6 | Comparison of knowledge and attitudes scores based on their practice in the dental operatory.

Treating patients	No ($n = 327$)		Yes ($n = 61$)		Mean Difference 95% Confidence Interval	*p*-value
	Mean	Standard Deviation	Mean	Standard Deviation		
Knowledge	5.87	1.28	5.65	1.43	0.22 (−0.130.58)	0.22
Attitude	6.15	1.83	7.31	1.42	−1.15 (−1.64 to −0.67)	0.00*

*$p < 0.05$ is considered statistically significant.

TABLE 7 | Comparison of practice-based responses of Arabian undergraduate dental students.

Dependent Variable	Do you want treat patients during this lock down?		Mean Difference (95% Confidence Interval)	*P*-value
Knowledge	I prefer online (tele dentistry) consultation	No	−0.01(−0.43 to 0.42)	1.000
		Only Emergency patients	−0.054 (−0.44 to 0.33)	1.000
	No	Only Emergency patients	−0.05 (−0.43 to 0.34)	1.000
Attitude	I prefer online (tele dentistry) consultation	No	0.22 (−0.37 to 0.81)	1.000
		Only Emergency patients	−0.15 (−0.68 to 0.38)	1.000
	No	Only Emergency patients	−0.36 (−0.90 to 0.17)	0.304

*$p < 0.05$ is considered statistically significant.

students revealed the use of PPE models when asked questions concerning prevailing practices and following protocols. They also had better knowledge, and attitude mean scores (5.88, 6.38) than those who didn't use PPE models (5.34, 5.72), summarized in **Table 4**. Social distancing was maintained by 95% of the undergraduates who had also scored statistically significantly higher than their peers on the attitude questions ($6.44 > 4.3$, $p < 0.001$) (**Table 5**). The 16% treating patient had statistically significantly higher mean attitude scores than those who did not treat patients ($7.31 > 6.15$, $p < 0.001$) but had lower knowledge mean scores ($5.65 < 5.87$, $p = 0.225$) (**Table 6**). No statistically significant difference was found in the mean knowledge and attitude scores when comparisons were made between those undergraduate dental students who preferred to teledentistry, who did not want to treat patients during the lockdown, and who only treated emergency patients using Bonferroni comparison (**Table 7**).

DISCUSSION

During the period of complete pandemonium across the globe, Saudi Arabia announced its first COVID-19 positive case on 2nd March 2020, and by 7th June, 2020, the total for confirmed cases had surpassed 1,00,000(17, 18). This unexpected outbreak put a strain on health systems of several countries and demanded that the health professionals step-up and accept the role of "Corona Warriors." Amidst the waves of rapidly transmitting infections was a wave of "mis-infodemic," which spread incorrect information, resulting in panic among the general population. The governments implemented varied guidelines, restrictions, bans, and curfews worldwide based on their healthcare systems, economies, and political ideologies. COVID-19 epidemics, etiology, clinical findings, epidemics, and treatment options necessitate widespread data from clinical trials (6, 19, 20). It has also been suggested that rapid discoveries can control the spread and further outbreaks of COVID-19. This disease spreads person-to-person, either through direct transmission by cough, sneeze, or droplet inhalation, or mucous membranes, or ocular contact of the eyes and saliva (8, 9, 19, 21). As a result of this hullabaloo, dental professionals had to face several challenges in the form of initial suspension of practice and later safe treatment of patients abiding by the prescribed infection control protocols (19). This study makes an effort to understand undergraduate dental student's knowledge, attitudes, and practices- training about COVID-19 and the transformed post- pandemic dentistry.

The current study evaluated the participating dental undergraduate students' knowledge by scoring them based on seven knowledge-based questions. The study demonstrated adequate knowledge about COVID-19 with a mean score of approximately six. This was in agreement with a previous study conducted by Srivastava et al. among dental health care professionals (22). Similarly, in a survey by Quadri et al. (23), dental interns, auxiliaries, and specialists scored above average scores when their knowledge was tested. However, in contrast to these findings, a prior study conducted in Georgia among the dental health care workers reported that more than half of the dental students, residents, and specialists did not have enough knowledge of viral infections (24). No prior studies have identified the correlation between gender and knowledge about COVID-19, whereas the current study reports a statistically significant difference in males' and females' knowledge, with females scoring better ($p \leq 0.001$).

In situations of public health crises like this, one's belief in government institutions' efforts shapes their morale, feeling of safety while also motivating them to effectively carry out duties assigned to them and ultimately be reflective in the nation's fight against the pandemic. 59% of the current study participants found government institutions' efforts satisfactory, others being unsure or finding it lacking. A similar study by Rabbani et al. (25) had found 75% of the Saudi Arabian healthcare workers unsatisfied with their institution's preparedness for the pandemic. These professionals' attitudes are associated with their practices, as noticed in this study wherein those with higher mean attitude scores were observed to practice social distancing. This difference was found to be statistically significant ($p \leq 0.001$).

After the interim suspension of non-essential dental treatments, new protocols have been imposed to resumption safe treatment of all cases. 84% of the participants have started treating patients. The respondents were questions about their adherence to safety protocols, and it was noted that 93% wore PPE models and 95% maintained social distancing guidelines. These numbers indicate awareness of required measures and implementation of set standards for infection control (26). However, despite relaxation regarding dental procedures that are allowed and precautionary measures, the majority (44%) still preferred to handle only emergency cases.

In the present study, accurate scores were obtained for knowledge and attitude by undergraduate students regarding COVID-19. Diverse scores were evident regarding preventive practice during COVID-19.especilly for the question on dental practice. Similarly, a recent Arabian study (27) found adequate knowledge and attitude scores and low practice scores, and the authors conducted the study with postgraduate and undergraduate students. Hence, the findings were not compared with the present study. COVID-19 plays a vital role in its control and prevention and would help formulate appropriate protocols and reform the prevailing practices to combat such pandemics in the future. The knowledge and attitudes scores of Arabian dental undergraduates were evaluated based on practices. Amongst these, overall knowledge mean scores showed correlation with the use of PPE, while social distancing and treating patients during pandemic showed correlation with attitude mean scores. Almost similar scores on knowledge among dental healthcare professionals regarding COVID-19 were reported (28, 29). The present study was conducted with dental undergraduate students; However, these findings with previous studies were not comparable. An interesting finding was the preference of teledentistry by 28% of the dental students. Teledentistry is an innovative way of rising against the challenge of social distancing by utilizing available information and technologies using smartphones, tablets, and computers for live video or phone consultation recorded videos, etc. (11, 30). It comprises remote assessment of patients with teleconsultation

or telediagnosis, triage of patients, telemonitoring, and dental care provision remotely when possible and appropriate to the patients (9, 11, 31, 32). This pandemic has left many challenges to the dental profession, and it became mandatory to evaluate the knowledge and perception of oral healthcare professionals (9, 21). Prior surveys have shown this form of remote consultation gaining popularity for treatment for disabled, elderly, and patients who do not have access to health services and during the COVID-19 crises (31–33). COVID-19 plays a vital role in its control and prevention and would help formulate appropriate protocols and reform the prevailing practices to combat such pandemics in the future.

According to the best of our knowledge, this study is first conducted among undergraduate dental students in the Riyadh region, Saudi Arabia. However, while interpreting this study's results, certain limitations that this study had encountered need to be kept in mind. Firstly, due to the strict lockdowns imposed, face-to-face interviews were infeasible, resulting in this survey being conducted online, indicating the respondents' not having understood the questions accurately. The data assimilated has been self-reported by the respondents; thus reporting bias cannot be completely ruled out. In the present study dental undergraduate from Saudi Arabia was involved, and the authors tried to establish their perception of practicing dentistry during the pandemic period. It is a fact that dental undergraduate cannot do their own dental practices. Another limitation was using self-reported measures, convenience sampling, and a cross-sectional design, which cannot be generalized to the study findings. College and their province in Saudi Arabia of the dental undergraduate students did not take for evaluation. This might also make a difference that could be considered a potential limitation of the study. The questionnaire was sent to participants via social media, and we received only 388 responses; hence, the response rate was not sought. The present study looked into overall mean scores. The individual scores were not taken into consideration for the analysis. This also could be a potential limitation of the present study. Even though the dental undergraduates were not allowed to practice independently, the present study determines their knowledge and attitudes, and practices in the Arabian region. This study opens the arena to carry out nation-wide studies targeting a larger population from various regions of Saudi Arabia as well as in other counties to have a global comparison. Healthcare professionals form the backbone of any country's public health, and dentists play a vital role in this, with dental health being an integral part of general health. Correct knowledge about any disease plays an essential role in its control and prevention, especially in cases where the population is susceptible.

CONCLUSIONS

Accurate knowledge and attitude regarding COVID-19 and diversified opinions on dental practice during pandemic were evident among budding dental professionals from Saudi Arabia. The study observed mixed opinions among them in seeking help from professional societies. The majority of dental undergraduates were willing to handle only emergency cases.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Majmaah University, Saudi Arabia. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

BA: study conception. AAla and SAlg: study design. AAlj, BA, and SM: data collection. RA, SAlg, and SAld: data analysis and manuscript drafting. AAla and SM: data interpretation. RA, SAld and SM: critical revision of the manuscript. All authors approval of the final version. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.654524/full#supplementary-material

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MINI REVIEW
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Oral Mucosa, Saliva, and COVID-19 Infection in Oral Health Care

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The SARS-CoV-2 virus has shaken the globe with an ongoing pandemic of COVID-19 and has set challenges to every corner of the modern health care setting. The oral mucosa and saliva are high risk sites for higher viral loads and dental health care professionals are considered a high risk group. COVID-19-induced oral lesions and loss of taste and smell are common clinical complaints in the dental health care setting. The SARS-CoV-2 virus has been found to cause a wide range of non-specific oral mucosal lesions, but the specific diagnosis of these mucocutaneous lesions as COVID-19 lesions will facilitate the prevention of SARS-CoV-2 in dental health care settings and aid in proper patient management. The reported loss of taste and smell needs further investigation at the receptor level as it will give new insights into SARS-CoV-2 pathogenicity. The high yield of virus in the salivary secretion is a common finding in this infection and ongoing research is focusing on developing saliva as a rapid diagnostic fluid in COVID-19. In this review, we discuss the significance of oral mucosa, saliva and the relevance of the COVID-19 pandemic in dentistry.

Keywords: oral epithelial cells, saliva, taste, SARS-CoV-2, ACE2 receptor, COVID-19

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INTRODUCTION

Coronavirus disease 2019 (COVID-19) is an infectious disease that was first detected in large numbers in Wuhan, China; it is caused by a newly discovered coronavirus identified as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1). Coronaviruses are large RNA viruses with beta coronaviruses, including SARS-CoV and SARS-CoV-2, having been shown to be the deadliest viruses, causing respiratory distress syndrome (2, 3). Since 1960, six coronaviruses have been found to cause diseases in humans. In 2002, SARS-CoV caused a major outbreak known as severe acute respiratory syndrome (SARS), which caused about 10,000 fatalities worldwide (4). Only a decade later, another pathogenic coronavirus, known as the Middle East respiratory syndrome coronavirus (MERS-CoV), caused an endemic in Middle Eastern countries (4, 5). SARS-CoV-2 is the seventh member of the coronavirus family to affect humans (4). Interestingly, the genome of SARS-CoV-2 aligned with the genomes of viruses from bats (Bat-CoV and Bat-CoV RaTG13) in *Rhinolophus affinis* species of the Yunnan province with 96% similarity; structural analysis revealed a mutation in the envelope protein (Spike protein) and nucleocapsid protein (6). The coronavirus has a simple structure with few proteins (7). There are 4 major structural proteins: the envelope protein (E), spike protein (S), transmembrane protein (M), and nucleoprotein (N). The E, S, and M proteins facilitate virus entry into the host cells, virion assembly, and viral pathogenesis. The viral genome, is in close association with N protein and also aid the E protein in virion assembly (7).

At present, two modes of transmission for SARS-CoV-2 have been identified: direct and indirect transmission. Direct transmission includes contact with the infected individual's body fluids, respiratory or salivary droplets and, other body fluids such as feces, urine, semen, and tears (8). The signs and symptoms of COVID-19 can be divided into respiratory and extra-respiratory manifestations. The most common reported respiratory signs are cough, fever, and dyspnoea (9–11). There is a wide range of extra-respiratory signs and symptoms, including oral mucosal lesions and neurological dysfunctions, such as loss of smell, loss of taste, headache, and associated myofascial pain; these are now included in the diagnostic criteria of this disease (**Table 1**) (10, 19).

The nasal cavity, nasopharynx, oropharynx and oral cavity are identified as potential replication sites for the SARS-CoV-2 virus (20, 21). The oral cavity, which is rich in saliva and the oral microbiome, is a well-known site harboring various types of respiratory viruses (22, 23). The oral saliva has been found to contain a high yield of viruses, suggesting salivary glands as active proliferating sites for this virus (20, 24). Moreover, xerostomia and loss of taste can be associated with the salivary gland dysfunction associated with COVID-19 (23, 25). However, these signs are often masked by the more life threatening respiratory signs and symptoms, which need emergency medical attention most of the time. This review aimed to provide histological specifications of the oral mucosa and its functional significance in SARS-CoV-2 infection, highlighting the orofacial manifestations and its impacts on the dental health profession.

TABLE 1 | Orofacial manifestations of COVID-19.

Clinical features	References
Headache	(12–15)
Myofacial pain	(13–15)
Oral ulcerations	(14–16)
Burning sensation of the oral mucosa	(14, 16)
Oral vesicle formation	(16, 17)
Loss of taste	(14–16, 18)
Loss of smell	(14–16, 18)
Dry mouth	(14, 15)
Skin discomfort	(16)

ORAL MUCOSA

The oral mucosa is the specialized mucous outer covering layer of the oral cavity which consists of the stratified squamous epithelium and the underlying connective tissue (lamina propria) (**Figure 1**) (26). Apart from the common epithelial functions, such as protection and lining, oral mucosa is regionally specialized to form special functions like taste perception, sensory perception, mastication, and secretion (26). The oral epithelial cells have numerous structural and functional specifications to withstand physical and chemical attacks. Squamous epithelia possess structural properties like stratification and cornification of the keratinocytes and specific cell-to-cell interactions to maintain their barrier functions (26). The epithelial cells are metabolically active and are capable of reacting to external stimuli by synthesizing a number of cytokines, adhesion molecules, growth factors, and chemokines (27). The oral cavity is a dynamic ecosystem that varies over time in ways that influence spatial patterns of microbial community assembly (28). Among

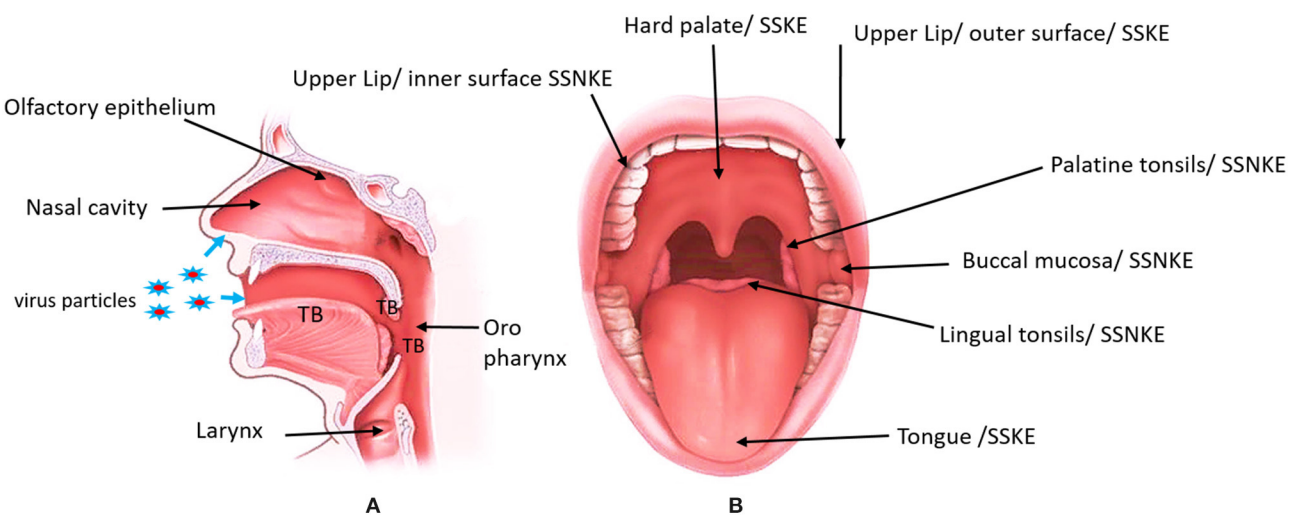

FIGURE 1 | Modified image indicating the location of the entry points of SARS-CoV-2 and the anterior view of the oral cavity labeling different areas of the oral mucosa. **(A)** Blue arrows indicate the nasal and oral entrance of the virus. The location of the olfactory epithelium and taste buds (TB). Olfactory epithelium is located on the roof of the nasal cavity. Taste buds can be found in the tongue, tonsils and oropharynx. **(B)** The specific location of the Stratified squamous keratinized epithelium (SSKE) and Stratified squamous non keratinized epithelium (SSNKE) in the oral cavity. https://www.informedhealth.org/how-do-the-tonsils-work.html, *"How do the tonsils work?"* Institute for Quality and Efficiency in Health Care (IQWiG, Germany), 17 Jan 2019.

the oral microbial community are common commensals that can be opportunistic pathogens when the host immunity is compromised. There are many species of bacteria, fungi and viruses which are either pathogenic or opportunistic, causing common oral diseases such as caries and periodontitis, oral candidiasis and viral mucosal infections (29, 30).

PATHOGENESIS OF SARS-CoV-2 IN ORAL MUCOSA

Oral viral infections are a common clinical complaint in dentistry, which is often associated with oral mucosal lesions. The herpes virus group (herpes simplex 1–8), human immune deficiency virus (HIV) and Zika virus are capable of infecting and replicating in the oral mucosa, leading to painful oral ulcers (22, 27). Viruses like paramyxovirus, HIV, cytomegalovirus and Epstein-Barr virus (EBV) have been found to replicate in salivary glands and negatively affect the normal functioning of the salivary glands (22). Several recent reports have described the oral manifestations of SARS-CoV-2 infection such as vesicular bullous lesions and ulceration (24, 25, 31).

The single cell RNA-seq (scRNA-Seq) studies of ACE2 expression have detected high levels of expression in keratinized epithelial cell surfaces of the oral cavity, such as the dorsum of the tongue and hard palate, rather than buccal or gingival tissues (32). In the human body, the ACE2 receptor is known to be important in regulating blood pressure homeostasis by regulating the renin–angiotensin–aldosterone system (RAAS), where it converts angiotensin I to angiotensin II; this cascades body functions to maintain blood pressure and sodium water retention (33). SARS-CoV-2 enters a host's body and invades host cells via the ACE2 membrane receptor; this binding leads to conformational changes and cleavage of the S protein from the virion, and releases the nucleocapsid into the cytoplasm (7, 34). The S protein is proteolytically cleaved by cellular cathepsin L and the transmembrane protease serine 2 (TMPRSS2) (33). Haga et al. found that SARS-CoV viruses can induce tissue necrosis factor (TNF)-α-converting enzyme (TACE)-dependent shedding of the ectodomain of ACE2, and that process was coupled with TNF-α production (35, 36). TNF-α is an inflammatory cytokine produced by macrophages/monocytes during acute inflammation and is responsible for a diverse range of signaling events within cells, leading to cell necrosis or apoptosis (37). These data suggest that cellular signals triggered by the interaction of SARS-CoV with ACE2 are positively involved in viral entry but lead to tissue damage. The presence of high ACE2 expression in the alveolar tissues, oropharyngeal mucosal cells, gastrointestinal tract, kidneys and endothelial cells, including oral tissues, indicated that those organs with high ACE2-expressing cells should be considered to be potential high risk sites for SARS-CoV-2 (21, 32).

ORAL MANIFESTATION OF COVID-19

The pathology of viral infections is often associated with either cellular destruction due to viral invasion or the consequence of host immune reaction to the viral antigen (23). In the oral mucosa, viral infections disrupt epithelial cells and trigger local inflammatory reactions which typically present with abrupt onset and the association of solitary or multiple blisters or ulcerations (23). Oral vesicles, blisters, macular popular rashes and ulcerations are the common clinical features of viral infections (23). In SARS-CoV-2, epithelial injury causes similar pathogenic features in the oral tissues, such as ulcers, erosions, bullae, vesicles, pustules, fissured or depapillated tongue, macule, papule, plaque, pigmentation, halitosis, whitish areas, haemorrhagic crust, necrosis, petechiae, swelling, erythema, Kawasaki-like angular cheilitis, atypical Sweet syndrome, and Melkerson-Rosenthal syndrome (19, 25, 38). The most common sites of involvement are the tongue (38%), labial mucosa (26%), and palate (22%) (19, 39). Oral lesions were almost equal in both genders (49% female and 51% male). Patients with an older age and higher severity of COVID-19 disease had more widespread and severe oral lesions (25).

The histological analysis of oral SARS-CoV-2 lesions is associated with defects in the vascular arrangement of the oral mucosa (40). Pathogenesis of oral mucosal lesion of COVID-19 are associated with the accumulation of lymphocytes and Langerhans cells in the vasculature of the subcutaneous junctions and virus induce keratinocyte destruction by the cytotoxic lymphocytes (41). Histological examination of biopsies of COVID-19 patients who also had skin manifestations confirmed the vascular ectasia with dilated capillaries, large blood filled spaces and perivascular lymphocytic infiltrate with eosinophilia (40).

A lack of oral hygiene, opportunistic infections, stress, immunosuppression, vasculitis, and hyper-inflammatory response secondary to COVID-19 were found to be the predisposing factors for the onset of oral lesions in COVID-19 patients (19, 39). Stress-induced oral ulceration can be increased among patients due to the unknown fear of the pandemic. It has been already reported that this pandemic has severely affected the mental health of the global community (42). Patients have reported changes in sensation in the tongue, plaque-like changes in the tongue and swelling in the palate, tongue and gums (25). Tongue lesions may be associated with the increasing activity of viral events on the epithelial mucosa of the tongue (39). On the other hand, immune suppression can lead to the harboring of opportunistic pathogens like *Candida albicans,* which can lead to the above observed tongue lesions (19). SARS- CoV-2 oral lesions healed between 3 and 28 days after they appeared. COVID-19-induced oro-mucosal lesions can be treated with mouthwashes, topical or systemic corticosteroids, systemic antibiotics and antivirals (39, 40). Increasing evidences are suggested that the antiseptic mouthwashes such as chlorhexidine, sodium hypochlorite and povidone-iodine found to be effective in reducing the SARS-CoV-2 viral load in the oral cavity and can be prescribed to patients with mucosal lesions as first line of therapy (43, 44). The topical or systemic corticosteroids, systemic antibacterial and antiviral needs to be prescribed according to the individual patient needs. Multidisciplinary team approach is important when prescribing or continuing systemic corticosteroids,

antibiotics or antivirals to COVID-19-induced oro-mucosal lesions (39).

COVID-19 INDUCED TASTE AND SMELL LOSS

Taste is a special sensation of the human oral mucosa which plays a vital role in the identification of nutrients and regulation of food intake. Humans are capable of detecting five basic tastes: sweet, sour, salt, bitter and umami. Tastes stimulate specialized cells known as taste receptor cells (TRCs), which contain taste signal transduction proteins. Sour and salty tastes modulate the function of TRCs by the direct activation of specialized membrane channels (45, 46). In contrast, sweet, bitter and umami taste transduction is mediated through the G protein-coupled receptor (GPCR) signaling pathway (47). TRCs are locally organized as taste buds (TBs) which are located in the dorsum of the tongue and extra oral taste buds can be found in the tonsils and oropharynx (**Figure 1A**). TBs are made of receptor cells, support cells and are innervated by branches of the VII (facial), IX (glossopharyngeal), and X (vagal) cranial nerves. Taste information is relayed to the brain and its recognition elicits behavioral responses to the food (48, 49). True loss of taste is extremely rare, and it is usually preceded by the inability to perceive the odor of food due to olfactory dysfunction or the deficiency of saliva to dissolve food molecules to get into the taste receptors (25, 50).

Smells or odorants reach the olfactory epithelium, which covers the cribiform plate and the upper part of the nasal septum and the middle/upper turbinates and dissolve in the mucus layer, binding/activating olfactory receptors (**Figure 1A**). Up to 30 million receptor neurons, which express up to 350 different olfactory receptors, can be found in the olfactory epithelium. A complex combinatorial coding, by which each odorant ligand may be recognized by an olfactory receptor combination, enables humans to detect billions of different odors. Olfactory information, which is processed and integrated in the olfactory bulb, is then projected onto the primary olfactory centers such as the limbic system (emotions) and the hypothalamus (memory), and is finally projected to the olfactory cortex, where humans acquire the consciousness of smelling (50, 51). Smell loss in respiratory infections are multifactorial and are caused by a combination of the mechanical obstruction of odorant transmission in the olfactory cleft due to mucosal type 2 inflammation (oedema or nasal polyps), leading to shedding, and/or degeneration of the olfactory epithelium and the reduction or loss of the sense of smell (51).

The SARS- CoV-2 infection associated sudden loss of taste and smell was reported in several countries in early March, with the rapid increase in COVID-19 patient numbers. Interestingly, a series of sporadic cases, predominantly in health care workers, reporting a sudden, severe, and sometimes isolated loss of smell and/or taste was reported in different countries (50, 52). Nasal congestion was found to be the driving factor for the loss of smell. It is possible that damage to the olfactory neuroepithelium can cause defects in smell detection. Loss of smell is common among females and loss of smell is associated with a loss of taste most of the time (51, 53).

Still, there are a lack of data on a specific loss of different tastants (flavors) (54). In a web-based questionnaire study ($n = 128$), 67 patients (52%) reported changes in taste sensation. Fifty-two patients reported a change in their spicy taste perception, 54 in salty taste, 53 in sour taste, and 61 in sweet taste. In a comparison between men and women, COVID-19 induce taste changes and changes in taste subgroups were found to be common among women, but this needs further investigations (55, 56). A possible reason for the loss of taste in COVID-19 might be due to the increasing number of ACE-2 receptors on the tongue keratinocytes and the keratinocyte cell death and slough production can block taste buds which can adversely affect taste perception (53, 57). However, the presence of ACE-2 receptor activity on taste receptor cells is unknown at present, hence the specific role of SARS-CoV-2 on specific taste bud cells (receptor cells and supportive cells) needs to be further investigated (57). It has been shown that GPCR can be found in a diverse range of body tissues, not only in the oral cavity but in the lung epithelial cells, blood brain barrier and blood vessels (58). It will be interesting to see the specific role of SARS-CoV-2 and GPCR interactions in terms of COVID-19 pathogenesis. On the other hand, COVID-19 induces salivary gland dysfunction, which leads to dry mouth, and can result in the malfunctioning of taste perception (59). Treatment with artificial saliva can improve the xerostomia-induced taste loss (60). Quantitative smell testing demonstrates that decreased smell function is a major marker of SARS-CoV-2 infection, and suggests the possibility that smell testing may help, in some cases, to identify COVID-19 patients in need of early treatment or quarantine (61). Song et al. found that a loss of taste was more frequent (21%) than a loss of smell (11%) in hospitalized patients, with the loss of taste but not smell being associated with severe COVID-19 (62). Most patients recovered their smell and taste dysfunctions within 2 weeks (50, 62).

Overall, there is no real evidence for any specific pharmacological option for the post-viral loss of smell including COVID-19. Some studies report an improvement in olfactory function following topical or systemic corticosteroid therapy (50, 63). Olfactory training is the only current evidence-based therapeutic option for post-viral olfactory loss, with COVID-19 positive patients reporting an improvement in smell (45.6%) and taste (46.1%) at the time of the survey; in 90.6%, this was within 2 weeks of infection (64). Over 90% of COVID-19 patients with a loss of smell may recover that sense within the first month, and olfactory training is strongly recommended if smell has not recovered after that period of time, but can be started earlier (65).

ROLE OF SALIVA IN COVID-19 PATHOGENICITY AND DISEASE DIAGNOSIS

Human saliva is a unique body fluid of the oral cavity. It is a hypotonic solution of salivary acini, gingival crevicular fluid and oral mucosal exudates (66). Approximately 90% of saliva is secreted from the salivary glands; the major glands include

TABLE 2 | Articles related to COVID-19 and dentistry.

Country	Study overview	Article type	References
Italy	Prevention of spread of SARS-CO-V-2	Review	(72)
Italy	Symptoms/signs, protective measures, awareness, and perception levels regarding COVID-19 among dentists in Lombardy, Italy	Questionnaire survey	(73)
China	COVID-19 and management protocols for dental practitioners and students	Review	(74)
Italy	Prevention of COVID-19 in Pediatric dentistry	Review	(75)
Brazil	Oral Manifestations in Patients with COVID-19	A living systematic review	(76)
Italy	Infection control in Dentistry	Review	(77)
Italy	Oral manifestations of COVID-19	A narrative review	(78)
Spain	Oral lesions of COVID-19	Cross sectional study	(79)
Multicenter study	Endodontic emergency management by endodontists and general dental practitioners in COVID-19 times	Online survey using questionnaire	(80)
USA	Epidemiology, symptoms, and routes of transmission of COVID-19	Review	(81)
India	Safety operative protocols	Commentary	(82)
France	Salivary and Nasal Detection of the SARS-CoV-2 Virus After Antiviral Mouth rinses	Randomized control trial	(83)
Brazil	Mouth wash reducing viral load of COVID-19	Systematic review	(84)
Nigeria	Impact on orthodontic patients	Online questionnaire cross-sectional descriptive study	(85)
India	Appropriate orthodontic appliances during the COVID-19 pandemic	Scoping review	(86)

the parotid glands, submandibular glands and sublingual glands (66). The salivary glands are highly vascular structures, where there is a constant exchange of substances. A normal person produces 600 mL of saliva per day. It is mainly composed of water (94–99%), with organic molecules accounting for ∼0.5% and inorganic molecules for 0.2% (66). It has the functions of lubricating the oral mucosa, digesting food, and cleaning and protecting the oral cavity, and is one of the most important factors affecting homeostasis of the oral cavity.

Viral infections are often associated with the infection induced inflammation of the salivary gland (22). Saliva based biomarkers are useful in diagnosis of several viral infections such as hepatitis A virus, hepatitis B virus, hepatitis C virus, HIV-1, measles virus, rubella virus, and mumps virus (66). Several routes of SARS-CoV-2 viral entry into the saliva have being suggested. There is direct entry to the oral cavity from upper and lower respiratory tract secretions, while circulatory viruses in the blood enter the gingival crevicular fluid. Studies reported a high yield of virus particles in the gingival sulcus and crevicular fluid and are suspected to provide favorable conditions for virus replication and maintenance (32). Moreover, SARS-CoV-2 salivary gland infections can produce large amounts of viruses in the salivary gland tissues and release them into the secretions (67). Studies performed on rhesus macaques found that there is a rapid infection in the salivary gland epithelial cells by SARS-CoV, suggesting salivary glands as very early proliferating sites for coronaviruses (68). Hence, increased ACE-2 expression in minor salivary glands compared to the lungs suggestive of salivary glands as an early target organ and saliva can be a vital source in the early diagnosis of disease before the respiratory symptoms appear (20, 31, 68).

In COVID-19, the impaired salivary gland secretions are often associated with xerostomia and taste loss (69). Xerostomia is the subjective complaint of oral dryness, while salivary gland hypofunction is an objective matter characterized by reduced salivary flow (70, 71). In SARS-CoV infections, xerostomia could be aggravated by impaired nasal breathing due to nasal congestion and rhinorrhea, where the oral breathing increase and it can impaired salivary gland function and xerostomia is secondary (25). Similar to COVID-19-induced oral mucosal lesions, pandemic-induced psychosocial factors have a greater impact on normal salivary gland function and quantitative secretions (25, 59).

The saliva-based COVID-19 diagnosis is getting increased attention for several important reasons. First, saliva specimens can be easily obtained, by asking patents to spit into a container, which is not an invasive procedure and minimizes the chance of exposing health care workers to the highly infectious SARS-CoV-2 virus; it is also ideal for testing the elderly vulnerable population, pediatric patients and community settings, where large sample collection is needed (**Table 2**) (87). There is a 92% positive rate of SARS-CoV-2 in saliva compared to nasopharyngeal aspirate and live virus can be successfully cultivated through saliva samples, highlighting the value of saliva in the diagnosis of COVID-19 (88). As discussed previously, the early detection of SARS-CoV-2 in the saliva can be vital in diagnosing COVID-19 patients before respiratory symptoms appear, which greatly aids in controlling public health measures such as the quarantine process (20, 88, 89).

FUTURE PERSPECTIVES WITH REGARD TO THE ORAL HEALTH PROFESSION

On March 11th 2020, the World Health Organization (WHO) declared COVID-19 to be a global pandemic. As of the 20th

January 2021, 96,866,468 cases had been reported globally, with 20,72,466 deaths. The first cases of COVID-19 were seen in Canada on February 10th 2020, and there have since been 723,908 cases and 18,421 deaths (90). The current public health regulations to prevent the spread of this virus have been based on the modes of transmission. Following the strict global (WHO) and Canadian public health guidelines was found to be effective in preventing the spread of COVID-19 (91, 92). Several excellent research and review articles have already been published on the impact of COVID-19 on clinical dentistry and the relevance of the oral cavity in SARS-CoV-2 infection (**Table 2**) (24, 72, 93). The dental regulatory authorities quickly adapted new rules and regulations with regard to patient care and prevention of the spread of SARS-CoV-2 (72, 93). Among the health care professions, dental professionals have a high risk of making contact with diseased individuals and spreading the disease in nosocomial settings.

The American Dental Association has developed guidelines to the patient care during COVID-19 pandemic (94). The dental treatments are divided into the urgent/emergency care and routine/elective procedures. The dental emergencies which needs immediate medical attention includes life threatening conditions uncontrolled bleeding, swelling and fractures which compromise patient's airway. Urgent dental care should focus on minimizing pain, reduce or control infection, and reduce the burden on emergency departments (94). Other than that suture removal, denture adjustment, replacing fillings to alleviate pain and snipping or adjusting orthodontic appliances to prevent trauma also considered as urgent dental care. The non-urgent routine procedures include initial dental visits, routine dental cleaning and preventive therapies, aesthetic dental procedures, and extraction of asymptomatic teeth and orthodontic procedures (94). The ultimate goal is to avoid unnecessary contacts and minimize the contact to prevent the further spread of the virus in the dental care settings. The COVID-19 pandemic opens up a variety of innovative technologies for meetings such as teleconferencing, video calls, and patient photographs. Brian & Weintraub discuss use of communication media such as Teledentistry to educate and consult patients during the pandemic period, where it would greatly facilitate the prevention of unnecessary dental visits for conditions which can be temporarily alleviated at home or postponed for a later date (93). The patients with underlying health conditions such as diabetes, cancer, cardiovascular diseases (CVD) and hypertension are more susceptible to developing COVID-19 thus needs special attention. For instance, diabetes is a metabolic disorder which adversely affect the periodontal health. The periodontal disease (PD) is a chronic inflammatory disease which induce increased cytokine production and the disease severity found to be increased with COVID-19 infection (95). It is important to identify patients with underlying comorbidities and advise them on maintaining good oral hygiene to prevent the further progression of existing PD (**Table 2**).

Dental health care personals should be trained to be familiar with COVID-19 related signs and symptoms. The triage screening is a successful method to identify and separate out patients into three categories: (1) Triage negative (asymptomatic and negative in screening questionnaire and no fever) (2) Triage positive (positive screening questionnaire and /or fever) (3) confirmed COVID-19 cases. However, it is extremely important to take all the necessary precautions when treating the first category (82). The ability to undertake robust patient screening would facilitate the avoidance of COVID-19 transmission in dental clinics. A non-invasive rapid screening test would be of great help to identify positive cases that warrant immediate quarantine or transfer to special clinic for further treatment (88, 93). Current research are focusing on developing biomarkers for early detection, treatment and prevention of COVID-19. In the oral health care settings saliva and mucosal epithelial cells are good candidates to develop the biomarkers to identify the asymptomatic carriers (**Table 2**).

Given the higher viral loads in the oral cavity, it is essential to use personal protective equipment (PPE). Protective goggles or face shields, masks, gloves, and caps should be regularly worn, discarded or properly disinfected between each patient. Salivary aerosols and blood need to be protected against to reduce the risk of infection with COVID-19 (96). The use of rubber dams can significantly minimize the production of saliva-contaminated splatters, droplets and aerosols, particularly when high-speed dental hand pieces and ultrasonic devices are used. The application of a rubber dam can significantly reduce airborne particles in an ∼3 foot diameter of the operational field by 70% (97). High-speed dental hand pieces without anti-retraction valves may aspirate and expel debris and fluids during dental procedures; also, the hand instruments used during general dental procedures produce a significant amount of aerosol spread (72). Good ventilation, regular and thorough surface disinfection before and after procedures with alcohol or chlorine and the proper handling of saliva-containing waste are critical in preventing the spread of COVID-19 (96). Recent studies shows that mouth rinses can reduce the SARS-CoV-2 virus load (98). Marui et al. showed that pre-procedural mouth rinses can significantly reduce microbial load in dental aerosols (99). Also, the use of pre-procedural mouth rinses before dental treatment can be advantageous during the pandemic (100).

We are too early to predict the post-pandemic effects of COVID-19. However, COVID-19 has a wide range of impacts on mental health, which can have a negative effect on the oral health of any given community; in particular, a greater impact can be seen in vulnerable populations such as people with low socioeconomic status who lack access to proper health care. On the other hand, this is a challenging time for dental health professionals and it could affect their psychological status, which can adversely affect their overall productivity. For instance, adopting new techniques to minimize the spread of disease, and reduced wages as this is associated with a decline in per capita dental visits (93). The timely vaccination of health care professionals and the vulnerable population is now a strategic priority for the prevention of COVID-19 in many countries. Dai and Gao in their progressive article discussed about the different vaccine candidates against SARS-CoV-2 (i.e., Inactivated virus vaccines, virus like particle or nanoparticle viruses, protein subunit vaccines, virus-vectored vaccines, DNA and mRNA vaccines and live attenuated vaccines) and compare

their effectiveness against COVID-19 (101). The world largest vaccination campaign begins with the BioNTech/Pfizer, and Moderna/NIAID vaccines and Oxford-AstraZenca's is now authorized and added to this mass prevention battle against COVID-19. However, the immunization programs needs further investigations for their effectiveness against the novel variants of SARS-CoV-2 (101, 102). Further studies need to be performed to identify the pathogenicity of SARS-CoV-2 on specific epithelial organs of the oral cavity and its effect on oral health. Salivary research can be directed toward designing rapid identification test kits as a chair-side test prior to any dental procedures in order to diagnose SARS-CoV-2 carriers. The use of corticosteroids, antivirals and antibiotics to treat the oral mucosal lesions of COVID-19 needs to be studied further using large samples in different demographic settings. The ongoing COVID-19 pandemic is an eye-opener to all of mankind to be vigilant and prepared to fight future pandemics. Specifically, scientific knowledge gained from this pandemic can be useful in designing public healthcare protocols to prevent future pandemics and vaccines, and therapeutic treatment research will be invaluable in patient management in any virulent coronavirus infections.

AUTHOR CONTRIBUTIONS

DSA and RKR contributed to the conception and critically revised the manuscript. Both authors contributed to the article and approved the submitted version.

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The Impact of Coronavirus Disease 2019 on the Disease Pattern of Oral and Maxillofacial Surgery Inpatients: A Comparative Study

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Objective: Oral and maxillofacial surgery (OMFS) is a high-risk specialty involving airway and aerosol-generating procedures, which is potentially of more risk in the era of coronavirus disease 2019 (COVID-19). We aimed to identify the impact of COVID-19 on the disease pattern of OMFS inpatients and surgeries under general anesthesia in a comparative study.

Materials and Methods: We reviewed the admission and operating theater records of OMFS patients from Jan 1 to Aug 31 in 2020 and 2019. The total number of cases, presenting disease patterns, and proportion of essential and non-essential medical services were compared between 2020 and 2019.

Results: There were 664 admissions and 356 general anesthesia surgical procedures included in this study. Both admission and surgery numbers were significantly reduced in 2020, compared with 2019 ($p = 0.012$ and 0.007, respectively). The proportion of malignancy cases increased significantly, whereas that of cleft lip and palate and temporomandibular disorder (TMD) decreased. There was a significant increase in the proportion of essential services compared with non-essential services in 2020 compared with 2019.

Conclusion: Our results first reported the epidemiological data of the impact of COVID-19 on OMFS disease pattern in a comparative study. The change of disease pattern and caseload will have a long-term impact on OMFS patient care, education, and training during the pandemic. Our paper provides evidence for health policy makers to consider the relocation of medical resources and optimization of medical education and services.

Keywords: COVID-19, coronavirus, oral and maxillofacial surgery, oral cancer, essential services, healthcare, pandemic, disease pattern

INTRODUCTION

The pandemic outbreak of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), which is also known as coronavirus disease 2019 (COVID-19), has been posing major impacts on health care (1). Since the declaration of the World Health Organization (WHO) of COVID-19 outbreak as an international public health emergency, different health-care policies have been adopted by countries worldwide. In general, there is a reduction in the number of elective procedures due to the risk of COVID infection and limited medical resources (2).

During the pandemic, prioritizing medical services is crucial to avoid collapse of medical systems. The health-care system failures during the outbreak of Ebola virus in 2014–2015 contributed to the increased number of deaths caused by measles, malaria, HIV/AIDS, and tuberculosis (3). Therefore, maintaining the essential medical services during an outbreak is of premier importance to avoid increased morbidity and mortality contributed indirectly by the insufficiency or inappropriate distribution of medical resources. According to the guidance by the WHO, priorities of elective surgeries change over time and vary from country to country. The main factors to consider while scheduling the elective treatments including the level of outbreak, availability of the health-care service in the area, and estimated length of the shortage of services (4).

Despite the high population mobility and density in Hong Kong, the citizens, government, and medical professionals have been striving for a reasonable control of the pandemic. From January 1, 2020, to September 19, 2020, there were a total of 5,010 cases of COVID-19 documented by the Department of Health of Hong Kong. Most of the cases were discharged after full recovery (4,708/5,010), while 103 (2.1%) were fatal. The number of patients hospitalized or pending admission was kept below 1,000 most of the time (**Figure 1**), which was within the isolation ward capacity in Hong Kong (5).

Oral and maxillofacial surgery (OMFS) is considered as one of the high-risk specialties due to the involvement of airway and aerosol-generating procedures. However, the impact of COVID-19 on the disease pattern of inpatients and operations in OMFS has yet to be studied. Globally, OMFS services were severely affected during the pandemic, while we have been keeping a certain level of OMFS services including elective cases in Hong Kong. This provides an ideal model to study the service pattern changes of OMFS during the COVID-19 era. Although WHO suggested health conditions and acute presentations that require time-sensitive intervention to be considered as essential medical services, the context-relevant definition in OMFS field is still lacking (4). The aim of this study is to investigate the impact of COVID-19 on the disease pattern in OMFS inpatients and surgeries under general anesthesia and to identify the context-relevant essential services in OMFS field for future reference when it comes to policy making and resource distribution.

MATERIALS AND METHODS

The study was approved by the Institutional Review Board of the University of Hong Kong (IRB Reference Number: UW 20-684), with the patient informed consent waived. We performed a comparative study in the Department of Oral and Maxillofacial Surgery, University of Hong Kong, Queen Mary Hospital, a tertiary hospital in Hong Kong. The study consisted of two parts. The first part focused on the distribution of inpatients admitted to the OMFS ward, Queen Mary Hospital; while the second part analyzed the cases operated in the operating theater (OT) under general anesthesia by the OMFS team. Records from January 1 to August 31 in 2019 and 2020 were reviewed and divided into eight groups below, with dental extraction cases excluded.

1. Dentofacial deformities
2. Benign pathologies
3. Malignancy
4. Dentoalveolar diseases
5. Infections
6. Cleft lip and palate
7. Temporomandibular joint diseases
8. Others (sleep endoscopy, trauma, nerve repair, etc.).

The total number of cases and proportions of different categories of cases were documented and compared so as to illustrate the difference in disease pattern between 2019 and 2020. Cases of malignancy, infection, and trauma were considered as in need of time-sensitive management, thus proposed as "essential medical services" according to the WHO guideline (4).

Polymerase chain reaction screening test for SARS-CoV-2 infection was conducted within 24 h before the operation or admission. Patients would be operated only if they had no travel history within 14 days, had not been in close contact with confirmed cases, were showing no symptom suggesting possible COVID-19 infection, and had negative PCR results. Patients in close contact with confirmed cases were observed for at least 14 days before presenting to the hospital unless they require a life-saving emergency surgery.

All statistical analyses were performed using IBM SPSS Statistics Version 26. Binomial test was performed to compare the difference in total number of cases, while chi square test was used to compare the proportions of essential medical services as well as different groups of cases. Bonferroni adjustment was applied for multiple group comparisons. All tests and reported p-values were two-sided. A $p < 0.05$ was considered statistically significant.

RESULTS

Comparison of Disease Distribution of Inpatients

A total of 664 patients were admitted in the designated periods. Significantly fewer patients were admitted to the hospital in 2020 compared with 2019 ($p = 0.012$) (**Figure 2**). None of the patients tested positive for COVID-19 upon admission or developed COVID-19 infection during their inpatient stay. No health-care professional in our team developed symptoms or tested positive for COVID-19 during the studied period.

The numbers and percentages of different groups of admissions are shown in **Table 1** and **Figure 3**. A significantly larger proportion of patients with malignancies were admitted in 2020 compared with 2019. In contrast, significantly fewer patients were admitted for dentoalveolar diseases,

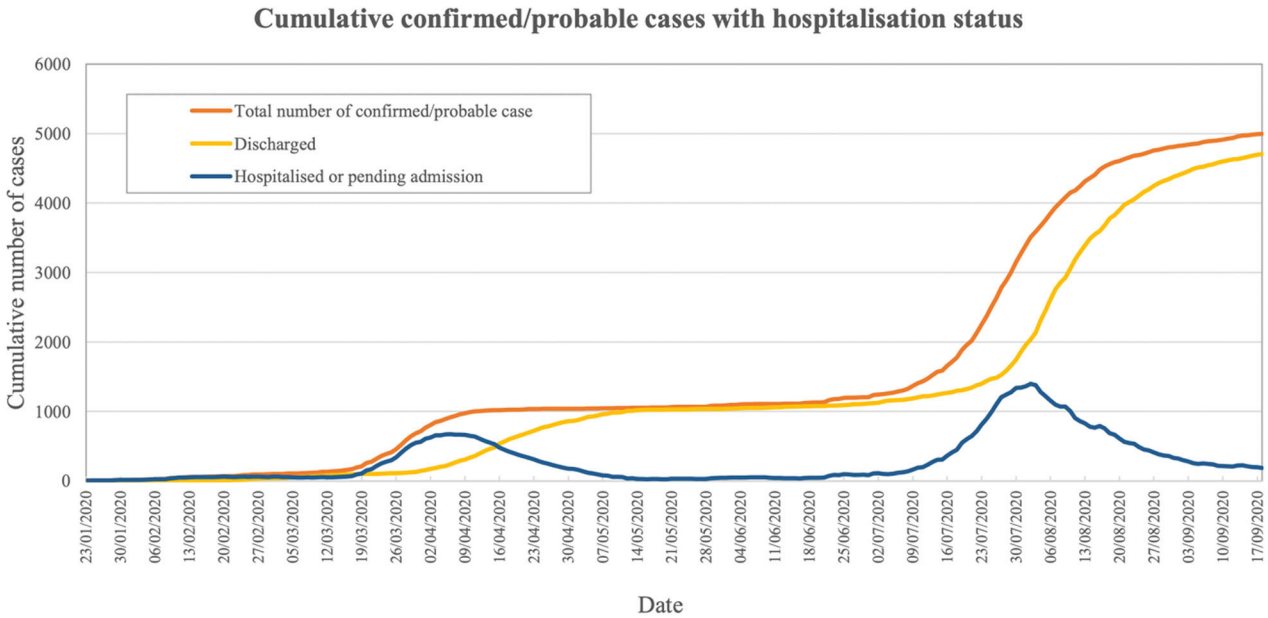

FIGURE 1 | Cumulative confirmed/probable cases with hospitalization status (5).

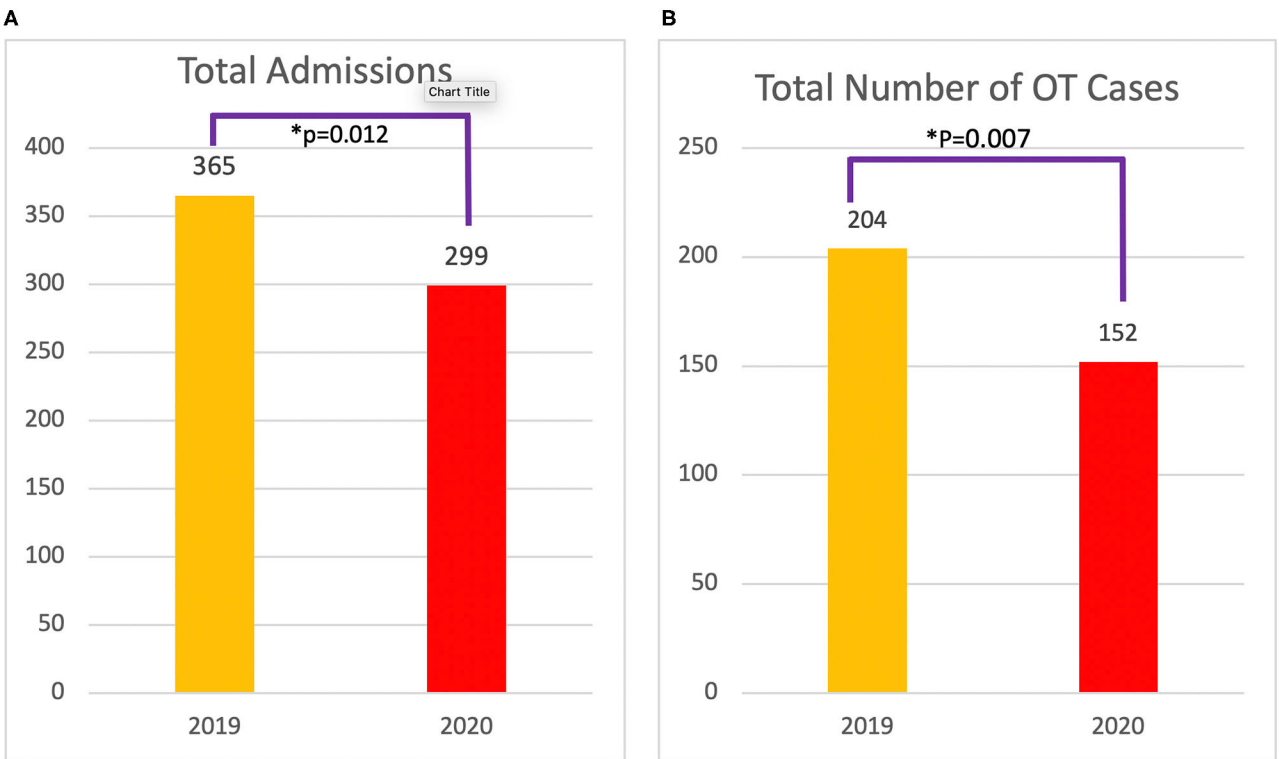

FIGURE 2 | Total number of admissions **(A)** and operating theater (OT) operations **(B)** from Jan 1 to Aug 31 in 2019 and 2020.

cleft lip and palate, and temporomandibular joint diseases. The admissions for the category of "others" also showed significant difference probably due to the decreased number of admissions for obstructive sleep apnea patients in 2020. The proportion of patients admitted for dentofacial deformity, benign pathology, and infections were similar

TABLE 1 | Number of admissions and OT cases in from Jan 1 to Aug 31 in 2019 and 2020.

	Admissions					OT				
	2019		2020		*p*-value	2019		2020		*p*-value
Dentofacial deformities	78	21.4%	58	19.4%	<0.001	63	30.9%	40	26.3%	0.001
Benign pathology	114	31.2%	91	30.4%		70	34.3%	52	34.2%	
Malignancy	39	10.7%	80	26.8%		16	7.8%	29	19.1%	
Dentoalveolar diseases	46	12.6%	21	7.0%		19	9.3%	11	7.2%	
Infections	33	9.0%	34	11.4%		8	3.9%	14	9.2%	
Cleft	13	3.6%	3	1.0%		8	3.9%	0	0.0%	
TMJ diseases	19	5.2%	4	1.3%		11	5.4%	1	0.7%	
Others (OSA, trauma, etc.)	23	6.3%	8	2.7%		9	4.4%	5	3.3%	
Total	365	100.0%	299	100.0%	0.012	204	100.0%	152	100.0%	0.007

NS, not significant; OT, operating theater; TMJ, temporomandibular joint; OSA, obstructive sleep apnea.

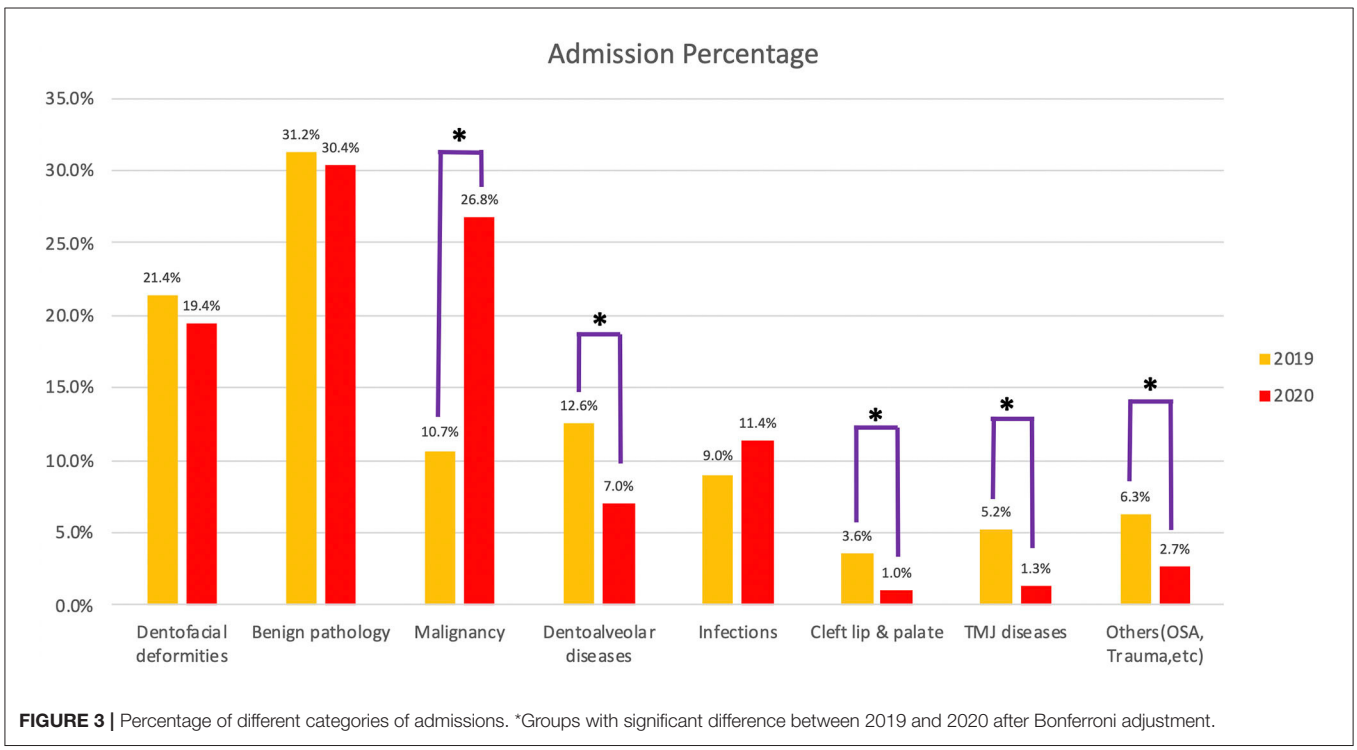

FIGURE 3 | Percentage of different categories of admissions. *Groups with significant difference between 2019 and 2020 after Bonferroni adjustment.

in 2019 and 2020. Percentage distributions of different groups of admissions in 2019 and 2020 are shown in **Figure 4**.

Comparison of Surgery Under General Anesthesia

A total of 356 patients were operated in the theater under general anesthesia. Compared with that in 2019, there was a decrease in total number of cases ($p = 0.007$) (**Figure 2**). None of the patients operated tested positive for COVID-19.

The number of percentage of cases in different categories is shown in **Table 1** and **Figure 5**. Significant increases in the percentage of malignancy and infection cases were observed in 2020. Priorities were given to the malignant cases with no limitation imposed. Different than most other hospitals during pandemic, we performed microvascular free flap reconstruction for oral malignancy cases as usual. No cleft lip or palate repair surgery was performed in 2020. The difference was significant between 2019 and 2020. Significantly less operations for temporomandibular joint dysfunction were performed in 2020. The proportions of surgeries for dentofacial deformity,

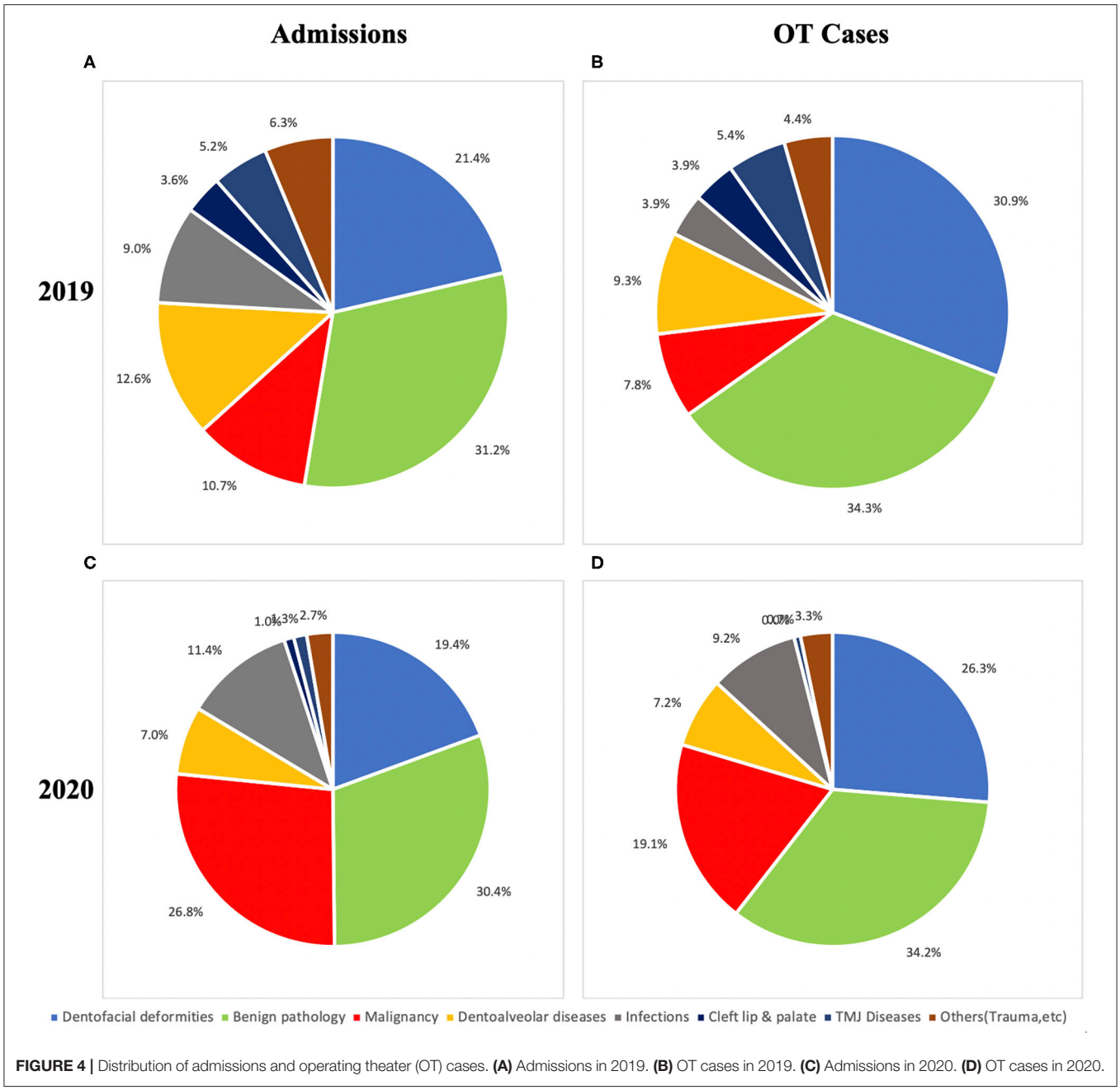

FIGURE 4 | Distribution of admissions and operating theater (OT) cases. **(A)** Admissions in 2019. **(B)** OT cases in 2019. **(C)** Admissions in 2020. **(D)** OT cases in 2020.

benign pathology, dentoalveolar diseases, and others (trauma, nerve repair, etc.) were kept at a similar level. The distribution of cases in 2019 and 2020 is shown in **Figure 4**.

Essential Medical Services

When malignancy, infection, and trauma were considered as time-sensitive essential medical services, the proportion of essential services increased significantly in both inpatient admissions and surgeries, with the $p < 0.001$. The decrease in the proportion of non-essential cases was also significant in both groups (**Figure 6**).

DISCUSSION

Since the outbreak of COVID-19, there have been numerous guidelines on the management of patients during the pandemic (6–8). However, to the best of our knowledge, the current study is the first comparative study to objectively report the significant decrease in total number of patients, the increase in malignancy cases, and essential medical services in OMFS under the influence of COVID-19 pandemic.

Compared with that pre-COVID-19, the total number of cases operated in the OT decreased mainly due to the limited supply of personal protection equipment and the reduction in OT sessions

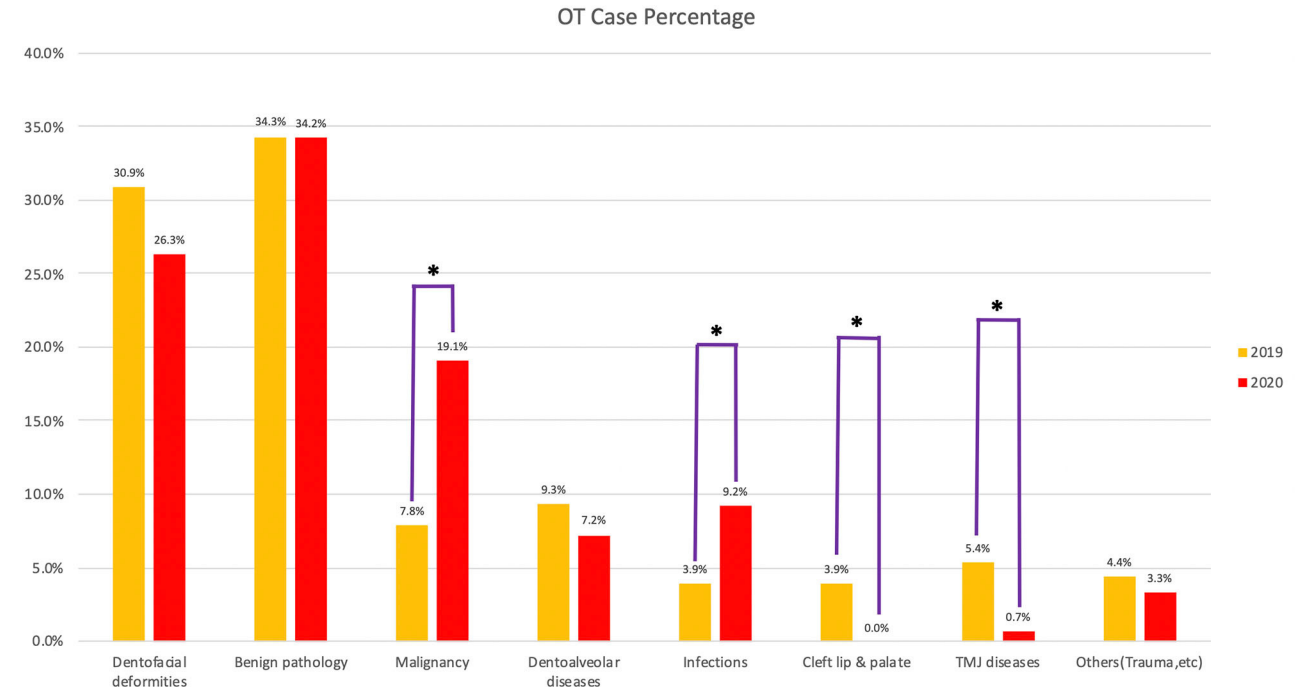

FIGURE 5 | Percentage of different categories of operating theater (OT) cases. *Groups with significant difference between 2019 and 2020 after Bonferroni adjustment.

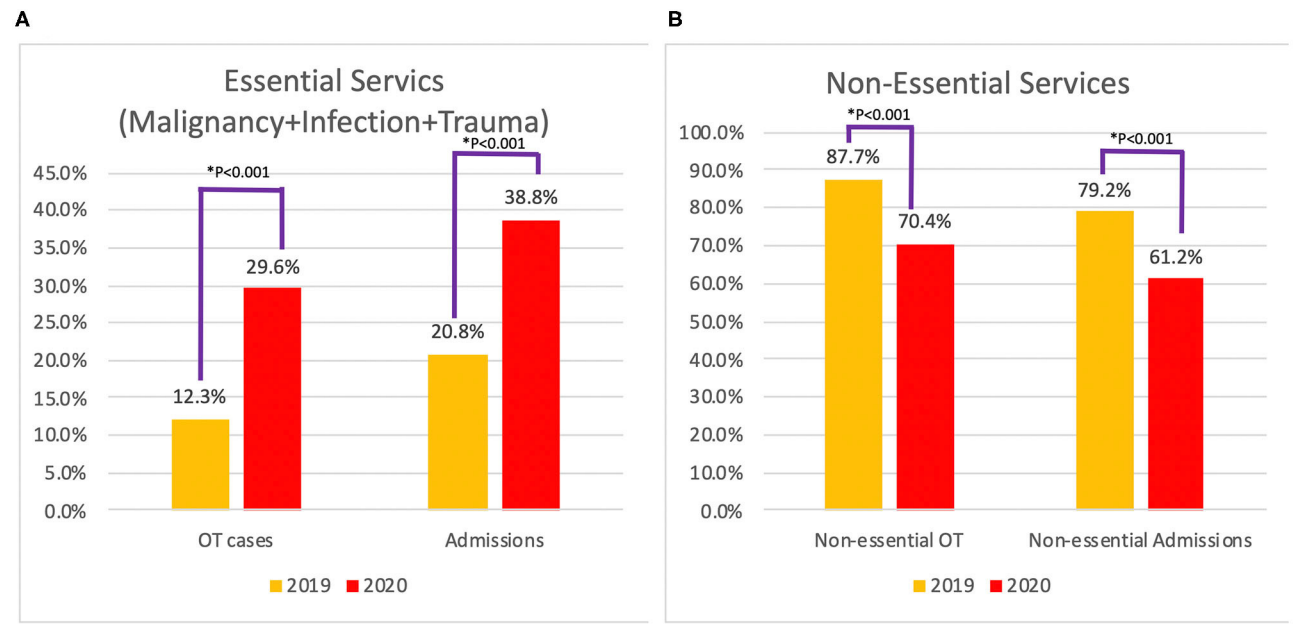

FIGURE 6 | Proportion of essential medical services **(A)** and non-essential services **(B)**.

assigned to OMFS. The reduction in the number of admissions could be attributed to reduction in operations as well as decrease of elective inpatient and outpatient services during the outbreak of COVID-19.

The proportion of essential medical services, especially the percentage of malignancy cases, increased significantly under the influence of COVID-19. Although there were no supportive scientific data available so far, various subjective

recommendations have been proposed to determine the priority of surgical treatments. From the country with the earliest outbreak, Yang et al. from China defined four categories of OMFS patients according to severity. The critically ill patients include those who require emergency interventions due to life-threatening conditions such as hemorrhage and obstruction of the upper respiratory tract following trauma, tumors, and infections. Subacute patients include those with stable vital signs but requiring urgent interventions such as closed fractures. This is followed by the patients who require expedited interventions including patients diagnosed with malignant tumors, chronic infections, osteomyelitis, etc., while the last group of patients are those who require elective procedures such as those with cleft lip and palate, dentofacial deformities, and benign tumors (9). The malignancy, infection, and trauma cases we included in the "essential medical service" belong to the first three categories in this classification, while the "non-essential medical services" in our study agreed with the last category of elective procedures. Others suggested balancing the risk of delaying the surgery with the resources required for the treatment when determining the priority of surgeries (10, 11). In most situations, priority was given to the essential services when resources were limited. However, when the current pandemic is expected to persist for a relatively long period of time, the changed disease pattern in OMFS might become the new norm. This will have long-term effects in patient care as well as education and training of surgeons. Our data provide reference for policy making and resource distribution in the future.

The precautions we adopted for managing patients in COVID-19 era were similar as the joint recommendations by OMFS in Spain (12). PCR screening test for SARS-CoV-2 infection was conducted within 24 h before the operation or admission. Patients would be operated on only if they had no travel history within 14 days, had not been in close contact with confirmed cases, were showing no symptoms suggesting possible COVID-19 infection, and had negative PCR results. Patients in close contact with confirmed cases were observed for at least 14 days before presenting to the hospital unless they require a life-saving emergency surgery. All cases documented in the current study showed negative results for COVID-19 tests. The operations were performed in the designated COVID-19-negative theater for the OMFS Department in Queen Mary Hospital. WHO guidelines were followed in terms of level of personal protective equipment (PPE) in ward and OT (13, 14). Regardless of the negative results, oral and maxillofacial surgeons were required to wear surgical masks at all time. Aerosol-generating procedures in ward such as changing or removing of tracheostomy tubes and irrigation of intra-oral wound were performed with whole body protection including surgical mask with facial shield, gown, gloves, surgical cap, and eye protection. The same recommendation of protection was applied in the OT. During the period studied, all of our patients and health-care professionals were kept safe from COVID-19 infection, which proved the effectiveness of the precautions we adopted.

In Hong Kong, although the proportion of non-essential services significantly decreased in 2020, we were able to maintain a certain level of service on orthognathic surgery, benign pathology, and dentoalveolar surgeries during the pandemic. This contrasts with the report by Barca et al. about the practice in Italy where all cases treated from Feb 29 to April 16, 2020, were due to either malignancy or trauma (15). A similar situation was observed in the UK where all non-urgent elective surgeries were suspended for 3 months starting April 15, 2020 (16). In the worldwide survey of OMFS surgeons conducted by Maffia et al., only 5.8% of surgeons were still performing orthognathic surgeries (17). This could be attributed to the different levels of pandemic in different parts of the world. In the future, when the pandemic is reasonably controlled, non-essential medical services need to be gradually resumed. The accumulated load of elective procedures might pose a challenge in the recovery and post-recovery periods. Our experience proved that with proper precautions, it is safe and pragmatic to keep a certain level of elective medical services during pandemic. This could also serve as a reference on how to resume OMFS service in a controlled manner when the outbreak is winding down.

As a single-center study, there are intrinsic limitations. The number of trauma cases in our center and the whole Hong Kong is limited, which made the statistical analysis for traumatology as an independent category difficult. There was no COVID-19-positive patient in our cohort. If a multicenter study could be conducted in the future, more comprehensive and widely applicable experience in OMFS patient management in COVID-19 era will be more valuable. Our study only investigated hospital admissions and operations. When the outbreak period is prolonged, data on outpatient management will be needed to guide the outpatient services, which could be time-dependent and lifesaving.

Compared with that pre-COVID-19, the number of admissions and surgeries decreased in the COVID-19 era. There was a significant difference in the disease pattern of OMFS with an increase in the proportion of malignancy cases and essential services. Our results also support that with proper precautions, non-essential medical services can be maintained during the pandemic. Our study has implication for policy and practice for OMFS with impact on patient care, education, and training.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of the University of Hong Kong (IRB Reference Number: UW 20-684), with the patient informed consent waived. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JJP: conceptualization, methodology, data curation, formal analysis, writing—original draft, and writing—review and editing. CPM: conceptualization, formal analysis, project administration, validation, and writing—review and editing. YYL, WSC, and WFY: project administration, supervision, validation, and writing—review and editing. YXS: conceptualization, formal analysis, funding acquisition, supervision, validation, and writing—review and editing. KYL: statistical analysis and validation. All authors approved the final manuscript for publication.

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Optimizing Safe Dental Practice During the COVID-19 Pandemic: Recommendations Based on a Guide Developed for Dental Practices in China

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The current global coronavirus disease 2019 (COVID-19) outbreak is still exerting severe global implications, and its development in various regions is complex and variable. The high risk of cross-infection poses a great challenge to the dental practice environment; it is therefore urgent to develop a set of pandemic prevention measures to ensure dental practice safety during the COVID-19 outbreak. Therefore, we combined the epidemiological characteristics of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), public emergency measures for COVID-19, characteristics of dental practice, and relevant literature reports to develop a set of dynamic practice measures for dental practices in high-, medium-, and low-risk areas affected by COVID-19. This will help dental practices to achieve standard prevention and ensure their safe and smooth operation during the pandemic. It is hoped that these measures will provide a reference basis for dental hospitals and dental clinics in their care and pandemic prevention work.

Keywords: COVID-19, SARS-CoV-2, infection control, dental clinics, public health, prevention, disinfection

INTRODUCTION

From the beginning of 2019 to March 25, 2021, the cumulative number of confirmed cases of coronavirus disease 2019 (COVID-19) in the world is more than 125,700,000 and causing more than 2,756,000 deaths, which shows that COVID-19 is still spreading around the world. COVID-19 vaccines have been developed currently. However, due to the emergence of a variety of mutated strains of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1), coupled with the uncertainty of vaccine efficacy, the pandemic is still severe and undoubtedly poses a huge threat and harm to the health of people worldwide. It also presents a great challenge to dental practices, which are characterized by a great demand for consultation and emergency treatment, as well as an environment that has a high level of spattering (2). This is greatly increasing the risk of cross-infection in the dental clinical practice process. Thus, how can dental staff establish effective protection to ensure safe and smooth dental practice implementation?

Studies have shown that the main routes of transmission of SARS-CoV-2 are respiratory droplets and contact transmission, with an additional possibility of air and aerosol transmission (prolonged,

closed, high concentrations). Furthermore, SARS-CoV-2 can be isolated from stool, urine, and conjunctival secretions. Thus, attention should also be paid to contact or aerosol transmission caused by its contamination of the environment (3–6). It is well-known that instruments and operations commonly used in dentistry are prone to generate large amounts of droplets and aerosols, and dental care personnel are therefore at risk of inhaling large amounts of aerosols. SARS-CoV-2 can persist in aerosols for up to 3 h (7). Due to the direct contact operation on the dental cavity, the dental mucosa is considered a potential high-risk route for SARS-CoV-2 infection (8). Moreover, the complex structure of the turbine handpiece, saliva ejector, and dental chair drainage pipe that are not easily cleaned and disinfected and the use of sharp instruments during practice makes dental care personnel prone to occupational exposure (9). This may cause an increase in cross-infection among dentists, nurses, and patients and could become a difficult point for prevention and control during the COVID-19 pandemic. To truly and comprehensively identify studies on the prevention and control of the pandemic in dental practice, the authors used keywords such as "COVID-19," "SARS-CoV-2," "COVID-19 dental," "dental," and "infection control" on the PubMed and China National Knowledge Infrastructure (CNKI) websites. It was hoped that the literature would provide insights into the measures and experiences of dental practices in other countries during the COVID-19 pandemic (10–16). Among them, Italy, Latin America, and Poland recommend that patients should undergo pretesting and triage, as well as reinforce personal protective equipment (PPE) usage and hand hygiene. A mouthwash that is effective against COVID-19, disinfection and sterilization, rubber dams in dental practice should also be used. Singapore suggested a "Proposed color-coded framework for dental practice during the COVID-19 pandemic" (17). However, the measures described in these articles are still not detailed or specific enough and lack dynamic guidelines for pandemic prevention.

Therefore, there is an urgent need to develop scientific and comprehensive dynamic guidelines applicable to the dental clinic and dental hospital practice. This should be based on the characteristics and policies related to the COVID-19 pandemic in different periods and regions. It would help control infection sources in time, cut off the transmission pathways, protect the safety of the three parties involved (namely, doctors, nurses, and patients), and ensure the safe and smooth operationalization of dental practice work. Therefore, based on the development of the COVID-19 pandemic and the dental clinical practice, we summarized the practice measures implemented by Chinese dental clinics during the COVID-19 pandemic. The effectiveness of these dynamic measures has been confirmed because no dentists have been infected with COVID-19, except for a few dentists in Wuhan, who were reported to be infected with COVID-19 at the beginning of the outbreak, so we hope that these measures can guide domestic and foreign dental hospitals and dental clinics for smooth and safe practice during the COVID-19 pandemic. The specific practice measures are as follows.

BE GUIDED BY THE COVID-19 PREVENTION POLICIES AND MEASURES ISSUED BY NATIONAL AND REGIONAL HEALTH AUTHORITIES

China issued eight editions of the Diagnosis and Treatment Protocol for COVID-19 from January 15, 2020, to August 19, 2020 (18). These were issued in conjunction with daily updates for areas at high, medium, and low risk of an outbreak, making important dynamic guidelines for people to recognize and implement effective measures against the COVID-19 outbreak. As of March 1, 2021, 48 online learning sessions on infection control during hospital outbreaks have been held (19). Meanwhile, Guangdong Province issued daily dynamic guidelines for hospital outbreak prevention and control according to the pandemic changes. All regional dental hospitals and dental clinics have adjusted their systems and measures for conducting the dental practice promptly according to the policies and measures issued by the state and local provinces and municipalities.

INTRODUCTION OF "HEALTH CODES" AND COMMUNICATION BIG DATA TRIP CARDS FOR RAPID IDENTIFICATION OF PATIENT RISK LEVELS

The "health code" is filled in by the individual using information such as the identity card number, location information, health status, exposure history, and travel and residence history. The platform reviews the information and grants the applicant a QR code in red, yellow, or green. Holders of red and yellow codes are subject to a 14- and 7-day intensive or home quarantine, respectively, while holders of green codes are allowed normal passage. This system dynamically assesses and regrants codes according to the risk level of the pandemic.

The Communication Big Data Trip Card is a software developed by the China Academy of Information and Communication Technology, in conjunction with three basic telecommunication companies, allowing mobile phone users to check information on all the cities and regions they visited in the past 14 days (20, 21).

These two "electronic bodies" can help dental institutions quickly identify the risk level of patients, reduce triage time, achieve the purpose of less exposure for people, and more proper government supervision, making a significant contribution to China in the control of pandemics (22).

However, there will be no digital identity for those who buy smartphones unconditionally or have behavioral and cognitive limitations. The operation of the health code considers the plight of ""people without codes" in advance, and coresidents can help people without codes apply for health codes. These can be saved or even printed and have a validity period of 14 days (23). Nonetheless, it is still difficult to implement these digital technologies in countries where smartphones and the Internet are not widely available.

Because of the large amount of personal data collected to apply for electronic identity, there is the possibility of privacy breaches, as some privacy advocates still refuse to apply for electronic identity. For now, without electronic identity, their daily travel will be impacted. In this regard, several recent studies have discussed the future of electronic identity after the pandemic (24–26). A number of issues have been highlighted, such as whether to upgrade, improve, or delete the electronic identity after the pandemic, whether the private information can be completely deleted, and whether it could be used by criminals. These are issues that China needs to resolve in the near future. The author believes that to prevent unauthorized access to such data that could be used for criminal activity, it is necessary to develop new privacy software and establish more ideal confidentiality systems and laws.

DENTAL INSTITUTIONS SHOULD IMPROVE ALL PANDEMIC PREVENTION WORK AND POLICIES BEFORE STARTING A DENTAL PRACTICE

Establish a COVID-19 Pandemic Prevention and Control Team to Strengthen Supervision and Guidance Work and Strive to Promote and Improve the Level of Nosocomial Infection Control

Through networking, train whole staff in all protocols, including the receiving process and in the use of protective equipment. All personnel must be trained and qualified before taking up their duties, and it is particularly important to strengthen training on infection control for the dental support staff; even if they are not involved in direct patient care, they are often in contact with the patients' environment, leading to the possibility of contact transmission at any time (27, 28).

Implement Whole-Staff Health Confirmation Before Starting a Dental Practice

Hospital staff returning from low-risk areas will be required to return to work with a green code for health and with no abnormalities in their communication big data trip. Hospital staff returning from medium- and high-risk areas need to be isolated at home or centrally for 14 days and test negative for viral nucleic acid before returning to work. Daily temperature checks are required for all commuting to and from work, and no gatherings are allowed to avoid cluster infections. Regular nucleic acid testing for hospital staff should be carried out after starting dental practice to rule out nosocomial infections.

Implementation of Online Booking and Dental Care Consultation Services

Online appointments should be implemented in separate time slots to control the number of people attending each time slot, and only one patient should be booked per hour to avoid crowding. Fill in the epidemiological questionnaire form during online appointments to initially screen high-risk individuals. Online appointment numbers should be limited to patients with acute conditions such as severe dental pain, pericoronitis, post-operative osteitis, dry socket or abscess, cellulitis, tooth fracture or dislocation, and certain emergency restorative procedures (29). Furthermore, non-urgent patients should be encouraged to postpone their visits. Simultaneously, an "Internet + telephone" consultation service should be developed to actively provide health assessment, consultation guidance, psychological guidance, and other services. Additionally, detailed epidemiological history should be collected to correctly guide patients to the dental clinic in an orderly manner to reduce the risk of infection (30).

Development of Contingency Plans for COVID-19 Outbreaks in Dental Specialties

Since dental clinics are generally not designated clinics for treating COVID-19 patients, when four categories of people (confirmed cases, suspected cases, patients with febrile symptoms, and close contacts) are screened out, they need to be transferred to the designated COVID-19 clinics for further treatment (**Figure 1**). A separate isolation room should be set up at the location nearest to the dental practice facility's exit for temporary housing of patients pending transfer. The transfer route should be delineated to achieve the shortest outdoor distance and least contact with people (31), with daily access closed and only passable when the emergency plan is activated. Simultaneously, each department should set up a separate, well-ventilated, and disinfected single room as an isolation clinic and an isolation surgery room in the operating room, which is not open daily and is used only for the emergency treatment of these four categories of people. Because it is difficult to accurately predict the changes and development of the pandemic, it is important to reflect on the emergency management ability of hospitals to respond well to these changes (32).

Dental patients with fever or severe respiratory symptoms but no abnormalities in green health code or communication big data trip cards should be immediately notified to the department and the person in charge of COVID-19 infection control. Under secondary protection (see **Table 1** for details), the receiver should lead the patient to the isolation room through a special emergency channel. The hospital's COVID-19 infection control staff should bring the patient to the fever clinic for consultation. After the nucleic acid test and computed tomography (CT) examination are found to be unremarkable, and a specialist rules out the COVID-19 infection, the patient can visit the dental clinic. After that patient leaves, the area through which he or she passes should be fully disinfected. The receiving staff should be isolated at home or centrally while awaiting the patient's screening results. If the results are unremarkable, the receiving staff can go to work normally; if the results are abnormal, they need to be observed in centralized isolation for 14 days. A negative nucleic acid test should be received before they can return to work.

If a dental patient is found to be in close contact of a suspected or confirmed COVID-19 case, the department and the person

FIGURE 1 | Pre-screening and triage process in dental institutions during the coronavirus disease 2019 (COVID-19) pandemic.

in charge of COVID-19 infection control should be notified immediately, and the local Centers for Disease Control and Prevention (CDC) should be notified as well. The receiver should bring the patient to the isolation room *via* the emergency lane under Level III protection. Furthermore, the patient will wait to be brought by the CDC personnel to the designated COVID-19 treatment facility for treatment. In the event of an emergency requiring immediate treatment or surgery for the four above categories of people or patients with unknown epidemiologic history, the patients should be placed in an isolation consultation or isolation surgery room for consultation or surgery under Level III protection (33), with proper isolation and disinfection measures and timely screening for SARS-CoV-2 infection after treatment (34, 35). If the vital signs are stable, the patient should be promptly transferred to a designated treatment facility for the subsequent consultation and treatment of COVID-19. The personnel involved in the practice need to be isolated at home or centrally for 14 days and must test negative for nucleic acid before returning to work.

However, the emergency passage can only be temporarily developed according to the current building structure, and there is no special emergency passage. When transferring the four categories of people, it is difficult to completely avoid crowds. It is only possible to arrange personnel to evacuate the crowd in time to ensure the transfer route's safety as far as possible when a similar situation occurs. Therefore, in the future, the buildings of dental hospitals or dental institutions should set up special emergency passages for the timely and safe evacuation of special groups of people in response to similar public health emergencies.

SYSTEM FOR STARTING THE PRACTICE OF DENTAL INSTITUTIONS DURING A PANDEMIC

Implementation of a Three-Level Pre-screening and Triage System for Dentistry

Guarding should be implemented at the four entrances of the dental institution: the entrance of the main gate of the dental hospital or dental clinic, the entrance of the outpatient lobby on the first floor, the entrance of the front desk of the clinic, and the entrance of the ward Three-level pre-screening and triage should also be implemented for the outpatient clinic: the first level at the outpatient lobby, the second level at the front desk of the clinic, and the third level at the dental chair (36). The staff at the outpatient hall is under Level II protection. The staff at the front desk of the clinic is under Level I protection. The staff at the dental chair is under Level II protection (see **Table 1**, **Figure 2** for details). Different levels of protection for different positions should also be implemented, at least three epidemiological history inquiries and temperature measurements for all patients should also be conducted, and the nucleic acid test reports and CT reports should also be checked when necessary. Each level in the three-level pre-screening and triage is indispensable.

TABLE 1 | Requirements and scope of application of three levels of wearable protective.

Protection level	Wearing requirements	Scope of application
Level I	Disposable work caps, overalls, medical-surgical masks	The front desk of all outpatient departments and wards
Level II	Disposable work caps, overalls, medical-surgical masks or medical protective masks, goggles or protective face shields, disposable isolation suits, disposable latex gloves	Pre-screening triage staff in the primary outpatient lobby Tertiary clinic operators; exposure to patients with severe fever or respiratory symptoms but without unusual epidemiological history Cleaning personnel
Level III	Disposable work caps, overalls, medical-surgical masks or medical protective masks, goggles or protective face shields, protective clothing, disposable latex gloves, waterproof boot covers	Exposure to suspected or confirmed COVID-19 cases

The pre-screening and triage site should be marked, relatively self-contained, well-ventilated, and equipped with rapid hand disinfectant, surface disinfectant, PPE, and temperature detection devices. The pre-screening and triage counters and items should be disinfected every 2 h and whenever contamination is encountered.

Differentiation of Dental Practice Items by Risk Level

The high-, medium-, and low-risk areas released daily by the state are divided according to the zoning and classification criteria, which are refined to community-based units. The risk level of the pandemic is dynamically adjusted and announced on time. The pandemic is handled according to the principles of "early, small, strict, and practical" (37). The specific classification principles are (**Table 2**): ① High-risk areas are defined as areas with more than 50 new cases of COVID-19, with a cluster outbreak within the last 14 days; ② Medium-risk areas are defined as areas with new confirmed cases of COVID-19 within 14 days, but with the total number of confirmed cases of COVID-19 not exceeding 50 cases, or areas with the total number of confirmed cases of COVID-19 exceeding 50 cases, but with no cluster outbreak within 14 days; ③ Low-risk areas are defined as areas with no confirmed cases of COVID-19 or no new cases of COVID-19 for 14 days.

This shows that the classification of the pandemic's risk level in each region is dynamic and constantly changing. Dynamic adjustments should be made in practice items, and dental chair arrangements according to the national and regional pandemic changes and the different risk levels of COVID-19 in different regions. Studies have shown that the bacterial load is five times higher after simultaneous dental treatment in multiple chairs, while this difference is reduced to two times higher with single chairs (38). Therefore, it is important to rationalize practice items and chair settings during a pandemic to achieve four-handed dentistry to reduce infection and occupational exposure risk.

FIGURE 2 | Three-level pre-screening and triage. **(A)** Level 1 lobby triage. **(B)** Level 2 clinic front desk triage. **(C)** Level 3 consultation space triage.

Furthermore, dental chairs should be set up in well-ventilated consultation rooms with air sterilization equipment (3, 38). The measures for performing dental practice during periods of different risk levels are as follows:

High-Risk Areas

In such areas, dental clinics are completely closed, while dental hospitals, depending on their scale, retain 4–6 medical staff and one guide per day for dental emergencies and on-site consultations. A dedicated infection control specialist is also established to supervise and guide medical staff in infection control and achieve standard prevention. Patients attending the clinic must hold a green code and communication big data without abnormality. Furthermore, they must present the results of a nucleic acid test taken within 7 days and CT reports within 7 days only if necessary. Medical practice should be conducted in a separate room with good ventilation and sterilization equipment, and only one dental chair can be used in a large multi-chair room. The practice items are mainly for dental emergencies, and slow handpieces can be used for emergencies. The orthodontics department can receive return visits and suspend spattering operations, but the inpatient department of maxillofacial surgery must postpone elective surgery and only accept patients with dental emergencies requiring inpatient treatment. Patients are admitted in a single room, and only one person is allowed to accompany each patient. Patients and accompanying persons need to undergo nucleic acid detection and CT screening before being admitted to the hospital, and they can only be admitted if there is no abnormality. During hospitalization, the patient and accompanying staff should be monitored for body temperature and respiratory symptoms every day. They should not go out without permission. Nucleic acid testing and CT screening must be repeated after going out.

Medium-Risk Areas

At this time, some dental outpatient consultations can be gradually resumed, and the number of the medical staff at work can be increased appropriately according to the number of patients. Except for periodontal treatment, dental implants, and dental preparations, which are highly spattering procedures, the rest of the procedures can be resumed gradually. Dental practices should be carried out in separate consultation rooms. Furthermore, two consecutive dental chairs in a large multi-chair room cannot be used simultaneously. Seats at an interval of one chair should be used. Attending patients should present their green code and communication big data without abnormalities. Furthermore, a COVID-19 nucleic acid test report and/or CT report taken within the last 7 days should be presented if necessary. During the medium-risk period, principles for admitting patients to the ward remain the same as those during the high-risk period.

Low-Risk Areas

Daily dental outpatient practice will resume at this time. For highly spattering operations such as tooth extraction (except for deciduous teeth), periodontal treatment, and dental implants, patients will be required to hold a green code and communication big data without abnormalities, as well as present a 7-day COVID-19 nucleic acid test report and, if necessary, a 7-day CT report. Conversely, other procedures do not require a nucleic acid test report. All chairs can be used normally (except dental isolation chairs). The ward may add elective procedures as appropriate, and single-room admission should be adopted as far as possible. For multi-bed wards, patients should be placed one bed apart, windows should be opened regularly for ventilation in the ward, and the patients' and accompanying persons' temperature should be monitored. Moreover, respiratory symptoms should be observed daily during hospitalization. Nucleic acid testing and CT screening are still required before the hospitalization of patients and accompanying persons.

DEVELOPMENT OF A SYSTEM FOR THE MANAGEMENT OF PATIENTS AND ACCOMPANYING PERSONS IN DENTAL FACILITIES

Investigating the Epidemiological History

During the pandemic, each patient and the accompanying person must fill out the COVID-19 Epidemiological Questionnaire (39). The health code and communication big data trip cards should be reviewed, and the hospital should keep the questionnaire. The questionnaire's content should be dynamically adapted to the epidemiological characteristics of COVID-19, taking into account the daily release of areas at high risk of the pandemic.

TABLE 2 | Hierarchical differential guidelines for dental institutions to start practice.

	High-risk areas	Medium-risk areas	Low-risk areas
Consultation settings	Separate consultation rooms are open, and only one consultation space is available in large multi-place rooms	A separate consultation room starts a dental practice, with multiple consecutive consultations with one consultation space interval.	Resumption of daily consultation schedule
Dental practice items allowed	The entire hospital should be closed for routine outpatient care, and a 24-h emergency clinic should be set up, with a focus on emergencies and the use of low-speed turbines if necessary	Suspend high spattering operations; remaining items can be phased in, using low-speed turbine handpieces if necessary	Resumption of daily starting dental practice program
Patient sources	Emergency	A small number of online or telephone appointment numbers and emergency numbers in different time slots	The appropriate number of online or telephone appointments and emergency numbers in different time slots
Patient visit requirements	Need to have nucleic acid test report within 7 days and CT report if necessary	Present nucleic acid test report and CT report within 7 days if necessary	Nucleic acid test report within 7 days for high spattering operations and CT report if necessary
No anomalies in health code green code or communication big data	Need	Need	Need
Disinfection of objects surfaces	Terminal disinfection four times a day, disinfection of the dental chair after each consultation, and terminal disinfection of dental chairs after splattering operations	Terminal disinfection four times a day, disinfection of the dental chair after each consultation, and terminal disinfection of dental chairs after each splattering operation	Twice-daily Terminal disinfection, disinfection of the dental chair after each consultation, and terminal disinfection of dental chairs after each splattering operation
Floor and wall disinfection	Avoid dry sweeping, disinfect four times a day, disinfect wall height 2–2.5 m, disinfect anytime there is contamination	Avoid dry sweeping, disinfect twice a day, disinfect walls at the height of 2–2.5 m, disinfect whenever there is contamination	Avoid dry sweeping, disinfect twice a day, disinfect walls at the height of 2–2.5 m, disinfect whenever there is contamination
Surface disinfectants	1,000 mg/L chlorinated disinfectant solution can be used; see "8.1 Surface disinfectants" for other details	A disinfectant solution containing 500–1,000 mg/L chlorine can be used; see "8.1 Surface disinfectants" for other details	500 mg/L chlorinated disinfectant can be used; see "8.1 Surface disinfectants" for other details
Elevators	Elevator keys and cabs are disinfected every 2 h, and whenever there is contamination	Elevator keys and cabs are disinfected every 2 h, and whenever there is contamination	Elevator keys and cabs are disinfected every 2 h, and whenever there is contamination
Elevator disinfectants	500 mg/L chlorinated disinfectant or 75% alcohol	Same as high-risk areas	Same as high-risk areas
Toilet	Disinfect four times a day and whenever there is contamination	Disinfect four times a day and whenever there is contamination	Disinfect twice daily and whenever there is contamination
Toilet disinfectants	1,000 mg/L chlorinated disinfectant	Same as high-risk areas	500 mg/L chlorinated disinfectant
Air	Use the air disinfector throughout the practice, and use the UV lamp for 30–60 min when no one is around, and open the windows twice a day for more than 30 min each time	Same as high-risk areas	Same as high-risk areas
Air disinfectants	See "8.2.1 Air disinfectants" for details	Same as high-risk areas	Same as high-risk areas

For example, at the beginning of the pandemic, Wuhan was the center of the outbreak, so the location for investigating the epidemiological history was Wuhan. Any visits to Wuhan or contact with people who visited Wuhan within 14 days were ruled out (40), body temperature were tested, and respiratory symptoms were ruled out. On April 26, 2020, the COVID-19 patients in Wuhan were cleared, so Wuhan was no longer included in the epidemiological survey questionnaire.

Provide COVID-19 Nucleic Acid Report and/or CT Findings as Necessary

Rapid sequencing of the SARS-CoV-2 genome has led to the development of real-time multiplex reverse transcription-polymerase chain reaction (RT-PCR) assays as the gold standard for detecting viral RNA and identifying patients with COVID-19 and asymptomatic carriers (41). Furthermore, it is currently the main type of test used to determine whether a patient is infected with SARS-CoV-2 in China. Patients with mild COVID-19 can have no pneumonia symptoms; therefore, CT results alone cannot be used as a criterion to rule out COVID-19 infection. However, nucleic acid testing can be affected by the disease's course, specimen collection, testing procedure, or testing reagents, among other factors. The test should be performed at a medical institution qualified for nucleic acid testing to improve the testing's positive rate. The specimens should be collected by professionals and

sent for testing as soon as possible (3). The government qualifies nucleic acid testing institutions in China, and nucleic acid testing institution search, APPs, has been launched, through which the names and locations of testing institutions can be checked at any time.

Strengthen Patient Waiting Management in Dental Institutions

When patients visit dental institutions, they must all wear masks, and no accompanying persons can enter. In the case of the elderly, children, or patients with limited ability to act due to illness, one accompanying person may be allowed to enter and is required to wear a mask throughout. Patients should also be screened for green codes and communication big data to confirm lack of abnormalities before entering. A dedicated person should maintain order on the site, instructing patients to maintain a minimum distance of 1 m from each other (42), be seated one chair away from each other, maintain good cough etiquette, and avoid gathering of people.

INCREASE SELF-PROTECTION OF MEDICAL PERSONNEL IN DENTAL INSTITUTIONS

Selecting the Right Personal Protective Equipment

Since dental consultations are performed close to the patient, the operator's facepiece, eye mask, face mask, and operating arm are the areas closest to the patient and are the most contaminated (43). Thus, protection requirements should be at least Level II; Level III should be achieved when receiving the above four categories of people. Disposable protective equipment should be discarded after use and replaced when there is significant contamination with blood or body fluids. It is also necessary to avoid the overuse of PPE. Overlapping protective clothing is prone to breakage that is not easy to detect. It is more likely to be soaked with sweat during work, reducing the protective performance. Scientific and reasonable use of protective equipment can effectively reduce the risk of infection (44). The eye shields worn during operation often fog up, resulting in unclear vision, and are prone to occupational exposure. The anti-fogging method for the endoscope lens in the operating room can be borrowed; that is, iodophor can be evenly applied to the inner side of the eyepiece. The ionic iodine becomes molecular iodine, which plays an oxidizing role and forms a protective film that can last for 4–5 h against fogging.

Before the outbreak, dental practices generally used Level I protection with protective face shields or eye shields for highly spattering operations. The outbreak was so rapid that the vast majority of dental practices had inadequate protection measures in place. There was a shortage of protective materials, resulting in inadequate protective equipment for medical staff. If disposable gowns are not available, they can be temporarily replaced by cloth surgical gowns, which can be changed once every 4 h and washed and disinfected centrally. This can also have a protective effect (**Figure 2A**). In the case of sufficient materials, it is strongly recommended to use disposable isolation gowns, surgical masks, or medical protective masks. However, neither isolation nor surgical clothing can effectively protect the neck of medical staff, posing a risk of infection. Moreover, the use of disposable protective clothing is seldom applied during diagnosis and treatment in the Stomatology Department due to the high cost and shortage of materials. Therefore, the disposable shawl cap was quickly developed. This can be used with isolation or surgical clothing to strengthen the protective measures of medical personnel (**Figure 2C**), and standard prevention could be achieved insofar as high-risk environments are involved.

Strengthening Hand Hygiene

Many studies have shown the critical role of healthcare workers' (HCWs) hands in transmitting microorganisms in the healthcare setting and ultimately to patients (45). Handwashing can therefore slow the spread of the virus (46). Nonetheless, before the outbreak, hand hygiene compliance was poor among HCWs (47–49). Studies have shown that hand sanitizer dispensers and gloves are the most contaminated PPE (50). Therefore, it is very important to improve compliance to and accuracy of hand hygiene. WHO also issues an annual global call to action to health workers through its SAVE LIVES: Clean Your Hands campaign, held annually in the month of May. This campaign aims to educate health workers and patients on the importance of effective handwashing, which has become more urgent with the COVID-19 pandemic.

Use the seven-step handwashing technique and master the five moments requiring handwashing: two before and three after, two before: before contact with the patient and before aseptic operation; three after: after contact with the patient, after contact with the patient's surroundings and related objects, and after exposure to body fluids. When handwashing is not available, adequate rapid hand sanitizer should be deployed in the best configuration within the medical staff's reach, which will reduce unnecessary walking of medical staff and make it easier to improve hand hygiene implementation.

With the improvements in hand hygiene implementation rate, the frequency of handwashing and hand disinfection has greatly increased, consequently followed by an increase in the incidence of hand eczema (51–53). Several studies have reported that oral medical staff have a high incidence of hand eczema owing to different factors of moisture-related operations such as frequent handwashing, increased irritation from hand disinfectants, and the long-term use of rubber gloves (54–57). Because hand eczema involves macules, papules, vesicles, edema, scaling, hyperkeratosis, fissures, etc. (58), skin damage increases the susceptibility of acquiring contact infection. Moreover, wearing gloves can aggravate the symptoms of hand eczema; therefore, people with hand eczema who have been treated with the corresponding drug treatments should still daub emollients, temporarily rest after work, and reduce hand stimulation to avoid aggravation (59, 60).

Proper Donning and Doffing of Protective Equipment Are More Important

Wearing proper PPE can help medical staff reduce the risk of infection, but incorrectly donning and doffing PPE can expose medical staff to hazardous conditions that make them highly susceptible to infection. Multiple publications during the outbreak reported proper PPE donning and doffing (61–64), with hand hygiene implementation throughout the process of proper PPE donning and doffing. Since gloves are the most heavily contaminated protective equipment, both the Glove-in-Glove Technique and Bird Beak Technique methods of glove removal can be used (65) to reduce the chance of hand contamination. Proper donning and doffing of PPE are necessary to reduce the chances of infection effectively.

STRENGTHEN INFECTION CONTROL AND PREVENTION IN THE DENTAL CLINIC ENVIRONMENT

Sterilization of Object Surfaces and the Environment in the Dental Clinic

Studies have shown that coronaviruses can survive from 2 h to 9 days on surfaces of various materials such as plastic, metal, or glass (66, 67). Furthermore, self-service printers, desks/keyboards, desktops, door handles, medical equipment, utilities, and walls and floors are the most contaminated areas in the clinic (50), especially those that are subject to high-frequency use, such as elevator buttons and bathrooms. Therefore, the dental clinic should be kept clean and tidy, desktop items should be kept in cabinets as much as possible, and object surfaces should be properly disinfected to reduce environmental contamination.

Object surface disinfectant: ① use 75% alcohol to wipe object surfaces two times and allow action for 3 min (spray disinfection is prohibited); ② use a chlorine-containing disinfectant at a concentration of 500–1,000 mg/L to wipe or soak for 30 min; ③ use quaternary ammonium salt disinfectant at a concentration of 1,000−2,000 mg/L to spray or wipe; ④ use 0.1–0.2% peroxyacetic acid or 3% hydrogen peroxide to spray or soak for disinfection for an action time of 30 min. In cases of obvious pollution, water-absorbent materials containing 10,000 mg/L chlorine disinfectant can be used to wrap the pollutants and can be cleaned for disinfection again (68).

Measures to Reduce Aerosols in the Dental Clinic

Air Purification

(1) The fresh air system should be turned on in the dental clinic while ensuring the cleanliness of the fresh air system air intake and its surroundings; when there is no fresh air system, the doors or windows should be opened to enhance air circulation (69). An outbreak of COVID-19 was reported in an air-conditioned restaurant in Guangzhou, China, due to poor air circulation without a fresh air system and ventilation windows (70). Ventilating the clinic by opening windows to inject fresh outdoor air directly into the clinic is one of the quickest and most effective methods to reduce the amount of aerosols in the air inside the clinic (38).

(2) Air disinfection machines with human–machine co-presence may be used and kept running at all times during operation. These can also be used in an unoccupied environment with UV lamp irradiation for at least 30–60 min. If the temperature is lower than 20°C or higher than 40°C and indoor humidity is >60%, the irradiation time needs to be extended, while the power of the UV lamp should be tested regularly and the UV lamp should be cleaned 1–2 times a week. Every day after the end of the consultation, 0.2% peroxyacetic acid or 3% hydrogen peroxide can be sprayed using the aerosol spray method, with the dosage calculated as 20–30 ml/m^3 (1 g/m^3), and ventilation after 60 min of disinfection action. A total of 15% peroxyacetic acid can also be used for heating fumigation, with the dosage calculated as 7 ml/m^3 and ventilation after 1–2 h of fumigation action (68).

Patients Should Properly Gargle Before Dental Consultation

Several studies have confirmed that preoperative patient gargling reduces room air bacteria caused by dental procedures. Furthermore, during the COVID-19 pandemic, pre-consultation gargling should be performed with 1.5–3% hydrogen peroxide or 0.5–1.5% povidone-iodine for at least 30 s (71–73). Simultaneously, the patient should be instructed to gently spit into the gargling cup, use a strong aspiration device to aspirate the liquid from the gargling cup, and to try not to use or reduce the mouthwash basin's use to reduce droplet and aerosol production. SARS-CoV-2 has also been shown to be insensitive to chlorhexidine and Hibitane, so gargling with these solutions is not recommended (3, 74). However, recent studies have shown that in SARS-CoV-2-positive subjects, gargling with 1% hydrogen peroxide does not reduce oral viral load (75). However, the sample size in this experiment was small, and only RT-PCR was used as the detection method; thus, the statistical power of the results remains questionable. The author hopes that more studies can be conducted to assess the relationship between the use of mouthwash and SARS-CoV-2 to identify the type, method, and concentration of mouthwash that can reduce or even inactivate SARS-CoV-2 instantly, so that it can be applied in oral diagnosis and treatment to reduce the risk of infection.

Use Four-Handed and Six-Handed Operation for Oral Treatment, Prevention, and Control

According to several literature reports, the use of four-handed and six-handed operations in oral diagnosis and treatment can effectively improve work efficiency, reduce the work intensity of oral medical staff, and concomitantly achieve better standard prevention (76–81). Therefore, during the pandemic period, four-handed operations are a necessity for oral diagnosis and treatment (82, 83). Six-handed operations, if available, are better, as they can improve work efficiency and effectiveness, shorten the working time, reduce the time of medical personnel's exposure to aerosol pollution, and reduce the risk of infection. However, some institutions believe that the implementation of four-handed and six-handed operations requires more human resources,

and the operation cost will be greatly increased. Therefore, currently, many oral hospitals and dental clinics involved in daily oral treatment operations do not apply four-handed or six-handed operation. The author's unit has practiced four-handed operations for many years; during this pandemic, we realized the superiority of four-handed operation in the prevention and control of the pandemic in dental institutions, and we believe that the effective implementation of four-handed operations will increase the economic benefits of oral institutions and patient comfort.

Application of Powerful Aspiration Devices

To effectively reduce splatter contamination from dental operations, the literature emphasizes and recommends using strong aspiration devices. Studies have shown that the use of strong aspiration devices could reduce droplet splatter area by 93%. A strong aspiration group reduced aerosol particles by ∼90% compared to a weak aspiration group (84); thus, they should be used in conjunction with strong and weak aspiration in clinical operations. An extra-dental vacuum aspirator (EOVA) can be used, if conditions permit, to reduce droplet and aerosol contamination. The use of EOVA has been mentioned in the literature as an effective method to reduce air pollution in dental clinics. It is recommended for the treatment of patients with infectious diseases (85–88). EOVA devices were heavily promoted during the COVID-19 pandemic, but these devices were relatively expensive and not easily accessible across the board.

Use Anti-suction Turbo Dental Handpieces for Oral Treatment

In recent years, more attention has been directed toward the pollution of the dental treatment table water system. The pollution sources are mainly municipal water pollution and sudden stoppage of turbo dental handpieces, which causes patients' saliva and blood to flow through the turbo dental handpieces and into the lumen of the dental table water system (89, 90). The pollutants, after the back suction, will be ejected again the next time they are used, which can easily cause nosocomial infections (91). Although a variety of disinfectants have been used for the disinfection of dental treatment table water system in recent years (92, 93), it is possible to fundamentally solve the problem by using anti-suction turbo dental handpieces to prevent regurgitation. However, this will also increase the cost of oral institutions to a certain extent, and popularization and promotion may require time. Nevertheless, the authors believe that in the current pandemic period, effective prevention and control of each link are the first issues that oral doctors should consider. It is reported that 0.5 vol% H_2O_2 added to the water spray of dental handpieces drastically reduced the possibility of coronavirus spread during aerosol-generating dental procedures (94). Although these results still require confirmation, it may be a promising method to deal with water pollution in the future.

Use of Rubber Dams in Dental Practice

Studies have shown that using rubber dams during operations reduced colony counts by 82.7% (lamp-side sampling) and 83.9% (chest-side sampling) (95). Most studies have formed a broad consensus that rubber dams effectively reduced splatter transmission by 33% and reduced surface bacterial contamination by 80–99% during aerosol generation (96). Therefore, the use of rubber dams, where possible, can be effective in reducing aerosol formation during clinical operations.

DENTAL PANORAMIC RADIOGRAPHY AND CONE BEAM COMPUTED TOMOGRAPHY ARE RECOMMENDED FOR ORAL RADIOGRAPHY DURING THE PANDEMIC

Intraoral radiography, dental panoramic radiography, and cone beam computed tomography (CBCT) are commonly used imaging techniques in the Department of Stomatology. As mentioned earlier, SARS-CoV-2 can be present in saliva and aerosols (97–99). Since intraoral radiography easily induces nausea and cough, there is a high risk of transmission. Concomitantly, since it is necessary to put the sensor into the patient's mouth, there is also a risk of cross-infection. Dental panoramic radiography and cone beam computed tomography are, therefore, recommended during the pandemic (100, 101). However, some dental clinics are less equipped and only have intraoral radiography. The sensors can be covered with a disposable plastic film. After the film is soaked with 1,000 mg/L chlorine-containing disinfectant for 30 min, it is discarded into a medical waste bag (102), and the sensor is disinfected with 75% alcohol.

Radiologists should also conduct secondary protection. Patients should use povidone-iodine or hydrogen peroxide gargle for at least 30 s before undergoing oral radiology examination. After each patient's examination, 75% alcohol or 500 mg/L chlorine-containing disinfectant should be used to disinfect the examination room and equipment (103, 104).

STERILIZATION OF DENTAL CHAIRS BEFORE AND AFTER PRACTICE

Disinfection of Dental Chairs Before Starting Dental Practice

Routinely turn on the dental chair water line rinse for 2–5 min before starting practice to drain the residual fluid in the pipe from the previous day's consultation; this can reduce the bacterial content in the pipe by one third (**Table 2**). For dental chairs with a pipe disinfection function, the pipe should be disinfected before the consultation. Conversely, for dental chairs without pipe disinfection function, the water pipe can be flushed and disinfected before starting dental practice with 500 mg/L of chlorine-containing disinfection solution, 3% hydrogen peroxide, and 5% silver peroxide ion, and the air pipe of the dental chair should be flushed for 20–30 s (105, 106). Several studies have demonstrated that daily pre-consultation rinsing can flush out plankton deposited in the pipeline the night before and reduce the number of bacteria in the pipeline.

Disinfection of Dental Chairs Should Be Carried Out After Each Spraying Operation

During patient visits, the stain-proof film can be used to avoid stains in the frequently touched areas. At the end of each consultation, remove the stain-proof film, disinfect the dental chair's surface, and flush the pipes. A chlorine solution at 500–1,000 mg/L can be used for terminal disinfection of the dental chair after each splattering operation. The higher the concentration of chlorine-containing disinfectant, the more effective the disinfection, but the more corrosive it is to the pipes; therefore, this is an emergency practice measure under the COVID-19 pandemic.

Terminal Disinfection

During the pandemic period, terminal disinfection using 500–1,000 mg/L of chlorine disinfectant is performed 2–4 times a day. Disinfection of the dental chair pipe should also be performed simultaneously. For dental chairs without the pipeline disinfection function, the same disinfection method for the dental chair pipe before starting practice should be carried out. After rinsing, the power should be turned off and the pipe should be left for 30 min and rinsed with clean water. The pipe disinfectant's concentration should then be tested to prevent the disinfectant from corroding the dental chair pipe.

DENTAL APPLIANCE HANDLING

According to the Regulation for Disinfection and Sterilization Technique of Dental Instruments (WS 506–2016), the hazard degree of oral instruments can be divided into three groups: critical dental instruments, semi-critical dental instruments, and non-critical dental instruments. According to these requirements, it is important to choose the appropriate disinfection and storage methods (107). Among them, semi-critical and non-critical oral instruments only need to be cleaned and preserved after disinfection. However, during the pandemic period, oral instruments should be sterilized using high temperature and high-pressure steam and stored separately (except instruments with low temperature resistance) (108). Only one person should conduct sterilization or disinfection to avoid cross-infection. Separating semi-critical and non-critical dental instruments after packaging sterilization greatly increases the operating costs of oral medical institutions, especially of smaller dental clinics. This will cause them to not sterilize their equipment, and the equipment will be sent to other oral medical institutions for sterilization. Such scenarios not only increase the operation cost but also increase the workload. However, only by doing an adequate job of infection control in every detail of oral diagnosis and treatment operation can we avoid cross-infection and protect the safety of doctors, nurses, and patients.

After use, dental instruments are placed separately and recycled promptly, depending on the instrument material, function, and disposal method (107). A disinfection-cleaning-disinfection process can be used to treat dental instruments during an outbreak. It is advisable to pre-treat dental instruments at the chairside, decontaminated by wiping with 75% alcohol. It has been shown that the contamination rate of instruments decreases substantially after chairside pre-cleaning, while the cleaning time can be shortened, and the damage rate of instruments can be reduced (109). After chairside pre-treatment, instruments can be placed in 75% alcohol for 30–60 min, or in a chlorine-containing disinfectant solution at 1,000–2,000 mg/L for 30 min, before being soaked in a 1:150 multi-enzyme solution and sealed. Instruments that cannot be soaked (e.g., high-speed turbine handpieces or scaling machine handles) are stored dry and sealed after surface pre-treatment and promptly recycled to the supply room for centralized cleaning and disinfection. Dental instruments used by the four categories of people should be sealed after immediate chairside disinfection and stored wet or dry in a special sealed box, recovered by the supply room specialist, and sent to the supply room for disinfection *via* a special channel. The supply room should make contingency plans for instruments after use by the four categories of people before starting a dental practice. Designated personnel should be appointed to clean and disinfect them, which should reach Level 3 protection, and separate cleaning rooms should be set up. Disinfection equipment should be marked with clear and conspicuous labels to distinguish them from other instruments to avoid cross-infection.

MEDICAL WASTE MANAGEMENT FOR DENTAL PRACTICE

Medical waste, a hazardous by-product, carries the risk of infection. During outbreaks of major infectious diseases, improper collection, storage, transportation, or disposal of medical waste will cause ecological pollution and increase the risk of disease transmission (110).

The dress code for cleaning personnel performing waste collection during an outbreak includes long-sleeved overalls, disposable hat, disposable surgical mask, disposable isolation gown, waterproof latex gloves, waterproof boots, and face shield. Recovery of items after use for the four categories of people should be under Level III protection.

A storage room for isolation items should be designated to recover items after use for the above four categories of people, and the special bags and sharps boxes for medical waste should be carefully checked to ensure that they are not damaged or leaking. Double-layered bags should be used for medical waste, with a gooseneck knot closure, to seal them in layers. Each bag and sharps box should be tied or affixed with a Chinese label, and the label content should include medical waste generation unit, generation department, generation date, and category. The items should be marked as having been used for the four categories of people to enhance the warning effect. Before leaving the contaminated area, these items should be disinfected by spraying the bag's surface with 1,000 mg/L chlorine disinfectant (pay attention to spraying evenly) or adding a medical layer waste bag on the outside prior to transportation to the government-designated COVID-19 patient medical waste disposal facility. At the end of the transport, the transportation tool should

be disinfected with 1,000 mg/L chlorine-containing disinfectant solution (111).

COVID-19 VACCINATION

China has been developing and producing the COVID-19 vaccine and has gradually started vaccinating key populations (e.g., medical personnel, frozen food industry, and logistics) with the COVID-19 vaccine since the end of December 2020, with rollout gradually being extended to all citizens. As of 24:00, February 9, 2021, 40.52 million doses of vaccination have been administered nationwide. The authors received COVID-19 vaccination on February 4 and March 4, 2021, respectively, without adverse reactions. However, recently, a new study showed that SARS-CoV-2 had evolved into more than 800 different subtypes or branches since the outbreak at the end of 2019 (112), with some strains not even detectable by nucleic acid tests. Admittedly, the protection rate of the COVID-19 vaccine currently in use is difficult to determine. This is a major challenge for future pandemic prevention and control; therefore, pandemic prevention and control cannot be slackened.

LIMITATIONS

These measures also have limitations. For example, a health code, a three-level pre-testing triage, three-level protection, and four-handed operation are easier to implement in countries with abundant medical resources. According to the literature, many countries are experiencing shortages of supplies during the pandemic. Because of poor detection capabilities and insufficient knowledge of infection prevention and control (IPC) protocols (113–118), it is difficult to implement these measures. But during the pandemic, we must strive to achieve standard prevention and to avoid cross-infection. The authors recommend the following measures in response to these situations.

- Set up an IPC team to develop an IPC policy and emergency plan, considering the available resources, to guide medical staff and patients to protect themselves during the pandemic. Strengthen IPC knowledge by training, including that in handwashing, PPE use, etc. (119).
- In case of insufficient medical staff, the number and frequency of patient visits should be reduced to decrease the pressure on medical staff. Also, reassign the medical staff posted in the pre-testing and triage positions when all oral diagnoses and treatments cannot be guaranteed with four-handed operations, which should be performed for as many high-spray procedures as possible, to reduce aerosol pollution.
- When there is no air disinfection equipment, the operation should be conducted in a well-ventilated consulting room.
- Manual instruments should be used as much as possible to reduce aerosol pollution (120). During periodontal treatment, manual scaling can be used instead of ultrasonic cleaning; use slow dental handpieces instead of high-speed handpieces when the use of handpieces is necessary.
- Frequent handwashing should be performed in situations where hand sanitizers are in short supply.
- When a mask is not obviously contaminated or damaged, it should be disinfected with vaporous hydrogen peroxide, ultraviolet germicidal irradiation, and moist heat (121, 122). However, this method is only to be used when masks are in short supply.
- Cloth isolation gowns or surgical gowns can be used instead of disposable gowns. Although either cloth or surgical gowns can be used, they exhibit higher bacterial detection rates than do disposable gowns (123); however, one should change the cloth or surgical gown every 4 h and have centralized cleaning and disinfection facilities available. These gowns can be used in an emergency in case of a shortage of disposable gowns, but they have a high permeability (124), and should be replaced when there is obvious contamination.
- In the case of shortage of disposable protective face shields, one shield can be used repeatedly, but it must be strictly disinfected and stored in a clean area. The commonly used disinfection methods are as follows: After wiping and disinfecting with 75% alcohol, irradiate under ultraviolet light for 1 h (125); soak in 1% sodium hypochlorite solution for at least 10 min; soak in 2% glutaraldehyde for 10 min, rinse with normal saline, and then air-dry; and ethylene oxide (ETO) sterilization (126). Without a disposable protective face shield, a simple protective face shield can be made using a transparent, flexible plastic film and rope (127).

CONCLUSION

Although the global COVID-19 pandemic is still ongoing, dental care for patients with dental diseases cannot be stopped. We should learn from experience and actively implement pre-screening and triage to control the infection source, taking into account the pandemic trend and the above dynamic measures on dental practice under the pandemic. According to the etiological and epidemiological characteristics of the COVID-19 virus, and to its pathogenic and epidemiological characteristics, the key to infection control is the reasonable, correct, and effective use of disinfectants. Simultaneously, we should adequately implement infection control and prevention and cut off transmission routes. Additionally, we should achieve standard prevention, protect susceptible people, protect doctors and patients in both directions, and avoid cross-infection to ensure safe and smooth dental practice.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for

participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

LL was responsible for the study concepts and design, and literature research. MZ was responsible for the clinical studies and experimental studies. XC was responsible for the data acquisition and analysis. SC was responsible for the statistical analysis. CX was responsible for the manuscript preparation. WX was responsible for the manuscript editing. LJ was responsible for the study design. XZ was responsible for the experimental studies. PC was responsible for the guarantor of integrity of the entire study, definition of intellectual content, and manuscript review. MR was responsible for the guarantor of integrity of the entire study and manuscript review. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.619357/full#supplementary-material

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Dental Education in the Time of COVID-19 Pandemic: Challenges and Recommendations

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Moving within the second wave of the coronavirus (COVID-19) pandemic, dental education delivery has been profoundly affected by this crisis, so has the structure, evaluation, and future of dental education. Both pre-clinical and clinical dental education have experienced challenges ranging from fully online educational content to limited dental training for senior dental students. This crisis appears to be a tipping point that produced confusion in dental teaching especially clinical sciences. Although medical institutions immediately started to adapt to the unexpected COVID-19 crisis, dental and oral health educational services are profoundly impaired due to the dental team's propinquity to the patient and the aerosols generated during routine dental therapeutic procedures. Dental students unlike other medical students are considered to be at the highest risk due to the nature of their clinical training that includes working in the oral cavity of patients using aerosol-generating equipment. Some dental schools have taken the leadership and documented their modifications during this pandemic; however, there is a serious need for further investigation and wide range screening of the situation in the dental schools during the COVID-19 crisis. The aim of this mini-review is to present these challenges and how academic dental institutions have implemented strategies to overcome them.

Keywords: dental school, dental students, dental education, COVID-19, pandemic

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INTRODUCTION

December 2019, Coronavirus disease 2019 (COVID-19) was firstly spotted in Wuhan, China, as pneumonia of unknown origin (1). COVID-19 flare-up spread rapidly not only in China, but also worldwide, therefore, on 11 March 2020, the World Health Organization (WHO) affirmed the SARS-CoV-2 virus, more commonly known as COVID-19 as a pandemic (2). The overall number of confirmed cases and mortalities are 78,194,105 and 1,754,369, respectively, in 216 countries as of December 25, 2020 (3). Human-to-human contact via droplets and aerosol has been linked to the transmission of the SARS-CoV-2 virus (4). On the 15 March 2020, the majority of countries all over the world started to impose a lockdown of their population and dental practices were asked to close temporarily. Not to mention, dentists were reported to be among the highest professional risk groups of being infected and a possible vector of the transmission of the SARS-CoV-2 virus (5).

Academic dental schools are considered as competitive and demanding learning communities. Although there have been many outstanding innovations in teaching methodologies during the last few years in higher education, the COVID-19 pandemic highlighted the structural difference between dental and medical schools in the methods of instruction, and the practical and clinical educational daily activities. In the academic dental schools, students have a 2-year preclinical and a 2-year clinical dental course curriculum designed to prepare them for licensure and practice upon graduation (6). Dental chairside teaching is far more complex than most higher education, as senior dental students take the responsibility for the management of the patient's oral health under guidance from clinical specialists (7). Moreover, clinical dental interventions demand the integration of both intellectual and technical skills, including a sensitivity to the patients' needs as well as technical ability, and most critical, risk consideration. In other words, dental students learn what should be done, when to intervene effectively, and finally how to critically appraise treatment outcomes.

All levels of the educational system in Egypt and worldwide have been affected by COVID-19 (8). The worldwide temporary closure of the academic institutions affected around 931,345,922 students in 94 countries representing 54% of total enrolled learners (9). Egyptian private and public universities either canceled or postponed all campus in-person events in order to minimize gatherings and hence control the routes of the virus transmission (10). However, these actions elevated the medical, economical, and social burden on both undergraduate and graduate communities (11). The experiences of oro-dental health education in clinical settings varied remarkably based on the national spread of the virus. Due to the rapid second wave spread of COVID-19, it is imperative for dental schools to apply dynamic adjustments to the delivery of educational clinical services and community services, in order to protect students, patients, and educators meanwhile sustaining continued student academic and research progress.

Some medical academic institutions have taken the action and documented their adjustments during the pandemic; yet; there is an urgent demand for further analysis and wide range screening of the condition in the Egyptian dental schools during the COVID-19 crisis. Thus, the current review aims to illustrate how one of public dental schools in Egypt acted in response to the COVID-19 pandemic and to present the ongoing challenges, and how academic and clinical educators have worked to overcome them.

SOUTH VALLEY UNIVERSITY DENTAL SCHOOL EXPERIENCE

On March 25, South Valley University undergraduate dental students were not allowed to perform in-person activities within the dental school and clinics based on the Egyptian prime minister decree for holding all the educational activities. Administrative and secretarial activities were only part-time accessible (2 days/week). Lectures and examinations moved on the web. The professors started recording video lectures to be available online on the e-learning platform of the University (*http://app.svu.edu.eg/ecourses/faculties3.aspx*). Moreover, intermediate and summative examinations have been performed online, except for final year students, who performed their written examination at the university halls following social distancing rules and strict protective infection control measures.

Early July, the university council regulated the process of carrying out clinical training for healthcare professionals. There were many specific challenges for educators which required rigorous attention in balancing the safety of dental students and staff and the adoption of effective protective measures whilst maintaining high quality educational services. The dental clinics remained available only for the management of dental emergencies. Restorative, esthetic, prophylactic, and all non-essential treatments were canceled. Mid October, the start of fall semester witnessed the restart of education activities on patients. Part of the clinical training activities of dental students was performed through case presentation, reading and critical appraisal of scientific literature, interactive discussions based on clinical scenarios, and update training in cross-infection control. The dental faculty administration placed strict rules to regulate the dental clinics including the limitation of patients' daily numbers, limitations of the accompanying person (one person allowed), temperature checking at the entrance of the clinics.

NON-CLINICAL EDUCATION CHALLENGES

According to the Egyptian Supreme Council of Universities regulations, the majority of Egyptian dental programs adopted the Hybrid Learning Model, in which lectures (theoretical part) were introduced via e-learning platforms, while in-person learning was limited to preclinical (laboratory), and practical (clinical) courses that cannot be delivered remotely. This strategy was implemented to minimize the physical interaction between students, in order to control the outspread of the infection. Meanwhile it allowed dental students to acquire their practical competencies essential for dental education and important for students' satisfaction, in spite of the compromised educational environment.

Teaching practical courses remotely requires resources and unhurried critical planning. For example, the presence of a stable internet connection is mandatory to provide online educational services, which might be a challenge to some of the developing countries. Besides, this new system requires a fundamental change in the mentality of both the faculty and students to perform differently in the educational process (10). Learning a new skill (preclinical or clinical) requires the integration of both; verbal and non-verbal educational methods (12). Dental students gain many practical skills without meaningful verbal expressions, such tacit knowledge usually provides a strong base to much of our dental skills (13). COVID-19 pandemic highlighted the need for educators and clinical teachers to understand the importance of tacit knowledge and how to provide alternative teaching modalities. Internationally, some dental programs started to monitor the students preclinical performance via novel methods like ZOOM, Microsoft Teams, and Whatsapp. The use of distant video illustrations, and the evaluation of the students' practical

performance online might be a practical solution, although more studies are essential to evaluate their effectiveness. Some methods like the five-step method (14) can be modified for preclinical dental teaching. Before the students perform the procedure, the students visualize the procedure without any verbal explanation in order to help them to imagine the procedure before applying it. Then, the procedure demonstrated by the educator is repeated with verbal narration and detailed explanation of steps. Later, the students are asked to repeat the steps so that they can be internalized. And finally, the students perform the procedure with the educator observing and providing feedback as needed.

With the gradual breakthrough that has taken place in the lockdown procedures done in Egypt as well as many other countries, the majority of dental students have resumed their in-person practical classes since October 2020. The return to the practice had to deal with new challenges such as social distancing in classes, management of modified schedules, and the new mandatory public health guidelines (15). The Association for Dental Education, Asia Pacific (ADEAP) developed and published detailed guidelines for safe provision of dental education (including pre-clinical and clinical settings) during the COVID-19 pandemic (16). Although we serendipitously followed many of these items (like the majority of dental programs) during the pandemic (17), it's important to exchange these guidelines and distribute them globally in order to facilitate providing dental education in a safe environment. Regarding the in-person classes, dental academics need to emphasize strict infection control measures (protective face masks and shields, social distancing, and hand hygiene) among students, educators, and staff. The application of these measures is crucial for the safety of the work environment. Students, faculty, and staff should be only allowed to participate in limited, in-person classes, activities, and events that permit attendees to remain spaced at least six feet apart (e.g., lecture hall with seating spaced six feet apart). Besides, dental school should completely avoid out-of-class social activities and events and communications. It's important to continuously remind students, faculty, and staff not to share objects (e.g., laboratory and/or clinical supplies). Routinely scheduled cleaning and disinfection of frequently touched areas should be applied and monitored (e.g., on-time and consistently).

Despite these challenges, it may be a great opportunity to share experiences and information between dental schools, and to implement novel strategies in dental education, especially there are few hindrances to traditional dental learning scenarios. The main aim is to offer the dental students a new alternative that is satisfactory for their training. Although this might look enthusiastic, future studies are important to evaluate the impact of these guidelines and techniques on the learning outcomes, due to the unique demands of dental education (18).

PRACTICE-BASED CLINICAL CHALLENGES

The resumption of routine clinical dental activities was a difficult decision and should be guided by the virus updated status and national health guidelines to manage it. Dental academics had to plan for a safe recovery of clinical teaching for students, patients, educators, and staff with contingency plans. This is very crucial as SARS-CoV-2 is known to be highly contagious and the status of virus transmission in the Egyptian community remains unclear. Certain clinical training (like journal club and case presentation) were well-suited for teledentistry (19). In these cases, case presentation, and discussions could be done using online platforms (ZOOM, Webex, Microsoft Teams) (20). This approach can aid in conducting problem-focused interactions with students without the need of their physical presence (21, 22). On the other side, the therapeutic clinical training in the university clinics represented the main challenge for clinical dental education, specially the management of bio-aerosol, the insurance of the dental team compliance with the obligatory additional infection control measures, the application of social distancing policies to reduce overcrowding in the clinic, and thus reduce the exposure to others as well as the bio-aerosol generated during the clinical procedures (23).

Dental Bio-Aerosols

Almost all dental procedures include a set of mechanical preparation, this includes the use of air turbines, air-water syringe, ultrasonic scalers, rotary handpieces, and air abrasion which generate bio-aerosols. Interestingly, these procedures include routine dental examination and hand-scaling which many dentists would consider safe to perform (24). Bio-aerosol generated during dental procedures contains a spectrum of microorganisms within tiny particles called droplet nuclei (1–5 μm) or droplets (>5 μm) (25). Large droplets tend to fall quickly due to the gravity, while droplet nuclei are airborne for hours due to their low settling velocity with the ability to propagate further before being inhaled inside the respiratory system or contaminate the clinic exposed surfaces (26).

Recent evidence demonstrated three main routes for the transmission of SARS-CoV-2 in dental settings: (1) direct transmission via inhalation of the virus via cough droplets; (2) transmission via oral, nasal, or eye membranes; and (3) direct contact transmission (27). All these three transmission routes are facilitated by dental procedures generated aerosols (28). It's important to highlight here that the majority of previous studies quantifying bio-aerosol generation during dental instrumentations have a range of differences in between them. Nevertheless, their findings should be taken into consideration when operating in this pandemic.

The reduction of bio-aerosol generation can be accomplished by using many protocols (26, 29). In our experience, we followed two different approaches to control bio-aerosol generation: (1) the use of pre-operative mouthwash; and (2) the regulation of daily dental procedures (30, 31). The use of pre-operative mouthwash (1% hydrogen peroxide, 0.2% povidone iodine, or alcohol free options such as 0.2% chlorhexidine rinse) has been shown to control the bacterial burden (23). In order to regulate the daily clinical practice, it was logical to prioritize senior dental students in the clinic as the most skillful clinical cohort with more structured clinical skills (32). Less experienced dental students have been found taking significantly longer time (2–3 h)

than those of experienced dentists for doing the same clinical intervention, which exposes patients, students, educators, and staff to bio-aerosol for an extended period of time. Besides, it's preferable to prioritize patients with dental emergencies or acute dental pain, and mandate the use of the rubber dam (with aerosol generating procedures) until the situation becomes clearer or with the mass distribution of the vaccine.

Infection Control

Infection control continues to be one of the most critical issues in healthcare service worldwide including dental schools. Infection control and prevention is crucial in providing a safe environment for students, patients, educators, and healthcare workers within clinical settings in dental schools (33–35). Since its establishment, the Faculty of Oral and Dental Medicine at South Valley University has followed the infection control regulations published in the Summary of Infection Prevention Practices in Dental Settings published by the Center for Disease Control and Prevention (CDC) as the standard infection control measures (36). The transmission of SARS-CoV-19 virus from human to human through the respiratory droplets of the patients (37) requires new regulations in order to control the infection outbreak.

Recently, multiple guidelines and recommendations have been published in order to share the modification in the infection control measures between dental professionals (26, 38). Although we applied many of these measures serendipitously, it is crucial to establish rational evidence-based protocols for all clinical settings to make sure that students, educators, and staff are understanding and applying these protocols properly, and thus do not compromise infection control measures especially at this crisis.

During the pandemic, we strictly applied the social-distancing regulation in the operating as well as patients' waiting rooms. Moreover, the clinic administrative board effectively monitored the hygiene levels in the clinic and patients waiting areas between appointments. This was achieved by using a hospital grade disinfectant that is effective against other viruses such as norovirus or 0.1% sodium hypochlorite or >60% alcohol based wipes (23). These applied measures are closely matching these applied in other countries like France, China, and Iran (15, 26, 38).

According to recent evidence, dental schools should perform primary screening when scheduling an appointment online or over the phone (26, 38). As we don't have online or phone scheduling at the dental clinics in South Valley University, screening of students, patients, faculty, and staff was applied including temperature checking and a questionnaire of any recent respiratory problems or fever at the entrance of the dental hospital. Inside the clinics, dental students, assistants, clinicians, and educators followed strictly the standard precautions for the airborne, as well as contact infections, which include but not limited the use of PPE and the hand hygiene protocols (39). Dental schools need to oblige students and assistants to use disposable surgical caps and long-sleeved polyethylene gowns with elasticized wrists which are cautiously disposed of after every patient. In some high-risk facilities, faculties, and/or clinical educators may be forced to change gowns between each student/patient, and patients are asked to wear disposable gowns. Furthermore, students, staff, and educators are required to wear a surgical mask or N95/P2 respirators inside the dental clinic. The N95/P2 surgical respirators have been known to provide more effective protection from both: airborne particles (0.3–0.6 μm) and from liquid droplets (40). Moreover, protective eyewear is an important protective gadget as the virus has been isolated from conjunctival samples from COVID-19 positive patients (41). Recent studies (42–45) showed that whilst dental students have a positive attitude toward infection control, their compliance is poor, specifically regarding eye protection, with 28% of senior students in some schools admitting to only use eyewear protection sometimes. Finally, all academic dental institutions should clinically assess the compliance of their students periodically to the infection control in the dental settings to ensure their understanding of the infection control obligations.

QUESTIONS CONCERNING THE FUTURE OF DENTAL INSTITUTIONS AND EDUCATION

Although COVID-19 pandemic has a worldwide unlimited devastating impact, this pandemic should alarm the health professionals to be more prepared for any future emerging pandemic. Dental academic institutions must learn from this experience and remember the binding professional responsibility and sharing information. Regarding dental clinical education, it's crucial to answer many questions that may help in understanding what could be done in the future; what will be the basic infection control standards, after the COVID-19 vaccination? The design and infrastructure of educational clinics including patients waiting areas may also need to be reconsidered in the future regarding the positioning, spacing of dental units, and the central air ventilation. In the same context, it is important to know when dental students and educators will receive the vaccine? Are they considered among high risk groups or just educational institutions? Institutional support plans for students, educators, and staff will be vital to help them dealing with the negative consequences of this current crisis.

Regarding pre-clinical dental education, the main challenge that e-learning faces is how to teach efficiently practical pre-clinical lessons in a safe environment. Since most of the dental subjects require practical interaction; therefore, it is not feasible to teach them only online. We believe that dental students will face a difficulty to fulfill the dental practical skills only with an online-based education system. That's why it is suggested that e-learning can be improved by enhancing its interactivity, showing dental procedures in real situations, in addition to providing 3D simulations to mimic the real teaching experience. Finally, It will be important to evaluate in the future the pedagogical effects of the structural change in the dental educational techniques caused by the COVID-19 crisis.

CONCLUSION

The SARS-CoV-2 crisis has forced a paradigm shift on the performance of the dental academic institutions. Due to its uniqueness, clinical dental education faces special challenges compared to other medical specialties. Hybrid learning will probably be a cornerstone of future dental education. Educational clinical dental settings need to be re-adjusted as quickly as possible, according to the new infection control measures, to ensure high quality training for dental students, as well as continuation of community dental services, in a safe clinical environment. Finally, post-pandemic, dental academic institutions must consider documenting and sharing their guidelines and experiences in published research. This knowledge will help dental institutions to improve the overall educational process and to provide both pre-clinical and clinical dental education in a safe environment.

AUTHOR CONTRIBUTIONS

All authors have read and approved the final article. MGH conceived and designed the review. HA revised the manuscript. MGH and HA wrote and revised the final manuscript.

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SYSTEMATIC REVIEW
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Effectiveness of Pre-procedural Mouth Rinses in Reducing Aerosol Contamination During Periodontal Prophylaxis: A Systematic Review

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Background: Aerosol-producing dental procedures are of concern in the spread of infections, especially during the COVID-19 pandemic. Periodontal prophylaxis is the most common aerosol-producing procedure conducted in dental practice globally. During COVID-19, many national and international organizations advocated the use of pre-procedural mouth rinsing to prevent the spread of infections from aerosol-generating procedures in the dental setting; however, many questioned the scientific basis for such recommendations.

Objective: This systematic review aimed to evaluate the effectiveness of pre-procedural rinsing when preforming periodontal prophylaxis in reducing aerosol contamination in the dental setting.

Methods: A comprehensive standardized search strategy was employed, informed by a defined PICO question across four electronic databases. The review of the literature was conducted using the PRISMA framework. Agreement between assessors was determined throughout. Synthesis of study characteristics and key outcomes were conducted. Cochrane's risk-of-bias tool for randomized trials (RoB 2) was employed to assess the quality/bias among studies.

Results: The initial search yielded 731 citations across the four databases; 95 potentially effective studies were identified, with 56 effective studies found. Thirty randomized control trial studies were identified, 21 with a focus on effectiveness of pre-procedural mouth rinsing, involving 984 participants (aged 18–70). Agreement between assessors was high (Kappa >0.80). Various pre-procedural mouth rinses were tested, most frequently chlorhexidine (CHX) in 18 studies. The concentrations, volume, and prescribed duration of rinsing varied among studies, hampering meta-analyses. Nonetheless, all studies identified significant reductions in bacterial contamination, as measured by colony forming units (cfu). The effectiveness of CHX over other agents was evident with more than half of the studies (7/15) reporting over a 70% reduction in bacterial contamination (cfu). There were concerns over the risk of bias in most studies (76.2%); 19.0% had a high risk of bias and 4.8% were of low risk of bias.

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Conclusion: There is substantial evidence to support pre-procedural mouth rinsing, such as with chlorohexidine, to effectively reduce aerosol contamination when performing periodontal prophylaxis compared to mouth rinsing with water or not rinsing.

Keywords: COVID-19, periodontics, splatter, bioaerosol, air polishing, debridement, periodontal scaling

INTRODUCTION

The cornerstone for maintaining periodontal health is effective dental plaque control. This may be achieved through a combination of diligent home care practices and compliance to scheduled dental visits, whereby the dentist or hygienist undertakes the necessary scaling, polishing, and root debridement using ultrasonic scalers and air polishers. For individuals who have been affected with periodontitis, it is particularly crucial that they comply with scheduled dental visits regardless if they are in the active or maintenance phase of periodontal therapy.

Interruptions to regular dental services have been unexpectedly imposed due to the COVID-19 pandemic as part of the collective efforts to reduce the risk of transmission within dental clinics. Around the globe, the dental fraternity resolved that only urgent and emergency dental care should be permitted during the pandemic. Amidst dynamic health and community-related updates of the pandemic, the dental profession developed various guidelines to assist dentists to make appropriate clinical decisions in the management of their patients (1–3). These guidelines were necessary, although in some instances the available evidence to support them was questioned.

For patients with periodontal concerns, this disruption to scheduled periodontal therapy may not cause immediate pain or discomfort. Nonetheless, postponement of regular care can aggravate or be detrimental to their oral health status, may increase their risk of non-communicable diseases, or worsen their health status, particularly those with underlying systemic conditions (4). Non-surgical periodontal therapy like scaling, polishing, and root debridement are aerosol-generating procedures (AGP) and carry a high risk for aerosol contamination (5, 6). This causes concern for increased risk of infectious disease transmission during these procedures during the COVID-19 pandemic. There is an urgent need to reduce or eliminate the risk of aerosol contamination from AGPs given the necessity to carry out treatment to avoid periodontal disease progression (7).

One of the most widely advocated methods to reduce the level of contamination in the aerosol during dental procedures is pre-procedural mouth rinsing (8). The aim of our review was to investigate the effect of mouth rinsing before periodontal prophylaxis (pre-procedural mouth rinsing) on aerosol contamination in dental clinics. The findings from this review have implications in providing evidence to support or refute current guidelines for pre-procedural mouth rinsing.

METHODOLOGY

Search Strategy

The PICO strategy (9) was employed in focusing the review questions: What is the effectiveness of pre-procedural rinsing in periodontal prophylaxis in reducing aerosol contamination and what are the factors attributing to its effectiveness? The study population (**P**) was periodontitis patients receiving interventions (**I**) for reducing aerosol contaminations during non-surgical prophylaxis including dental scaling and tooth polishing, root planning or debridement, and air polishing using powered instruments with/without use of adjunctive antimicrobials. Findings from the relevant studies were to be compared (**C**) to the subjects or patients that did not receive similar interventions, with the primary outcomes (**O**) of interventions being reduced aerosol contamination.

Selection Criteria

Electronic database searches were conducted on Scopus, MEDLINE via PubMed, Cochrane Library, and Web of Science up to 8th April 2020 using the predefined keywords "aerosol" and "dental prophylaxis" (Appendix 1 in **Supplementary Material**). Selection of key words and terms for search strategy were informed by Medical Subject Headings (MeSH) and previous related reviews (8, 10–19). No time limit was set in this search. Our initial search did not find any references for viral contamination in aerosol; hence the review is limited to bacterial contamination only.

Data Selection and Extraction

The reviewers in this study were consulting specialists in Periodontology (S.M-S.) and Dental Public Health (T.N.M., H.R., and C.M.), and a dental graduate (N.S.). Initially, titles and abstracts were independently screened by two reviewers (S.M-S. and N.S.) to identify potential effective studies. Then, full-text articles were retrieved for the secondary screening by two additional reviewers (T.N.M., H.R., C.M.) for consensus on the eligibility. Disagreement between reviewers were resolved with the supervising author (C.M.) and Kappa statistics was used to assess the agreement between assessors throughout.

In synthesis of evidence from 'effective' studies, details included authors, article publication year, design of study, sampling size and allocation of test and control groups, details of intervention, type and description of periodontal prophylaxis procedures, and primary outcomes in terms of statistically significant findings and reduction of aerosol contamination between groups measured by colony forming units (cfu) using means and percentages. If permissible, mean cfu reduction % was

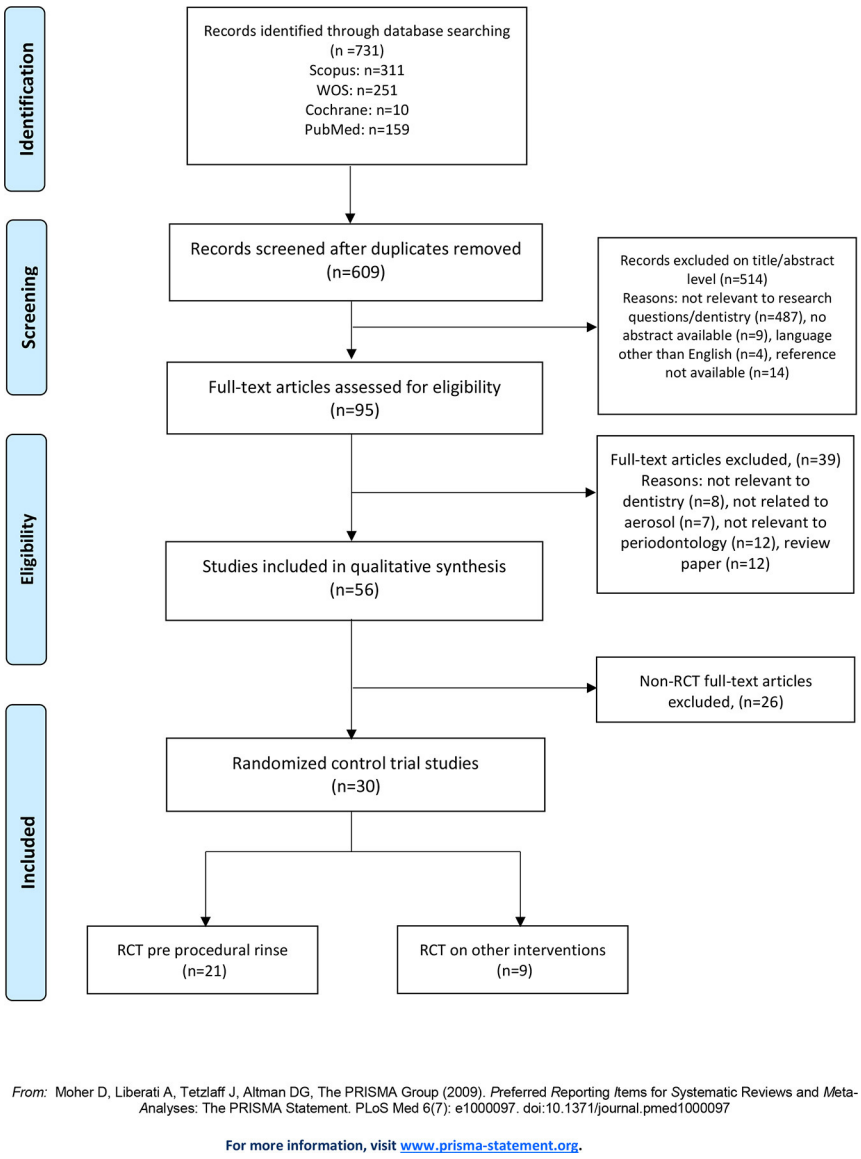

FIGURE 1 | Summary of the selection process for systematic review.

calculated by Mean cfu reduction (%) = [(total amount of mean cfu at baseline—total amount of mean cfu after prophylaxis)/total amount of mean cfu at baseline] x 100%. When baseline data were not provided in the articles, mean reduction percentage was calculated as Mean cfu reduction (%) = (total amount of mean cfu for control group—total amount of mean cfu for test group)/total amount of mean cfu for control group] x 100%.

Quality and Risk of Bias Assessment

An assessment of quality and risk of bias assessment was conducted on effective studies that informed the review employing the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) (20). Domains evaluated were: Domain 1—risk of bias arising from the randomization process, Domain 2—risk of bias due to deviation from the intended interventions, Domain 3—risk of bias due to missing outcome data, Domain 4—risk of bias in measurement of outcomes, and Domain 5—risk of bias in the selection of the reposted results. Using specific signaling questions for each domain, response options including **Yes** (Y), **Probably yes** (PY), **Probably no** (PN), **No** (N), and **No information** (NI) available were made. Finally, the overall risk-of-bias judgement was made for each article based on the criteria for **Low Risk**, judged to raise **Some Concerns**, or **High Risk** of bias. Agreement between evaluators for this section (S.M-S., T.N.M., and H.R.) were discussed with the supervising author (C.M.) and the inter-evaluator reliability was calculated using Kappa statistics.

RESULTS

Identification and Screening

The initial search yielded 731 articles across four databases. After removal of duplicates, the "title and abstract" of 609 articles were assessed, identifying 95 "potentially effective" studies (Agreement between assessors was high, $\mathbf{K} = 0.96$). The full texts of potentially effective studies were then assessed, and 56 studies were identified as "effective studies" (Agreement between assessors was high $\mathbf{K} = 0.88$). No additional studies were identified through "reference linkage" and among the effective studies 30 randomized control trial (RCT) studies were identified, 21 with a specific focus on pre-procedural rinsing (21–41) (**Figure 1**).

Characteristics of the Studies

The study characteristics and periodontal procedures undertaken to generate aerosol in the studies included in this review are described in **Table 1**. Studies were published between 1992 and 2020. Approximately a quarter (6/21) were split-mouth design RCTs (21–25), 13 were full-mouth design (27–40), and one did not provide details of study design (41). The vast majority were parallel-arm TCTs (19/21) and two were RCTs of cross-over design. Over a third of studies (8/21) were identified as double-blinded interventions, and one claimed to be a single-blind study. The total number of participants among the studies was 984, ranging from 18 to 120 among studies, and of varying ages (18 to 70 years old). Participation was high among studies, except in one study where a subject received/ initiated antibiotics during the course of the study (36).

In eleven studies there were three experimental groups; nine studies had two or four experimental groups. One study had all participants as their own controls (41). Of the 21 RCTs, 18 used chlorhexidine (CHX)-containing mouth rinse as either a test (21, 22, 24, 26, 28–41) or as a positive control group (27). Other agents tested were novel antiseptics (four studies) (22, 23, 25, 36), herbal essential oils, EO (two studies) (28, 37), cetylpyridinium chloride, CPC (three studies) (32, 35, 38), povidone iodine (two studies) (30, 31), chlorine dioxide (one study) (24), aloe vera (one study) (30), and herbal extract (two studies) (34, 40). Controls used were saline, sterile water, distilled water, hydro alcohol, or no rinse at all.

Apart from using pre-rinses, some studies added other interventions to examine the impact on reducing bacterial load, namely the use of high-volume evacuation, HVE (three studies) (21, 22, 26) and irrigation using ozone (one study) (31). The protocol for pre-procedural rinsing varied: participants were instructed to rinse between 30 s and 2 min, the amount of mouth rinse used range between 10–20 ml, and participants waited between 2 and 40 min before they were given periodontal prophylaxis. Most studies (19/21) used ultrasonic scaling as the periodontal prophylaxis procedure, and two studies used polishing devices (29, 37). The duration of the periodontal prophylaxis ranged from 3 to 30 min.

Effectiveness of Pre-procedural Rinse

Among the 21 studies, the majority (95.2%, 20) assessed bacterial contamination for aerosols (**Table 2**). For the most part, the key outcome measured was bacterial count expressed as colony forming units (cfu) on blood agar plates; however, incubation protocol differed among studies. One study assessed bacterial count per ml of blood, from blood drawn from the antecubital fossa (23); another study, in addition to aerosol bacterial contamination, assessed bacterial contamination from salivary samples (40). The sites of data collection differed among studies in terms of number of samples obtained, position, direction, and distance from subjects' mouth. However, there were no notable differences in the reduction of cfu from the aspects of periodontal prophylaxis devices used nor location of aerosol sampling collection from these studies. Approximately half of the studies (52.4%, 11/21) obtained the sample at or near the operator and dental assistant. Mostly, CHX rinse were tested (80.9%, 17/21), with various concentrations and volumes. Among studies comparing CHX with other agents (71.4%, 15/21), the effectiveness of CHX over other agents was evident, with more than half of the studies (7/15) reporting over a 70% reduction in cfu.

Assessment of Bias

Risk of bias varied among studies, **Figure 2**. For the most part (90.5% of studies), there was of unclear risk of bias in terms of the randomization process (domain 1) with 9.5% being of low risk of bias. There was generally a low risk of bias in terms of deviation from the intended interventions (95.2% of studies, domain 2) and the remaining were of questionable risk of bias (4.8%). There was a high risk of bias regarding missing outcome data in approximately 1 in 20 studies (4.8%), although 95.2% of studies in this regard were of low risk of bias (95.2%). For a third of studies (33.3%) there was a low risk of bias regarding the measurement of outcome; approximately half (52.4%) had an unclear risk of bias and 14.3% were of high risk of bias. In terms of selection of reported results, all studies were of low risk of bias.

DISCUSSION

As the number of fatalities and morbidities due to COVID-19 continues to rise it is important to acknowledge that oral health remains an integral element of overall health and well-being (42). Despite the uncertainties associated with the exact characteristics for SARS-Cov-2 transmission in dental settings, the dental team and administration must ensure safety of all personnel and patients, as well as other related parties involved in providing dental care to the public, such as cleaning and services. Reducing contamination of aerosol produced in dental clinics is a simple way to minimize and prevent cross-infections and has been increasingly reviewed during this pandemic (8, 43). The majority of these reviews focus on recommendations for general precautions in dental practice, but do not emphasize the aerosol contamination from periodontal prophylaxis, as one of the most common AGPs in dental clinics.

Our review is limited to aerosol contamination. Although our search was focused on microbial contamination in dental aerosol, there was no literature found on virus, which would provide more insight on possible COVID-19 cross-contamination in dental clinics. A majority of these studies included the use of CHX as

TABLE 1 | Pre-procedural rinse study characteristics (Ctd).

No.	References	Design	Subject size (N)	Pre-rinse intervention groups	Additional intervention group	Control group	Duration of rinse and interval before procedure	Periodontal procedure
1	Devker et al. (21)	Split mouth, parallel	90 patients, 30 per group 18 - 45y/o	0.2% CHX	Scaling with HVE (140mmHg), CHX + scaling with HVE	No CHX pre-rinse/no HVE/no combination	2 min pre-rinse 10 ml *interval:NA*	Piezoelectric ultrasonic, 10 min scaling
2	Sawhney et al. (22)	Split mouth, parallel	60 patients, 20 per group 25–54y/o	0.2% CHX (1:1 in water), antiseptic (*contents: NA*) (1:1 in water)	With / without HVE	Water	2 x 30 sec pre-rinse 15ml CHX / 20ml antiseptic, *interval:NA*	Piezoelectric ultrasonic, *duration: NA*
3	Fine et al. (23)	Split mouth, crossover, double blind	18 patients, 9 per group *age: NA*	Antiseptic mouthwash (*contents and concentration: NA*)		5% hydro alcohol	30 sec pre-rinse 20 ml *interval:NA*	Magnetostrictive (Cavitron) ultrasonic, 5 min scaling
4	Saini (24)	Split mouth, parallel, double blind, placebo controlled	120 patients, 40 per group 18 - 55y/o	Chlorine dioxide, 0.2% CHX		Water	1 min pre-rinse, 10 ml *interval:NA*	Piezoelectric ultrasonic 10 min scaling, power medium 15ml/min flow
5	Fine et al. (25)	Split mouth cross over, double blind, repeated at 1 week after	18 patients, 9 per group >18y/o	Antiseptic mouthwash (*contents and concentration: NA*)		5% hydro alcohol	30 sec pre-rinse, 20 ml, 10 min before scaling	Ultrasonic, 10 min scaling
6	Narayana et al. (26)	Split mouth parallel	45 patients, 15 per group *age: NA*	0.12% CHX	With HVE (30 - 40 psikg/cm2)	No rinse, no HVE	30 sec pre-rinse 10 ml *interval:NA*	Piezoelectric (EMS) ultrasonic, 20 min scaling
7	Rajachandrasekaran et al. (27)	Full mouth, parallel	50 patients, 25 per group 20 - 50y/o	Herbal oral rinse (*contents and concentration: NA*)		0.12% CHX	1 min pre-rinse 15 ml 10 min before scaling	Magnetostrictive (Cavitron Bobcat Pro) ultrasonic, 10 min scaling
8	Shetty et al. (28)	Full mouth, parallel	60 patients, 20 per grp 25 - 45y/o	0.2% CHX, Tea tree oil (*concentration: NA*)		Distilled water	*Duration: NA* 10 ml 2 min before scaling	Ultrasonic 10 min scaling
9	Santos et al. (29)	Full mouth, parallel	23 patients, 23 per group 10-40y/o	0.12% CHX		Distilled water	1 min pre-rinse, 15 ml 10 min before prophylaxis	Jet hand I, sodium bicarbonate, 4 min polishing
10	Paul et al. (30)	Full mouth, parallel	60 patients, 20 per group 18 - 35y/o	0.2% CHX, 1% Povidone iodine, 94.5% aloe vera extract		None	1 min pre-rinse, *volume: NA* 10 min before scaling	Piezoelectric ultrasonic, 20 min scaling

(Continued)

TABLE 1 | Continued

No.	References	Design	Subject size (N)	Pre-rinse intervention groups	Additional intervention group	Control group	Duration of rinse and interval before procedure	Periodontal procedure
11	Kaur et al. (31)	Full mouth, parallel, double blind	60 patients, 20 per group 20 - 50yold	0.2% CHX, 1% Povidone iodine	Irrigation with ozone(0.082mg/h)	None	1 min pre-rinse, *volume: NA interval:NA*	Ultrasonics, 10 min scaling
12	Retamal-Valdes et al. (32)	Full mouth, parallel, single blind	60 patients, 15 per group 18 - 70y/o	0.075% CPC + 0.28% Zn lactate + 0.05% NaF, 0.12% CHX + 10% alcohol		Water, no rinsing	1 min pre-rinse, 20 ml *interval: NA*	Magnetostrictive ultrasonic, 10 min scaling, frequency 25k Hz, power <50%
13	Reddy et al. (33)	Full mouth, parallel	30 patients, 10 per group *age: NA*	Non-tempered CHX 0.2%, tempered CHX 0.2%		Sterile water	1 min pre-rinse, *volume: NA interval:NA*	Ultrasonic scaling *duration: NA*
14	Gupta et al. (34)	Full mouth, parallel, double blind, placebo controlled	24 patients, 8 per group 25 - 55y/o	0.2% CHX, herbal extracts (*contents and concentration: NA*)		Water	1 min pre-rinse, 10 ml, 10min before scaling	Piezoelectric ultrasonic, 30 min scaling
15	Joshi et al. (35)	Full mouth, parallel, double blind	40 patients, 10 per group mean age 32.5	0.05% CPC (47°C), 0.2% CHX (47°C), 0.05% CPC (18°C), 0.2% CHX (18°C)			1 min pre-rinse 10 ml 10 min before scaling	Ultrasonic, 30 min scaling
16	Fine et al. (36)	Full mouth, crossover, double blind	18 patients, (1 initiated antibiotic, data excluded at the end) *per group: NA age:NA*	Antiseptic mouthwash (*contents and concentration: NA*)		5% hydro alcohol	30 s pre-rinse 20 ml 40 min before scaling	Magnetostrictive (Cavitron 3000) ultrasonic, 5 min scaling at each phase
17	Logothetis et al. (37)	Full mouth, parallel	18 patients 6 per group 25–54y/o	0.12% CHX, EO (*contents and concentration: NA*)		Distilled water	2 x 30 s pre-rinse 15 cc each rinse 10 min before air polishing	Polishing device, 3 min polishing
18	Feres et al. (38)	Full mouth, parallel, double blind, placebo controlled	60 patients, 15 per group 30 - 70y/o	0.05% CPC, 0.12% CHX		Water, no rinsing	1 min pre-rinse 15 ml *interval:NA*	Magnetostrictive (Cavitron Select) ultrasonic, 10 min scaling
19	Mohan et al. (39)	Full mouth parallel	20 patients, 10 per group 25 - 40y/o	0.2% CHX		Saline	1 min pre-rinse *volume: NA interval:NA*	Ultrasonic scaling *duration: NA*
20	Swaminathan et al. (40)	Full mouth, parallel	30 patients 10 per group 18–50y/o	0.2% CHX, herbal rinse (*concentration: NA*)		Saline	60 s pre-rinse 15 ml *interval:NA*	Ultrasonic scaling *duration: NA*
21	Serban et al. (41)	*NA*	80 patients, 40 per group 20–65y/o	0.1% CHX		Sterile water	*Duration: NA volume: NA interval:NA*	Ultrasonic scaling *duration: NA*

HVE, high volume evacuator; CHX, chlorhexidine; CPC, cetylpyridinium chloride; PI, povidone iodine, EO, essential oil; NA, information not available inarticles.

TABLE 2 | Pre-procedural rinse study main findings (Ctd).

No.	References	Outcome (unit)	Microbiological evaluation	Site of collection	Significant results (*p* values)	% of reduction of cfu
1	Devker et al. (21)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 24 h,	From patient's mouth: 1. 6in - operator's nose, 2. 6in - assistant's nose, 3. 12in - patient's chest, 4. 36in - patient's right side	Significant cfu count/reduction: - in all groups, in all location (Student's paired t-test, - $p < 0.01$), - in HVE alone was better than CHX alone, - in combine CHX + HVE was better than CHX or HVE alone	Mean cfu reduction between CHX - no CHX, HVE - no HVE, CHX+HVE - scaling only at: - operator's nose: 59.2%, 83.2%, 88.1% - assistant's nose: 60.7%, 81.6%, 87.7% - patient's chest: 55.9%, 83.1%, 87.9% - patient's right side: 48.0%, 65.0%, 79.3%
2	Sawhney et al. (22)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar plates incubated at 37°C for 24 h	1. Patient's chest 2. Dental unit tray, 3. 6in away from patients' mouths	Significant cfu count/reduction: - in all groups (ANOVA, $p < 0.05$) - between CHX-water (Student's t-test, $p = 0.001$) and CHX-Listerine (Student's *t*-test, $p = 0.025$)	Mean aerobic cfu reduction between CHX, antiseptic and water: - with use of HVE: 95%, 70%, 40% - without use of HVE: 65%, 45%, 20%
3	Fine et al. (23)	Bacterial count per ml blood (cfu/ml)	Blood drawn from antecubital fossa then incubated on agar plates at 37°C for 24 h (aerobically), or 5 days (anaerobically)		Significant cfu count/reduction between antiseptic and control both aerobic and anaerobic colonies ($p = 0.00001$)	Mean cfu reduction between antiseptic-control for: - aerobic: 92.3% - anaerobic: 87.8%
4	Saini (24)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 48 h	From patient's mouth: 1. 1 feet - patient's chest 2. 1 feet - operator 3. 1 feet - assistant 4. 2 feet - 12 o'clock 5. 8 feet - 6 o'clock	Significant cfu count/reduction: - in ClO2 and CHX compared to water (ANOVA, $p < 0.001$) in all positions, - highest at patient's front, and almost the same in all other areas (ANOVA, $p < 0.001$)	Mean cfu reduction between water, ClO2, CHX at: - patient's chest: 2.1%, 85.4%, 88.0% - operator position: 2.1%, 85.7%, 87.7% - assistant position: 2.3%, 85.3%, 88.1% - 12 o'clock: 3.8%, 85.7%, 87.6% - 6 o'clock: 3.4%, 89.2%, 92.8%
5	Fine et al. (25)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 24–72 h	From patient's mouth: 1. 1 feet - patient's chest 2. 1 feet - operator's chest 3. 1 feet - assistant' chest 4. 2 feet - 12 o'clock 5. 8 feet - 6 o'clock	Significant cfu count/reduction: - in CHX compared to control (Student's *t* test, $p < 0.001$)	Mean cfu reduction between CHX and control at was 94.1% and 33.9%
6	Narayana et al. (26)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on on blood agar incubated at 37°C for 48 h	Left of patient (between patient and assistant)	Significant cfu count/reduction: - in CHX pre-rinse group compared to no rinse (ANOVA, $p < 0.001$) - when HVE was used compared to no HVE (ANOVA, $p < 0.001$) - when both CHX and HVE were used (ANOVA, $p < 0.001$)	Mean cfu reduction between test-control groups for use of: - CHX: 61.4% - HVE: 67.0% - combination of CHX+HVE: 86.0%
7	Rajachandrasekaran et al. (27)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on MeReSa with supplements agar plates, incubated at 37°C for 48 h	From patient's mouth: 1. 2 feet - patient's right 2. 2 feet - behind patient 3. 2 feet - patient's left 4. 3 feet - patient's right 5. 3 feet - patient's left 6. 5 feet - patient's right 7. 5 feet - patient's left 8. 9 feet	Significant cfu count/reduction: - in CHX (control) compared to herbal for MRSA (One way ANOVA, $p = 0.0001$) - in herbal group compared to CHX for MRSA colony compared to Actinobacter in all 8 locations (One way ANOVA, $p = 0.0001$)	Mean cfu reduction between herbal - CHX: - for MRSA: 55.6% - for Actinobacter: 17.5%

(Continued)

TABLE 2 | Continued

No.	References	Outcome (unit)	Microbiological evaluation	Site of collection	Significant results (*p* values)	% of reduction of cfu
8	Shetty et al. (28)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on Trypticase soy agar plates	1. 6in - operator's nose 2. 6in - dental assistant's nose 3. 12in - patient's chest level	Significant cfu count/reduction: - between CHX-water, CHX-TTO, TTO-water, (Kruskal-Wallis, Mann-Whitney U, $p < 0.001$)	Mean cfu reduction between CHX-water, TTO-water, CHX-TTO at all positions were 20.8%, 6.7%, 27.7%
9	Santos et al. (29)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on Brain heart infusion (BHI) agar, incubated at 37°C, 48 h	1. operator's forehead 2. 10cm from operator's mouth (vertical downward) 3. 15cm from patient's mouth - patient's chest	Significant cfu count/reduction: - between interval T1 - T2 for both CHX and water (Wilconxon test comparing within groups; $p < 0.001$) - in al 3 positions (Kruskal-Wallis): i- clinicians forehead: $p = 0.0074$ ii- clinician's chest: $p = 0.0051$ iii- patient's chest: $p = 0.0035$	Mean cfu reduction following CHX rinse at 1month at: - operator's forehead: 36.1% - operator's chest: 35.8% - patient's chest: 40.5%
10	Paul et al. (30)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 48 h	From patient's mouth: 1. 12in - patient's chest 2. 12in - operator's chest	Significant cfu count/reduction: - in all groups, in both location (one-way ANOVA, $p = 0.001$) - highest in CHX, AV then PVO-I (independent *t* test, $p = 0.001$) - between CXH - PVP-I and PVP-I - AV (ANOVA, *post hoc* comparison, $p = 0.001$)	Mean cfu reduction between CHX - PVP-I, CHX - AV and PVP-I - AV at: - operator's chest: 69.1%, 9.3%, 66.0% - patient's chest: 60.4%, 8.3%, 56.8%
11	Kaur et al. (31)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 48h	1. operator's chest, 2. 9feet behind patient's head	Significant cfu count/reduction: - in all groups, in all locations (paired t test, *post-hoc* Tukey's test) for aerobic ($p < 0.01$) and anaerobic bacteria ($p < 0.001$) - for aerobic bacteria at patient's chest between CHX-PI and PI-Ozone ($p < 0.01$) - for anaerobic at patient's chest between CHX-Ozone ($p < 0.05$)	Aerobic cfu reduction between CHX, PI, Ozone at: - operator's mask: 57%, 54%, 47% - patient's chest: 35%, 37% 29% - behind patient: 36%, 47%, 29% - anaerobic cfu reduction between CHX, PI, ozone at: - patient's chest: 43%, 36%, 35% - behind patient: 44%, 32%, 38%
12	Retamal-Valdes et al. (32)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on enriched TSA blood agar, incubated at 37°C for 72 h	1. support board in front of patient 2. operator's forehead 3. patient's chest	Significant cfu count/reduction: - in CPC+Zn+F and CHX compared to water and those who did not rinse (Kruskall-Wallis and Dunn tests, $p<0.05$) at operator's forehead and patient's chest	Mean cfu reduction between CPC+Zn+F / CHX - no rinsing at: - all areas: 70%, 77% - operator's forehead: 89%, 94% - patient's chest: 55%, 60% - support board: 70%, 81% Mean cfu reduction between CPC+Zn+F / CHX - water at: - all areas: 61%, 70% - operator's forehead: 78%, 87% - patient's chest: 55%, 60% - support board: 59%, 75%
13	Reddy et al. (33)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°Cfor 48 h	4 feet from patient's mouth: 1. 3 o'clock 2. 6 o'clock 3. 12 o'clock	Significant cfu count/reduction: - in tempered and non-tempered CHX compared to water (ANOVA, $p < 0.001$) - in all positions as a cumulative data	Mean cfu reduction between water, non-tempered, tempered CHX at: 19.3%, 83.2%, 90.0%

(Continued)

TABLE 2 | Continued

No.	References	Outcome (unit)	Microbiological evaluation	Site of collection	Significant results (*p* values)	% of reduction of cfu
14	Gupta et al. (34)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar, incubated at 37°C for 48 h	1. patient's chest 2. operator's chest 3. assistant's chest	Significant cfu count/reduction: - among all 3 groups (ANOVA, $p < 0.001$) in all 3 locations - CHX significantly reduced cfu compared to herbal mouthwash (independent t test, $p < 0.001$) in all 3 locations	Mean cfu reduction between CHX - water, herbal - water, CHX - herbal at: - patient's chest: 71.3%, 38.4%, 35.2% - operator's chest: 71.6%, 35.0%, 36.6% - assistant's chest: 16.1%, 6.9%, 9.3%
15	Joshi et al. (35)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar plates, *details of incubation: NA*	From patient's mouth: 1. 12in - neck of patient 2. 12in - operator's chest 3. 12in - assistant's chest	Significant cfu count/reduction: - patient's chest had highest contamination ($p = 0.02$) - between cold CPC - cold CHX (unpaired *t*-tests, $p = 0.0284$) - equally in CPC and CHX (ANCOVA, $p < 0.001$) - greater in warm CPC and CHX ($p < 0.001$)	Mean cfu reduction CPC - CHX at: - all positions: 0.68% - 21.8% (not significant) - patient: warm CPC - cold CPC 26.3%, warm CHX - cold CHX 31.8% - operator: warm CPC - cold CPC 18.2%, warm CHX - cold CHX 31.4% - assistant: warm CPC - cold CPC 13.0%, warm CHX - cold CHX 20.9%
16	Fine et al. (36)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on enriched soy agar, incubated at 37°C for 24–72 h	2 in from patient's mouth	Significant cfu reduction between antiseptic and water ($p = 0.0001$)	Mean cfu reduction between test - control was 93.6% and 32.1%
17	Logothetis et al. (37)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar plates incubated at 37°C for 48h	From patient's mouth: 1. operator's mask 2. 2 feet - assistant 3. 3 feet - 12 o'clock 4. 3 feet - 9 o'clock 5. 3 feet - 3 o'clock 6. 5 feet 8in - 4 o'clock 7. 6 feet - 6 o'clock 8. 9 feet - 6 o'clock	Significant cfu reduction: - in all locations by CHX compared to others ($p = 0.001$)	Mean cfu reduction between CHX-water, EO-water and CHX-EO at: - operator's mask: 69%, 1%, 70% - 2 feet - assistant: 60%, 7%, 67% - 3 feet - 12 o'clock: 43%, 8%, 51% - 3 feet - 9 o'clock: 42%, 0%, 42% - 3 feet - 3 o'clock: 42%, 0%, 42% - 5 feet 8in - 4 o'clock: 35%,−5%, 30% - 6 feet - 6 o'clock: 30%,−5%, 25% - 9 feet - 6 o'clock: 25%,−5%, 20%
18	Feres et al. (38)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar incubated with 10% CO2 at 37°C for 72 h	From patient's mouth: 1. 12in - clinician's forehead 2. 12in - support board 3. 12in - patient's chest	Significant cfu count/reduction: - in CPC and CHX compared to water and no rinsing - equally in CPC and CHX in all locations (Kruskal-Wallis and Mann-Whitney *U* tests, $p < 0.05$)	Mean cfu reduction between CPC - water / no rinsing and CHX - water / no rinsing at: - all: CPC: 68% / 77%, CHX: 70% / 78% - operator: CPC: 79% / 78%, CHX: 73% / 72% - board: CPC: 79% / 82%, CHX: 76% / 79% patient: CPC: 61% / 65%, CHX: 66% / 78%
19	Mohan et al. (39)	Bacterial count (cfu)	Bacterial contamination in aerosol, cultured on blood agar incubated at 37°C for 24 h	3 feet from patient (6 o'clock)	Significant cfu count/reduction: - within CHX ($p = 0.0049$) - between CHX and saline ($p = 0.0037$)	Mean cfu reduction between CHX - saline was 66.6% and 2.0%

(Continued)

TABLE 2 | Continued

No.	References	Outcome (unit)	Microbiological evaluation	Site of collection	Significant results (*p* values)	% of reduction of cfu
20	Swaminathan et al. (40)	Bacterial count (cfu) in saliva and aerosol	Bacterial contamination in aerosol, cultured on BHI agar incubated anaerobically at 37°C for 24 h	From patient's mouth: 1. 1 feet 2. 2 feet 3. 3 feet	Significant cfu count/reduction in: - aerosol at 3feet and saliva in all locations (Kruskal-Wallis, $p < 0.001$) - between CHX-saline, herbal-saline, CHX-herbal ($p < 0.001$)	Mean cfu reduction between CHX - saline and herbal – saline at: In aerosol: - 1 feet: 56.2%, 24.9% - 2 feet: 50.6%, 17.5% - 3 feet: 62.7%, 37.7% In saliva: - saline / CHX / herbal: –182% / 64.7% / 0.4% - CHX – saline: 103.0%, - herbal – saline: 47.7%
21	Serban et al. (41)	Total number of bacteria (cfu/m3).	Bacterial contamination in aerosol, cultured on blood agar, *details of incubation: NA*	Dentist's mask	Significant cfu count/reduction: - in CHX compared to water for bacteria ($p < 0.001$) and haemolytic bacteria ($p < 0.001$)	Mean cfu reduction between CHX - water for: - bacteria: 83.2% - haemolytic bacteria: 74.8%

HVE, high volume evacuator; CHX, chlorhexidine; CPC, cetylpyridinium chloride; PI, povidone iodine; EO, essential oil; NA, information not available in articles.

the main antiseptic agent to reduce aerosol contamination, as it is a well-established antimicrobial agent used in dentistry. CPC has also been widely tested in anti-plaque and anti-gingivitis studies (44, 45) as well as infection control in the dental clinic for disinfection of hands and surfaces (46, 47). Its potential to reduce microbial load after dental scaling is promising and, in this review, CPC had been included in three of the studies.

The key outcome measure among studies was bacterial contamination, which is predominantly related to associated aerosol contaminations. Given the importance of viruses such as COVID-19, there is a need to investigate the effectiveness of mouth rinses on viral counts. The lack of *in vivo* viricidal studies in part relates to the challenges and associated risk in culturing the virus (17). *In vitro* studies have shown chlorhexidine (0.12%) to be effective against most viruses, in as little as 30 s (48). Difference in effectiveness is thought to be due to physical/chemical structures of viruses' envelopes. In addition, several mouth rinses have been shown to be effective against standard strains of fungi *in vitro* (49). Whilst evidence of aerosol contamination and evidence of growth from such does suggest, at least theoretically, the risk of transmission, evidence from blood, saliva, or other samples can confirm actual transmission and potentially the reduction in risk following use of mouth rinses (50, 51). All studies demonstrated some degree of effectiveness of the mouth rinses, although their effectiveness varied widely. This is in part related to differences in study design (i.e., split mouth vs. subject level randomisation), differences in mouth rinses agent, differences in concentration among the same agent, differences in number and where assessments were conducted (i.e., distance from patient's mouth), and the use of other preventive measures (such as use of high-volume suctions). Such heterogeneity among studies precludes the ability to perform a meta-analysis. Nonetheless, the evidence suggests that mouth rinses are effective in reducing bacterial contamination and there is a need to consider their role in preventing viral infections, such as COVID-19.

A recent publication by Meister et al. (52) reported potential *in vitro* antiviral efficacy of some commercially available oral rinses against strains of SARS-CoV-2 when exposed within 30 s in saliva. Reasonably, strains of the virus reacted differently in many levels of susceptibility depending on the formulation prepared and contents of active ingredients in these rinses. Nevertheless, this finding may mark a turning point in efforts to lower the transmission of viruses, such as COVID-19, through use of oral rinses in the near future. Also noteworthy are the new trials being conducted to study the efficacy of oral mouthwashes on COVID-19 patients (https://clinicaltrials.ucsf.edu/trial/NCT04409873, https://clinicaltrials.gov/ct2/show/NCT04341688) that could help provide safe alternatives to dental practices and healthcare for the public at large.

Continuous periodontal care for periodontitis patients is of the utmost importance and must be done in a timely manner to prevent progression and reinfection of the disease, especially among high-risk individuals (53–56). Progression and reinfection of periodontal pockets does not only have implications for oral health, but also systemic health, given the bidirectional link between periodontal disease and

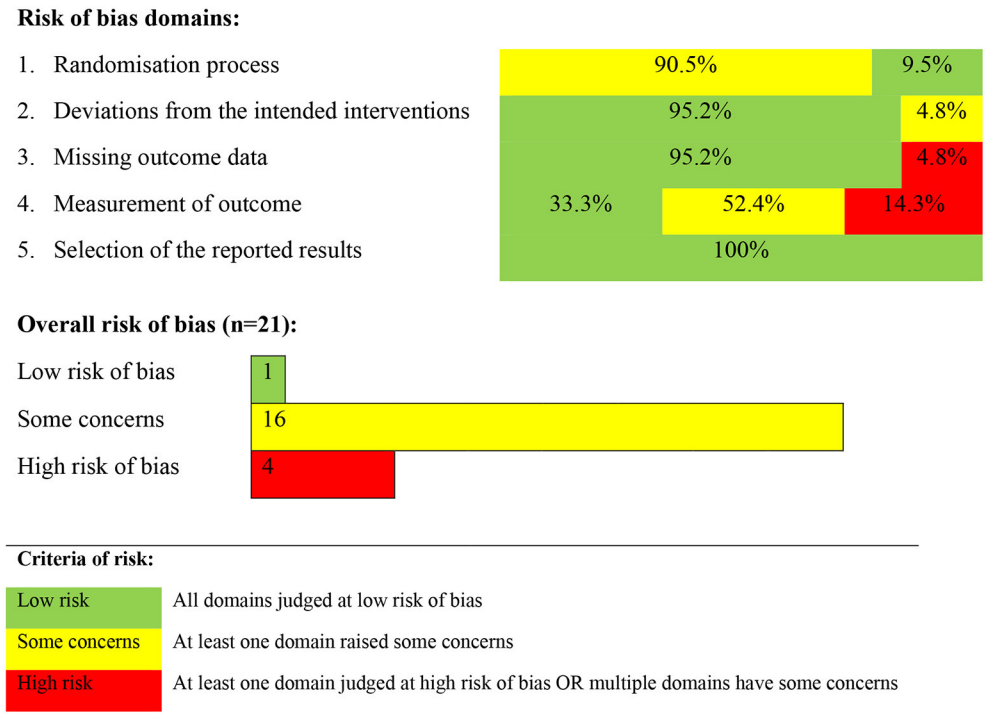

FIGURE 2 | Risk of bias criteria for the literature studied.

common non-communicable diseases such as diabetes mellitus, rheumatoid arthritis, and hypertension, and those who are immune suppressed. The treatment needs of the patients should not be hampered during this pandemic, but instead should be further prioritized, as there are restrictions of movement, limited access to dental care, and fear of cross-infections from dental clinics. Resolving this issue would offer more benefits than containing the progression of periodontal disease in the population, as it would also improve the quality of life of patients (57, 58) with long-term supportive care (55).

Pre-procedural rinsing for clinical dental procedures has long been advocated for and, during the current pandemic, its importance to practice is more relevant than ever. A number of acceptable quality RCTs of pre-procedural mouth rinsing have been conducted. The focus has been on bacterial contamination rather than viral or fungal assay. A range of different pre-procedural mouth rinses have been tested (mostly chlorhexidine), of varying concentrations and amounts, and for dental procedures of different durations and using different techniques with and without additional means. We acknowledge that these systematic review findings do not differ much from the previous reviews, nevertheless it emphasizes on the importance of pre-rinsing particularly in periodontal prophylaxis procedures. This is especially important during the current pandemic where transmission bacterial-borne diseases could well be avoided by reducing the risk on dental personnel as well as the patients. This also supports the need to include the pre-rinsing procedure for dental patients as one of the mandatory SOP in current practice.

CONCLUSION

Our systematic review found no remarkable new evidence on the effectiveness of pre-procedural rinse in periodontal prophylaxis, but it highlights the importance of the procedure to be given a mandatory emphasis in the current pandemic SOP in dental clinics. Pre-procedural rinsing for 30 s to 2 min with selected antimicrobial solutions compared to water or no rinsing were found to effectively reduce aerosol contamination in periodontal prophylaxis on dental patients. There is evidence that chlorhexidine (either 0.12 or 0.2%) is an effective antimicrobial solution for this purpose. The use of HVE during the procedure also helps to reduce the aerosol contamination.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

CM, TM-D, and SM-S: conceptualization. CM, TM-D, and SM-S: methodology. SM-S, HR, TM-D, and CM: analysis. SM-S, NS, and TM-D: writing—original draft preparation. SM-S, HR, TM-D, and CM: writing—review and editing. CM: supervision. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.600769/full#supplementary-material

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Knowledge, Attitudes, and Social Responsiveness Toward Corona Virus Disease 2019 (COVID-19) Among Chinese Medical Students—Thoughts on Medical Education

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Purpose: To assess knowledge, attitudes, and social responsiveness toward COVID-19 among Chinese medical students.

Methods: Self-administered questionnaires were used to collect data from 889 medical students in three well-known Chinese medical universities. The questionnaire was comprised of three domains which consisted of demographic characteristic collection, seven items for knowledge, and eight items for attitudes and social responsiveness toward COVID-19. Data from different universities were lumped together and were divided into different groups to compare the differences, including (1) students at the clinical learning stage (Group A) or those at the basic-medicine stage (Group B) and (2) students who have graduated and worked (Group C) or those newly enrolled (Group D).

Results: Medical students at group B had a weaker knowledge toward COVID-19 than did students at group A, especially in the question of clinical manifestations ($p < 0.001$). The percentage of totally correct answers of COVID-19 knowledge in group C was higher than that in Group D ($p < 0.001$). There were significant differences between groups C and D in the attitudes and social responsiveness toward COVID-19. Surprisingly, we found that the idea of newly enrolled medical students could be easily affected by interventions.

Conclusions: In light of this information, medical education should pay attention not only to the cultivation of professional knowledge and clinical skills but also to the positive interventions to better the comprehensive qualities including communicative abilities and empathy.

Keywords: knowledge, attitude, COVID-19, Chinese medical students, social responsiveness

INTRODUCTION

Widespread interruptions of medical education have been seen throughout history by major conflicts or infectious pandemic (1). The structure, delivery, and future of both undergraduate and graduate medical education suffered as a result, requiring educators and learners to adapt to learning from a distance while aiming for normalization (2, 3). The suboptimal replication of patient encounters and gauging audience understanding and identifying knowledge gaps seemed to be the direct challenges faced by educators during the pandemic (3, 4). Importantly, the pandemic sounded a wake-up call for us and posed new challenges to medical education, such as insufficient emphasis on public health emergency preparedness, unsophisticated interdisciplinary cooperation mechanism, and insufficient guidance in medical ethics (5). In other words, it put forward higher and stricter requirements for disease prevention and control in the future, especially for public health security and emergency response capacity of infectious diseases (5, 6).

In late December 2019, a novel coronavirus pneumonia (NCP) epidemic occurred in Wuhan, Hubei Province, China. The World Health Organization (WHO) named the pneumonia caused by new coronavirus as Corona Virus Disease 2019 (COVID-19), and the International Committee on Taxonomy of Viruses (ICTV) named this pathogen as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV-2) (7). Compared with SARS, COVID-19 has the characteristics of a long incubation period, strong infectivity, and no obvious upper respiratory symptoms (8, 9). COVID-19 has been declared as a pandemic disease by the WHO on March 11, 2020, with approximately 81,000 confirmed cases in China and over 40,000 confirmed cases in other countries cumulatively (10, 11). Therefore, the Chinese government has implemented strict public health measures against the spread of COVID-19 and dispatched medical personnel from all over the country to support the first line of Hubei epidemic situation (5, 12).

At the same time, conflicts between doctors and patients in China are still difficult to resolve in recent years, mainly caused by the contradictions in the accumulation and distribution of medical resources, the defects of the medical system itself, and the low social trust between doctors and patients (13, 14). The total number of medical damage liability disputes was around 18,112 during 2019, almost 1.7 times of 2018 (15, 16). As The Lancet reported (17–19), Chinese doctors are under threat, which may explain the reason of the low professional happiness of Chinese doctors and the low conversion rate of Chinese medical students choosing to continue medical practice after graduation (13, 20–23). However, the relationship between doctors and patients seems to be more harmonious during this pandemic (24). Medical students in China, who cannot start their new term and are isolated at home, may be responding strongly to the COVID-19 pandemic, but no data are available to describe their perception and behaviors related to this infectious disease.

Generally, Chinese medical undergraduate education contains about 1-year public fundamental courses, nearly 2-year basic-medicine courses (physiology, pathology, anatomy, etc.), and 2-year clinical-medicine learning, including theoretical study (neurology, epidemiology, pediatrics, etc.) and clinical practice. The present study investigated the attitudes, knowledge, and social responsiveness of Chinese medical students in response to the pandemic for the first time, with the aim to compare the differences between medical students of different stages and better the phased cultivation of clinical medical students in the context of Chinese excellent doctor education program reform. Importantly, it is wise for us to put insight into public health and disease prevention, thus cultivating medical teams with enough public health knowledge in face of such major infectious events.

METHODS

Development of the Questionnaire

The modified questionnaire, which was conducted in Chinese and derived from the seventh edition of diagnosis and treatment plan for pneumonia infected by novel coronavirus (25), was composed of three blocks as follows: (1) demographic characteristic of medical students, (2) attitudes and social responsiveness toward COVID-19 and the profession of doctors, and (3) knowledge related to COVID-19 including epidemiology and clinical manifestations.

The first section collected demographic data including age, gender, enrollment year, specialty choice, and whether he/she was the only child in his/her family. The second section reflecting the attitudes and social responsiveness contained eight questions, including five open-ended questions and three single-choice questions as follows: (1) "The main reasons for choosing medicine"; (2) "Supposing you were at work, your first choice during the pandemic would be"; (3) "Supposing your family is against you supporting Hubei, your choice would be"; (4) "The reasons for your choice of being a front-line worker in Wuhan"; (5) "Things I can do as a medical student during the pandemic"; (6) "Do you agree that doctors are full of happiness"; (7) "What is your future plan after COVID-19"; and (8) "Which clinical department will you work in". Knowledge related to COVID-19 (the third section) was assessed by seven items, consisting of one single-choice question, and six multiple-choice questions where the respondent may only choose a single answer or may choose multiple answers.

Sample Recruitment

This was the first study of clinical medical students' knowledge, attitudes, and social responsiveness toward COVID-19 in China. All participants were required to be medical students, whose specialty choice was Eight-year MD program or Five-year Undergraduate program in some Chinese well-known medical colleges, such as Xiangya Medical College of Central South University, West China School of Medicine of Sichuan University, and Peking University Health Science Center. The enrollment year of the participants was not used as an exclusion criterion in this study. Informed consents were obtained, and all questionnaires were administered anonymously between January 2020 and March 2020. All the participants in our study were enrolled *via* convenience sampling and were required to answer the questionnaire without any intervention by the external factors through an online platform named Wenjuanxing.

Students with SARS-COV-2 infection were excluded from this study, which may affect the mental status of them. A total of 889 clinical medical students were enrolled in this study, including 428 students in Xiangya Medical College of Central South University, 244 students in West China School of Medicine of Sichuan University, and 217 students in Peking University Health Science Center.

Statistical Analysis

Data from different universities were lumped together and were divided into different groups to compare the differences, including (1) students at the stage of learning clinical courses (Group A) or students at the basic-medicine stage (Group B) and (2) students who have graduated and worked (Group C) or newly enrolled (Group D). Data were expressed as the means and standard deviations (SDs) in the case of normally distributed data. Pearson's or Spearman's correlation tests were conducted to determine the correlations between variables. The associations between the independent variables and the dependent variables related to medical education were assessed by using univariate odds ratios (ORs) and their 95% confidence intervals (CIs). Statistical Product and Service Solutions version 26.0 (SPSS 26.0) was used for data analyses, with $p < 0.05$ as the level of statistical significance.

Ethics

All participants signed an informed consent document as required by the institutional ethics committee. This study was approved by the ethics committees of the 3rd Xiangya Hospital of Central South University.

RESULTS

Attitudes and Social Responsiveness Toward COVID-19 Among Chinese Clinical Medical Students

Table 1 shows the demographic characteristics of the participants, which matched the demography of the population to some extent (26–29). The proportion of students at different stages was balanced relatively (freshman, 26.3%; sophomore, 16.4%; junior student, 15.7%; senior student, 13.7%; fifth grade, 14.2%; senior 6 and above, 13.7%). It was found that 47.2% of the participants chose to volunteer to support Hubei Province and 46.9% chose to stick to their own hospitals if they had worked now (**Table 2**). Despite family opposition, 88.3% of the medical students surveyed were still willing to support the front-line in Wuhan, Hubei Province. Responsibilities of doctors were the main reason (92.7%) for those who wanted to work in the front-line (The vanguard and exemplary role of Communist Party members, 15.6%; Many doctors around me sign up for support, 8.2%; Be curious and want to experience, 11.4%; Others, 12.8%). As for the things medical students can do during the pandemic, the vast majority of participants said they would obey the arrangement of the government and the school (89.4%), encourage people around me to take active protective measures (86.3%), pay attention to the pandemic situation and learn efficiently (85.3%), and publish medical science articles and short videos (64.9%). When it came to the professional happiness of doctors, only 53% of the participants agreed or extraordinarily agreed Chinese doctors were full of happiness, 23.1% remained neutral, and 23.9% of the medical students were against the idea. In terms of target department, 12.5% of the participants preferred several departments with the heaviest workload during the outbreak (Department of infectious disease, 1.2%; Department of respiration, 3.6%; ICU or emergency, 7.7%), 87.5% preferred departments except abovementioned. The whole socio-demographic characteristics of the participants are presented in **Table 2**.

TABLE 1 | Demographic characteristics of Chinese clinical medical students.

Demographic characteristics	*n*	Percentage	Population (%)
Gender			
Male	387	43.5	36–47
Female	502	56.5	
Enrollment year			
2019	234	26.3	–
2018	146	16.4	–
2017	140	15.7	–
2016	122	13.7	–
2015	126	14.2	–
2014 and before	121	13.7	–
Specialty choice			
Eight-year MD program	543	61.1	–
Five-year Undergraduate program	346	38.9	–
The only child or not			
Yes	556	62.5	45–50
No	333	37.5	

The demography of the population was collected from the researches published in recent years, whose participants were clinical medical students in China (26–29).

Knowledge, Attitudes, and Social Responsiveness Toward COVID-19 in Medical Students at Different Learning Stages

Comparison of Knowledge of COVID-19 Between Students in Basic-Medicine and Clinical-Medicine Stages

A total of 302 students at the stage of learning clinical courses (Group A) and 426 students during the basic-medicine courses (Group B) were approached. **Table 3** shows a similar percentage of gender, residence, and whether he/she was the only child in his/her family.

Table 4 shows medical students at the basic-medicine learning stage had a weaker knowledge toward COVID-19 than the clinical-medicine group, especially in clinical manifestations ($p < 0.001$). Less than 30% of the participants knew SARS-COV-2 is the correct name of the virus first-occurred in Wuhan, and nearly 70% confused the concepts of COVID-19 and SARS-COV-2. The significant differences in epidemiology between

TABLE 2 | Attitudes and social responsiveness toward COVID-19 among Chinese clinical medical students.

Questions	*n*	Percentage
The main reasons for choosing medicine		
Dream and hobby	652	73.4
Medical family	78	8.8
Family recommendation	356	40.1
Stable job	340	38.3
High social status	158	17.8
Others	127	14.3
Supposing you were at work, your first choice during the epidemic would be		
Volunteer to support Hubei	410	47.2
Stick to your hospital	417	46.9
Ask for leave	12	1.3
Resign and change profession	4	0.4
Others	46	3.9
Supposing your family is against you supporting Hubei, your choice would be		
I will try my best to persuade my family and support Hubei	694	78.1
I will support Hubei without telling my family	91	10.2
I will follow my family's advice and not go to Hubei for support	104	11.7
The reasons for your choice of being a front-line worker in Wuhan		
Responsibilities of doctors	824	92.7
The vanguard and exemplary role of Communist Party members	139	15.6
Many doctors around me sign up for support	73	8.2
Be curious and want to experience	101	11.4
Others	114	12.8
Things I can do as a medical student during the pandemic		
Obey the arrangement of the government and the school	795	89.4
Encourage people around me to take active protective measures	767	86.3
Publish Medical science articles and short videos	577	64.9
Pay attention to the pandemic situation and learn efficiently	758	85.3
Do you agree that doctors are full of happiness		
Agree extraordinarily	101	11.4
Agree	370	41.6
Neutral	205	23.1
Disagree	167	18.8
Disagree extraordinarily	46	5.1
What is your future plan after COVID-19		
Clinical work in China	549	61.8
Clinical work abroad	29	3.3
Become a full-time scientific research personnel	24	2.7
Engaged in medical related profession	41	4.6
Not decided yet	231	26.0
Separated from the medical profession completely	2	0.2
Others	13	1.4
Which clinical department will you work in		
Department of infectious disease	11	1.2
Department of respiration	32	3.6
ICU or emergency	68	7.7
Departments except abovementioned	778	87.5

two groups were mainly reflected in the choices of chlorine-containing disinfectant (Group A: 73.1%, Group B: 61.5%, $p < 0.01$, OR: 1.71) and ultraviolet radiation (Group A: 66.5%, Group B: 55.2%, $p < 0.01$, OR: 1.62). Higher frequencies of right answer were found in group A among all the three questions related with clinical manifestations than group B. Besides, the bold OR

TABLE 3 | Demographic characteristics of medical students in different groups.

c	Group A *n* (%)	Group B *n* (%)	*P*-value	Group C *n* (%)	Group D *n* (%)	*P*-value
N	302 (41.5)	426 (58.5)		75 (16.5)	380 (83.5)	
Gender						
Male	130 (43.1)	187 (43.8)	0.82	26 (34.7)	170 (44.7)	0.108
Female	172 (56.9)	239 (56.1)		49 (65.3)	210 (55.3)	
Residence						
Urban	236 (78.1)	325 (76.3)	0.558	52 (69.3)	298 (78.4)	0.088
Rural	66 (21.9)	101 (23.7)		23 (30.7)	82 (21.5)	
The only child or not						
Yes	191 (63.2)	264 (62.0)	0.727	36 (48.0)	256 (67.4)	**0.001**
No	111 (36.8)	162 (38.0)		39 (52.0)	124 (32.6)	

$p < 0.001$ is indicated in bold.

indicated a significant association between better knowledge of COVID-19 and the clinical-medicine learning stage students.

Comparison of Knowledge, Attitudes, and Social Responsiveness Toward COVID-19 Between Graduated and Newly Enrolled Clinical Medical Students

In this study, participants were grouped by whether they have graduated and worked or just entered school. Group C: Doctors enrolled in 2008 or 2009 when he/she was an undergraduate. Group D: Clinical medical students enrolled in 2018 or 2019. A total of 455 samples (Group C: 75; Group D: 380) were obtained, using the same questionnaire (**Table 3**). The percentage of totally correct answers in Group C was higher than that in Group D in most of the questions of epidemiology and clinical manifestations of COVID-19 ($p < 0.001$, **Table 5**). Interestingly, there were significant differences between the two groups in the attitudes of becoming a front-line doctor in Wuhan and the professional happiness of doctors. Further sub-analysis about the items above showed that Group D seemed more active than Group C (**Figure 1**). Surprisingly, the idea of supporting Wuhan diminished significantly after the objections of their family among newly enrolled medical students (**Figures 1A,B**).

DISCUSSION

Medical education under the context of prevention and control of COVID-19 has been pushed to the forefront. It has gone beyond the scope of maintaining health and disease diagnosis and treatment and is increasingly linked to social responsiveness and national security, which we should attach vital importance to. In the face of new challenges and requirements to the pandemic, it is necessary to comprehensively analyze all kinds of problems that may occur in medical education reform and take precautions. Our study was one of the first hospital-based attempts to obtain an initial estimate of Chinese medical students' attitudes, knowledge, and social responsiveness toward COVID-19, especially under the impact of different learning stages of medical students, so as to provide effective suggestions on medical students' education.

Medical students during the clinical learning stage showed more solid knowledge toward COVID-19 than those of the basic-medicine stage, which was plausible by their deepening clinical knowledge and intellectual curiosity about disease (30). Intellectual curiosity, the core of the humanistic practice of medicine, is a desire for knowledge that leads to exploratory behavior, including an inherent and stable baseline trait (trait curiosity) and a variable context-dependent state (state curiosity) (31, 32). Studies in educational psychology suggested that trait curiosity is positively associated with academic achievement, and the educational process itself may influence the state curiosity of medical students (30, 33). What is more, for a long time, medical education in China has emphasized "treatment" more than "prevention." Specifically, in the curriculum system of clinical, basic, and other majors in medical education, the proportion of public health courses is relatively small and the structure is unreasonable (34). There are few intersections between clinical and prevention teaching and few opportunities for students from clinical backgrounds to participate in public health practice. In addition, the curriculum setting of proofreading public health emergencies in most medical schools in China is far from enough, and the proportion of professional knowledge related to public health emergencies and psychological crisis management is seriously unbalanced, or even missing, and the contents are relatively outdated and lagging behind. The majority of medical personnel are obviously deficient in the knowledge and skills of responding to emergencies. They can only temporarily train and learn protective skills in the face of an outbreak, which increases the risk of infection (6, 35). In the early stage of the response to the epidemic, we had to reflect on the unexpected casualties caused by the insufficient public health literacy of front-line medical personnel. So we should strengthen the teaching management of public health and preventive medicine in medical majors. Moreover, the training of public health and epidemic prevention talents must be expanded in scale and improved in quality. Medical colleges must set up schools of public health and strengthen the construction of schools of public health. Only in this way can a team of professionals who not only know public health but also know systematic epidemic prevention and emergency response be trained quickly (36).

TABLE 4 | Knowledge related to COVID-19 including epidemiology and clinical manifestations.

Question	Frequency of YES answer (%)		OR
	Group A *n* (%)	Group B *n* (%)	
Which one do you think is the name of the virus occurred first in Wuhan?			
SARS-COV-2	84 (27.9)	112 (26.3)	1.08
COVID-19	203 (67.2)	279 (65.5)	1.08
MERSr-COV	14 (4.6)	25 (5.8)	0.78
Ebola virus*	1 (0.3)	10 (2.2)	**0.14**
Which ways do you think are the distribution of SARS-COV-2?§			
Droplet transmission	298 (98.7)	421 (98.8)	0.88
Air-borne transmission	166 (55.0)	236 (55.4)	0.98
Contagion**	247 (81.8)	306 (71.8)	1.76
Fecal–oral transmission	161 (53.3)	244 (57.3)	0.85
Mother–baby transmission	43 (14.2)	60 (14.1)	1.01
Which masks do you think can obstruct SARS-COV-2?§			
N95	302 (100.0)	424 (99.5)	/
PM2.5 respirator	30 (9.9)	37 (8.7)	1.16
Sponge mask	5 (1.6)	8 (1.9)	0.88
Active carbon mask	8 (2.6)	11 (2.6)	1.03
Surgical mask	290 (96.0)	412 (96.7)	0.82
Which ways do you think can inactivate SARS-COV-2 effectively?§			
Heating at 56°C for 30 min	270 (89.4)	383 (89.9)	0.95
75% ethyl alcohol	293 (97.0)	403 (94.6)	1.86
Chlorine-containing disinfectant**	221 (73.1)	262 (61.5)	1.71
Chlorhexidine	81 (26.8)	111 (26.1)	1.04
Ultraviolet radiation**	201 (66.5)	235 (55.2)	1.62
What are the initial manifestations of COVID-19?§			
Fever, weakness, and dry cough	301 (99.7)	424 (94.8)	1.42
Digestive symptoms, like nausea, vomiting, and diarrhea***	280 (92.7)	345 (81.0)	2.99
Neurological symptoms, such as headache***	187 (61.9)	201 (47.2)	1.82
Cardiovascular system symptoms, such as palpitation and chest tightness**	173 (57.3)	193 (45.3)	1.62
Ophthalmic symptoms, such as conjunctivitis***	220 (72.8)	193 (45.3)	**3.24**
Only mild limb or back muscle pain***	222 (72.9)	151 (35.4)	**5.05**
Which of the following specimens can detect nucleic acids of SARS-COV-2?§			
Nasopharyngeal swab***	290 (96.0)	343 (80.5)	**5.85**
Sputum***	279 (92.4)	311 (73.0)	**4.49**
Secretion of lower respiratory tract***	264 (87.4)	320 (75.1)	2.30
Blood	176 (58.3)	242 (56.8)	1.06
Feces***	253 (83.8)	291 (68.3)	2.40
What are the criteria for the release of isolation and discharge of patients?§			
Temperature returns to normal for more than 3 days***	252 (83.4)	298 (69.9)	2.16
Respiratory symptoms improved significantly***	223 (73.8)	248 (58.2)	2.03
Pulmonary imaging shows obvious absorption of inflammation*	245 (81.1)	318 (74.6)	1.46
The detection of respiratory pathogenic nucleic acid shows negative consecutive times (Sampling interval shall be at least 1 day)	300 (99.3)	411 (96.5)	**5.47**

*OR: odds ratio [(Medical students at clinical-learning stage confirmed/Medical students at clinical-learning stage not confirmed)/(Medical students at basic-medical learning stage confirmed/Medical students at basic-medical learning stage not confirmed)] OR>3 or OR<1/3 is indicated in bold. §Multiple responses possible. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.*

When it came to the attitudes and social responsiveness toward COVID-19, almost all participants chose to do a favor to the society as medical students or as doctors supposing they were at work, revealing great social cohesion and adaptability. However, opinions seemed to differ greatly when talking about the professional happiness of doctors, which was definitely related to the high ratio of medical disputes in China (37–39). Occupational well-being is the key to maintaining the quantity and quality of new entrants (40–42), which may explain the low transformation rate from medical students

TABLE 5 | Percentage of totally correct answers to questions of COVID-19 between group C and group D.

General knowledge of NPC section items	Totally correct answer (%)		*P*-value
	Group C *n* (%)	Group D *n* (%)	
Which one do you think is the name of the virus in Wuhan?*	22 (28.8)	72 (18.9)	**0.042***
Which ways do you think are the distribution of SARS-COV-2?***	18 (24.0)	35 (9.1)	**<0.001*****
Which masks do you think can obstruct SARS-COV-2?	67 (89.3)	335 (88.2)	0.772
Which ways do you think can inactivate SARS-COV-2 effectively?***	44 (58.7)	67 (17.6)	**<0.001*****
What are the initial manifestations of COVID-19?***	35 (46.7)	52 (13.7)	**<0.001*****
Which of the following specimens can detect nucleic acids of SARS-COV-2?***	38 (50.7)	92 (24.1)	**<0.001*****
What are the criteria for the release of isolation and discharge of patients?***	55 (73.3)	166 (43.7)	**<0.001*****

*$p < 0.05$ is indicated in bold. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

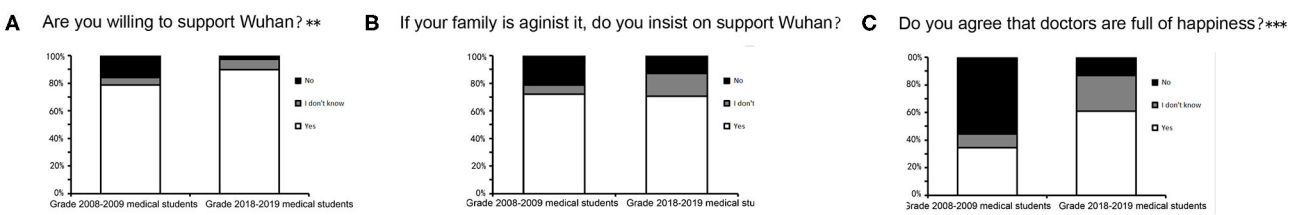

FIGURE 1 | Questions that were considered to be reflected attitudes and social responsiveness. **(A)** Are you willing to support Wuhan? **(B)** If your family is against it, do you insist on supporting Wuhan? **(C)** Do you agree that doctors are full of happiness? ** *p*-value is < 0.01. ***p*-value is < 0.001.

to doctors in China. Our results showed that newly enrolled medical students expected too much for professional happiness, which was much higher than that in the graduated group. Surprisingly, we found that the idea of newly enrolled medical students could be easily affected by interventions. In light of this information, more positive intervention such as policy guidance and communicative skills should be paid to medical students to maintain the high level of professional happiness, especially those newly enrolled. It is not only beneficial to medical students and doctors themselves but also conducive to ensuring the smooth and effective development of medical services and the stability and harmony of the entire society.

Being aware of the high conflict rate between doctors and patients in China, systemic managements and normalized media coverage and volunteerism have been performed to improve this situation (43–45). How to protect doctors from injuries in the process of practicing has always been the attention of the whole society. The Basic Health Care and Health Promotion Law is the first basic and comprehensive law in Chinese health field (45). The public have gradually realized the limitations of medicine during this pandemic, which will be helpful to build a stable foundation between the doctors and patients in China. Medical education is also constantly being reformed to cultivate modern high-quality doctors (46). Nowadays, medical education pays attention not only to the cultivation of professional knowledge and clinical skills but also to the comprehensive qualities including communicative abilities and empathy (47, 48). Surprisingly, a significant decline in empathy during medical school and residency was found in a systematic review, which was associated with gender, ethnicity, and specialty choice (49, 50). However, previous studies showed that well-received educational interventions could successfully cultivate empathy in undergraduate medical students, such as interventions of patient narrative and creative arts, writing, drama, communication skills training, and interpersonal skills training (51–53). It also emphasized the need for multicenter, randomized controlled trials, reporting long-term data to assess the longevity of intervention effects (51).

In addition, we further analyzed whether there were differences in knowledge and social responsiveness toward COVID-19 among participants of different demographic characteristics, because of the association of decreasing empathy and gender, ethnicity, and specialty choice (50). However, there were no significant differences in knowledge and social responsiveness toward COVID-19 among students in different gender (Male & Female), specialty choice (Eight-year MD program & Five-year Undergraduate program), and family (He/She is the only child & He/She is not the only child) (p both > 0.05).

However, there are some limitations in our study that must be acknowledged. (1) The participants may be worried about the confidentiality of this study since it was conducted by their peers, which may have impact on their responses. (2) We

only focused on students in some well-known Chinese medical universities, which is a good attempt, but further research will need to be carried out to expand the context covering medical colleges at different levels so as to better match the demographic characteristics of the target population. Despite these limitations, our work provides a basis for international comparisons of medical students' knowledge, attitudes, and social responsiveness facing great public emergency health and safety problems.

CONCLUSIONS

This is the first study to evaluate the knowledge, attitudes, and social responsiveness toward COVID-19 among Chinese medical students and found some differences between students at different stages to better the phased cultivation of clinical medical students during the medical education reform. Medical students during the clinical learning stage showed more solid knowledge toward COVID-19 than those of basic-medicine stage, probably due to the deepening clinical knowledge and intellectual curiosity about disease. When it came to the attitudes and social responsiveness toward COVID-19, almost all participants chose to do a favor to the society revealing great social cohesion and adaptability. Surprisingly, we found the idea of newly enrolled medical students could be easily affected by interventions. In light of this information, medical education should pay attention not only to the cultivation of professional knowledge and clinical skills but also to the positive interventions to cultivate the comprehensive qualities including communicative abilities and empathy.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors with requirement.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the ethics committee of the 3rd Xiangya Hospital of Central South University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The study idea was conceived by FW and HY. HY, YZ, and FW were responsible for the writing and revising manuscript. All authors were involved in the data collecting and statistics.

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An Online Cross-Sectional Survey on Oral Healthcare Among School-Age Children During COVID-19 Epidemic in Wuhan, China

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Background: Since the outbreak of Coronavirus disease 2019 (COVID-19), the government of China adopted many measures which changed people's lifestyle including oral health-related lifestyle to control the transmission. The aim of this study was to investigate oral health status, oral healthcare behaviors, and parental attitudes toward oral healthcare among school-age children in Wuhan during the COVID-19 outbreak and what the status would be when the outbreak is under control.

Methods: This study was an online cross-sectional survey facing elementary school students in Wuhan. The questionnaire was completed by children's parents or other family members. The information on demographic data, oral health status, oral healthcare behaviors, and parental attitudes toward oral healthcare was collected at the end of school closure. The chi-square test was used to test the association of different questionnaire items.

Results: A total of 18,383 subjects aged 6–13 years with complete data were included in this investigation, and 44.2% of them suffered pain or discomfort related to teeth and gums during the epidemic. While there might be an increasing need and concern of oral healthcare during the outbreak and even when the outbreak was controlled, the worry of infection made it difficult for people to meet their demands of dental attendance.

Conclusion: The risk of cross-infection during the treatment had a negative influence on parental attitudes toward dental attendance. Effective measures should be taken to meet people's demands of dental attendance.

Keywords: Wuhan, school-age children, oral health, epidemic, COVID-19

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INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a respiratory disease caused by a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The World Health Organization (WHO) officially recognized the outbreaks as a public health emergency of international concern on January 30, 2020 (1). As of June 8, 2020, a total of 6,931,000 confirmed cases and 400,857 deaths has been recognized in the whole world (2). This is a great challenge not only for China, but also for the world.

Oral disease is a major public health problem which affects children worldwide (3). Moreover, it would impact children's eating, speaking, emotional well-being, and general health when it happened to children (4). It is widely accepted that lifestyles are closely associated with oral disease (5), and great changes have happened on children's daily life since the outbreak of COVID-19.

Currently, the transmission of COVID-19 is regarded as starting with an animal-to-human transmission, followed by human-to-human spread. The modes of its interpersonal transmission include respiratory droplets, contact transmission, and aerosol routes. In addition, some asymptomatic spread cases were also reported (6). Considering these transmission characteristics of COVID-19, dentistry practices have a high risk of infection such as the frequent production of aerosols, constant presence of saliva, and the unavoidable touch of mouth, nose, and eyes (7). As a result, general non-emergency dental treatment was suspended and only emergency dental services were provided across China since January 2020 (8). Besides the limitation of dental attendance, many other measures, including lockdown for the whole Hubei province, quarantining infected and suspected people, restricting access to public spaces, and issuing a home quarantine order to all the residents, were adopted by the government of China to control the transmission efficiently. During this special domiciliary time, people have spent most of their time staying at home. For citizens in Wuhan, only online shopping provided by local supermarkets and markets was available and a narrow range of goods could be bought. This epidemic also has an indirect impact on people's lifestyle through psychology. It was reported that over half of Chinese suffered moderate-to-severe psychological impact during the initial phase of the COVID-19 outbreak (9).

With all of these changes, we hypothesized that the oral health status, the oral healthcare behaviors, and the attitudes toward oral healthcare of school-age children may have also changed. Wuhan, as the city facing the severest epidemic condition across China (10), may face more challenges than other cities on oral healthcare.

The aim of this study was to investigate oral health status, oral healthcare behaviors, and parental attitudes toward oral healthcare among school-age children in Wuhan during the COVID-19 outbreak and what the status would be when the outbreak is under control, thereby providing guidance for the following preventive and therapeutic oral healthcare in Wuhan and other districts which are affected by the epidemic.

MATERIALS AND METHODS

Ethical Clearance

This questionnaire survey was undertaken by the Department of Preventive Dentistry, School & Hospital of Stomatology of Wuhan University. The questionnaire was anonymous to ensure privacy protection. Ethical approval (Approval no. HGGC-035) for the study was obtained from the Ethics Committee of the School & Hospital of Stomatology of Wuhan University, and informed consent was obtained from the guardian of each subject.

Study Participants

This survey faces to elementary school students in Wuhan. In view of their age, parents or other family members are allowed to fill in the questionnaire instead.

Data collection was conducted from May 1 to 7, 2020. An online data collection was conducted because of the home quarantine order. The questionnaire was published on Wenjuanxing, and it was set as "per IP address and WeChat account can only submit the questionnaire once" through the platform to prevent double entry from participants. Then, we posted the link and the quick response code of the questionnaire, on WeChat groups and moments, attaching with a brief introduction, and asked people for passing on to their friends and relatives.

Questionnaire Survey

The questionnaire consisted of four parts: (1) demographic data; (2) oral health status; (3) oral healthcare behaviors; and (4) attitudes toward oral healthcare during and after the epidemic situation.

Demographic data was collected on gender, age, and living region, including each district in Wuhan and the other regions in China.

To understand oral health status, we listed options including dental caries, bleeding while brushing teeth, loss of restorative material, tooth trauma, bad breath, oral ulcer, and other oral discomfort (an open-ended option) for people to multiply choose. In addition, we also afforded "I don't know" and "I don't have any discomfort" options. A self-assessment regarding oral health status was required in the end of the questionnaire.

In the aspect of oral healthcare behaviors, questions were designed covering several areas: (1) the choices about using oral healthcare products for the home; (2) the choices about using oral health services toward prevention; (3) meal times; (4) frequency of having confectionery; (5) frequency of having sweet drinks; (6) frequency of having sugared drinks like milk, yogurts, milk powders, tea, soybean milk, and coffees; and (7) frequency of toothbrushing.

Attitudes toward oral healthcare were measured by questions for during and after the epidemic situation, respectively, including the level of concern on oral health, the level of concern on access to treatment, the level of worry on being infected in the process of oral treatment, and the attitudes toward dental attendance.

In this questionnaire, "before the epidemic" means the period when there is no outbreak of epidemic (before January 23, 2020); "during the epidemic" means during Wuhan lockdown (from January 23, 2020, to April 8, 2020); and "after the epidemic" means the period that the epidemic is under control.

Statistical Analysis

Data analysis was performed using the SPSS (PC version 23.0) software with the level of statistical significance set at $P < 0.001$. Subjects with missing data were excluded from the analysis.

The Optimal Binning method was used to select the optimal cutoff point of age. The chi-square test was used to test the association of different questionnaire items. McNemar's test was

taken into account to find out the different attitudes toward oral healthcare in different epidemic situations.

RESULTS

A total of 18,694 subjects took part in this investigation. Of these subjects, 159 children were excluded because their living region was out of Wuhan and 152 subjects were excluded because of their age. At last, 18,383 subjects (9,753 boys and 8,630 girls) between the ages of 6 and 13 years were included in this study. The age range of 9–10 is the cutoff point between younger and older school-age children in this study. The characteristics of the study group are shown in **Table 1**.

Table 2 presents children's oral health status during the epidemic. Almost half of the children (44.2%) suffered oral discomfort, and the younger group had a higher proportion than the older group (47.5 vs. 40.3%). Besides, more children aged 6–9 years had an increase in the severity of oral discomfort than the children aged 10–13 years during the epidemic (7.6 vs. 4.7%). No significant difference was found for gender in the items above. As for detailed experience of pain/discomfort the children suffered, the younger group had a higher rate of dental caries and loss of restorative material than the older group while more girls than boys suffered bleeding while brushing teeth.

Table 3 provides information on oral healthcare behaviors. As for the use of oral healthcare products for the home, the proportion of subjects who used electric toothbrush (33.1 vs. 30.2%), fluoride toothpaste (26.1 vs. 20.2%), mouth rinse (16.1 vs. 7.0%), and dental floss (8.8 vs. 8.0%) after the epidemic was higher than that during the epidemic. What is more, little difference was found for gender and significant difference was found for age in the use of oral healthcare products for the home. No matter the situation was during the epidemic or after the epidemic, the younger group had a higher rate of the usage of electric toothbrush and fluoride toothpaste while the older group had a higher rate of the usage of mouth rinse.

With regard to dental service utilization for preventive need, 28.3, 19.7, 10.1, and 8.7% of children took a routine check-up, pit and fissure sealant, fluoride varnish, and routine supragingival scaling before the epidemic, respectively. Moreover, the corresponding proportions were 55.1, 15.0, 10.2, and 18.6% when the epidemic was controlled. Children aged 6–9 years had a higher proportion of taking routine check-up (29.6 vs. 26.8%) and fluoride varnish (12.5 vs. 7.3%) than the older children and a lower proportion of taking pit and fissure sealant (18.6 vs. 21.0%) and routine supragingival scale (6.6 vs. 11.2%) before the epidemic. Besides, the parents of younger children had a higher willing of taking routine check-up (57.6 vs. 52.3%), fluoride varnish (13.0 vs. 7.0%), and pit and fissure sealant (17.8 vs. 11.8%) than the parents of older children and a lower

TABLE 1 | General characteristics of the study group.

	Male		Female		Total
	N	%	*N*	%	
Age (years)					
6	205	55.26%	166	44.74%	371
7	1,864	52.43%	1,691	47.57%	3,555
8	1,675	52.82%	1,496	47.18%	3,171
9	1,460	53.11%	1,289	46.89%	2,749
10	1,722	52.20%	1,577	47.80%	3,299
11	1,375	52.28%	1,255	47.72%	2,630
12	1,257	54.51%	1,049	45.49%	2,306
13	195	64.57%	107	35.43%	302
Total	9,753	53.05%	8,630	46.95%	18,383

TABLE 2 | Chi-square test for relationship of gender/age and oral health status during the epidemic.

	Gender				*P*-value	Age				*P*-value	Total	
	Male		Female			6–9 years		10–13 years				
	N	%	*N*	%		*N*	%	*N*	%		*N*	%
Experience of pain/discomfort related to teeth and gums					0.484					<0.001		
Yes	4,331	44.4%	3,788	43.9%		4,678	47.5%	3,441	40.3%		8,119	44.2%
No	5,422	55.6%	48,42	56.1%		5,168	52.5%	5,096	59.7%		10,264	55.8%
Severity of oral pain/discomfort compared with that before the epidemic					0.374					<0.001		
Increase	595	6.4%	505	6.1%		713	7.6%	387	4.7%		1,100	6.2%
No change	7,978	85.5%	7,130	86.2%		8,133	86.1%	6,975	85.4%		15,108	85.8%
Decrease	761	8.2%	636	7.7%		595	6.3%	802	9.8%		1,397	7.9%
Detailed experience of pain/discomfort related to teeth and gums												
Dental caries	1,511	35.8%	1,391	37.6%	0.246	1,888	41.1%	1,014	30.4%	<0.001	2,902	36.6%
Bad breath	1,173	27.8%	950	25.7%	0.031	1,109	24.2%	1,014	30.4%	0.194	2,123	26.8%
Oral ulcer	1,121	26.6%	916	24.7%	0.058	1,047	22.8%	990	29.7%	0.038	2,037	25.7%
Bleeding while brushing teeth	313	7.4%	397	10.7%	<0.001	358	7.8%	352	10.6%	0.087	710	9.0%
Loss of restorative material	256	6.1%	251	6.8%	0.241	351	7.6%	156	4.7%	<0.001	507	6.4%
Tooth trauma	35	0.8%	20	0.5%	0.115	29	0.6%	26	0.8%	0.901	55	0.7%

TABLE 3 | Chi-square test for relationship of age and oral healthcare behaviors during the epidemic.

	6–9 years		10–13 years		*P*-value	Total	
	N	%	*N*	%		*N*	%
Use of oral healthcare products for the home							
During the epidemic							
Manual toothbrush	7,197	73.5%	6,349	75.0%	0.050	13,546	74.2%
Electric toothbrush	3,144	32.1%	2,361	27.9%	<0.001	5,505	30.2%
Fluoride toothpaste	2,085	21.3%	1,598	18.9%	<0.001	3,683	20.2%
Mouth rinse	532	5.4%	755	8.9%	<0.001	1,287	7.0%
Dental floss	799	8.2%	663	7.8%	0.383	1,462	8.0%
After the epidemic							
Manual toothbrush	5,768	60.0%	5,316	63.9%	<0.001	11,084	61.8%
Electric toothbrush	3,407	35.4%	2,527	30.4%	<0.001	5,934	33.1%
toothpaste	2,643	27.5%	2,040	24.5%	<0.001	4,683	26.1%
Mouth rinse	1,422	14.8%	1,463	17.6%	<0.001	2,885	16.1%
Dental floss	857	8.9%	715	8.6%	0.427	1,572	8.8%
Use of oral health services toward prevention							
Before the epidemic							
Routine check-up	2,912	29.6%	2,287	26.8%	<0.001	5,199	28.3%
Pit and fissure sealant	1,829	18.6%	1,792	21.0%	<0.001	3,621	19.7%
Fluoride varnish	1,226	12.5%	625	7.3%	<0.001	1,851	10.1%
Routine supragingival scaling	648	6.6%	954	11.2%	<0.001	1,602	8.7%
After the epidemic							
Routine check-up	5,668	57.6%	4,466	52.3%	<0.001	10,134	55.1%
Pit and fissure sealant	1,751	17.8%	1,009	11.8%	<0.001	2,760	15.0%
Fluoride varnish	1,281	13.0%	597	7.0%	<0.001	1,878	10.2%
Routine supragingival scaling	1,566	15.9%	1,855	21.7%	<0.001	3,421	18.6%

willing of taking routine supragingival scale (15.9 vs. 21.7%) than the parents of older children after the epidemic. No dental service but routine check-up (26.4% for boys and 30.4% for girls before the epidemic; 54.0% for boys and 56.4% for girls after the epidemic) had a utilization difference for gender.

Table 4 shows the frequency of eating and toothbrushing. A percentage of 20.2% of children had a change of meal times. The proportion of children who had an increase in the frequency of confectionery, sweet drinks, and sugared drinks like milk, yogurts, milk powders, tea, soybean milk, and coffees was 18.4, 10.3, and 22.9%, respectively. With 7.4% of children who had an increase in the frequency of toothbrushing, only 62.3% of children brushed their teeth more than twice a day during the epidemic. The proportion of girls who had a stable meal time (81.3 vs. 78.4%) and who brush their teeth more than twice a day (65.3 vs. 59.7%) were higher than that of boys. The proportion of the younger group who had an increase in the frequency of meal times (18.2 vs. 16.7%) and who brush their teeth more than twice a day (64.2 vs. 60.2%) was higher than that of the older group.

Tables 5, **6** show parental attitudes toward oral healthcare during and after the epidemic situation. **Table 5** shows a comparison of parental concern on oral health and access to oral treatment during the epidemic with that after the epidemic. A significant difference in the level of concern existed in different periods (P-value of McNemar's test < 0.001). The levels of both concern on oral health and access to treatment after the epidemic were higher than those during the epidemic. **Table 6** shows the relationship of worry on being infected in the process of oral treatment and the attitudes toward dental attendance after the epidemic. The overwhelming majority (93.8%) of the parents worried on being infected in the process of oral treatment after the epidemic, and half of the parents (53.4%) still avoided the dental attendance after the epidemic (no treatment for 9.8%, deal with it by oneself and avoid going to hospital for 13.4%, and avoid dental practice except for emergency cases for 30.2%).

DISCUSSION

This study based on a large sample size with unequal gender distribution, which was resulted from the snowball sampling techniques and consisted with sex ratio imbalance in Wuhan (11).

The results of this study show that some changes happened on children's oral health status, oral healthcare behaviors, and parental attitudes toward oral healthcare in Wuhan during the COVID-19 outbreak. Besides, significant differences were found in oral healthcare between different age groups. What is more, while there was an increasing necessity and concern of oral healthcare because of the epidemic, the outbreak of the epidemic

TABLE 4 | Chi-square test for relationship of gender/age and oral healthcare behaviors during the epidemic.

	Gender					Age					Total	
	Male		Female		*P*-value	6–9 years		10–13 years		*P*-value		
	N	%	*N*	%		*N*	%	*N*	%		*N*	%
Meal times					<0.001					<0.001		
Increase	1,832	18.9%	1,360	15.9%		1,779	18.2%	1,413	16.7%		3,192	17.5%
No change	7,598	78.4%	6,975	81.3%		7,788	79.6%	6,785	80.0%		14,573	79.8%
Decrease	262	2.7%	242	2.8%		222	2.3%	282	3.3%		504	2.8%
Frequency increase of having desserts												
Confectionery	1,736	17.9%	1,635	19.0%	0.053	2,007	20.5%	1,364	16.1%	<0.001	3,371	18.4%
Sweet drinks	1,055	10.9%	824	9.6%	0.004	1,062	10.8%	817	9.6%	0.007	1,879	10.3%
Sugared drinks like milk, yogurts, milk powders, tea, soybean milk, and coffees	2,289	23.6%	1,896	22.1%	0.014	2,355	24.0%	1,830	21.6%	<0.001	4,185	22.9%
Frequency of toothbrushing					<0.001					<0.001		
Twice a day or more	5,822	59.7%	5,635	65.3%		6,318	64.2%	5,139	60.2%		11,457	62.3%
Once a day	3,524	36.1%	2,759	32.0%		3,190	32.4%	3,093	36.2%		6,283	34.2%
Less often than daily	394	4.0%	223	2.6%		325	3.3%	292	3.4%		617	3.4%
Seldom or never	13	0.1%	13	0.2%		13	0.1%	13	0.2%		26	0.1%
Frequency of toothbrushing					<0.001					<0.001		
Increase	707	7.3%	650	7.5%		602	6.1%	755	8.9%		1,357	7.4%
No change	8,447	86.8%	7,591	88.1%		8,688	88.3%	7,350	86.3%		16,038	87.4%
Decrease	578	5.9%	377	4.4%		546	5.6%	409	4.8%		955	5.2%

TABLE 5 | Parental attitudes toward the oral health care compared with that before the epidemic.

	During the epidemic		After the epidemic		*P*-value
	N	%	*N*	%	(McNemar's test)
The level of concern on oral health					<0.001
Increase	5,484	30.1%	6,340	35.0%	
No change	12,161	66.7%	11,475	63.4%	
Decrease	589	3.2%	293	1.6%	
The level of concern on access to treatment					<0.001
Extreme	1,783	9.8%	21,66	12.1%	
Severe	2,340	12.9%	2,705	15.1%	
Moderate	1,546	8.5%	1,816	10.1%	
Mild	4,086	22.5%	3,547	19.8%	
Minimal	4,716	26.0%	4,263	23.7%	
Not at all	3,672	20.2%	3,455	19.2%	

brought lots of difficulties for people to have a dental visit even when the epidemic was controlled.

Oral Health Status

On the whole, the school-age children in Wuhan had a poor oral health and dental caries was the most common dental disease among this group. According to some recent reports on dental health among school-age children in China, the prevalence of dental caries was 46.88% for boys and 49.63% for girls among the children aged 6–12 years in Chengdu (12). In Shenzhen, the prevalence of dental caries was 55.7% for 6–9-year-old children and 31.9% for 10–13-year-old children (13). The prevalence of self-reported caries in this survey was 41.1% for children aged 6–9 years and 30.4% for children aged 10–13 years. It is relatively low compared with that in the previous study. A main explanation for this is that it is a result acquired in a self-reported way and it is difficult for people to distinguish whether it was caries or not.

Considering that studies on self-reported oral health and its correlation with clinical evaluation among school-age children were scarce, information about changes on self-reported oral health status during the epidemic was collected to identify what effect the epidemic had on oral health status.

Among the children who suffered pain/discomfort related to teeth and gums during the epidemic, the younger group had

TABLE 6 | Chi-square test for relationship of the level of worry on being infected in the process of oral treatment and the attitudes toward dental attendance after the epidemic.

	The attitudes toward dental attendance after the epidemic																
	No treatment		Deal with it by oneself and avoid going to hospital		Avoid dental practice except for emergency cases		Some of dental practice can be performed under adequate protection measures		Going to hospital for dental treatment after testing for COVID-9		All dental practice can be performed under adequate protection measures		All dental practice can be performed without adequate protection measures		Total		*P*-value
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	
The level of worry on being infected in the process of oral therapy after the epidemic																	<0.001
Extreme	843	16.3%	873	16.9%	1,534	29.7%	1,162	22.5%	476	9.2%	258	5.0%	11	0.2%	5,157	30.4%	
Severe	404	9.4%	625	14.6%	1,482	34.5%	1,281	29.8%	283	6.6%	209	4.9%	10	0.2%	4,294	25.3%	
Moderate	139	6.6%	254	12.0%	726	34.4%	720	34.1%	149	7.1%	115	5.4%	9	0.4%	2,112	12.5%	
Mild	157	5.0%	313	10.0%	923	29.5%	1,277	40.9%	264	8.5%	179	5.7%	11	0.4%	3,124	18.4%	
Minimal	48	4.0%	92	7.6%	247	20.5%	518	43.0%	128	10.6%	164	13.6%	9	0.7%	1,206	7.1%	
Not at all	72	6.9%	116	11.1%	202	19.3%	353	33.7%	130	12.4%	165	15.7%	10	1.0%	1,048	6.2%	
Total	1,663	9.8%	2,273	13.4%	5,114	30.2%	5,311	31.3%	1,430	8.4%	1,090	6.4%	60	0.4%	16,941	100.0%	

a higher proportion of subjects who had an increased severity than the older group. It indicated that the dental health status of the younger group was more susceptible to the epidemic than the older group. It could be partly explained by the fact that the younger group had a higher proportion of subjects who had a negative change on their diets during the epidemic than the older group.

What interested us is that a significant difference existed in the percentage of subjects who suffered discomfort related to teeth between different groups when the group was divided by age but not gender, while it was quite the opposite in the percentage of subjects who suffered discomfort related to gums. The former result that the younger group had a lower proportion of subjects who suffered discomfort related to teeth than the older group can be explained by the specific timing of tooth replacement (14). The latter result showing that the boys had a lower percentage of subjects who suffered discomfort related to gums than the girls was consistent with some of the previous studies (15), but it was difficult to explain combining the oral healthcare behaviors shown in this study. In this study, girls were more interested in adhering to the oral hygiene behaviors and their parents paid more attention to their children than the boys, which were reflected in the higher prevalence of routine check-up, recommended frequency of toothbrushing, and stable meal times. All of these results indicated that the girls might have a better oral hygiene level than boys. This difference in behaviors was consistent with previous studies. Furthermore, in most of such studies, boys had a worse gum health status (16–19). The result in this study was probably caused by physiological character difference in gender, such as the specific timing of teeth replacement and the fluctuation of hormone levels with stress events (20). Further researches are needed on it.

Oral Healthcare Behaviors

The willingness to use oral healthcare products for the home and oral health services toward prevention had an increase when the epidemic was controlled. Generally, the younger group had a higher proportion of using recommended oral healthcare products and oral health services than the older group during and after the epidemic. It might be because parents tend to put more concern on the younger children.

Parental Attitudes Toward Oral Healthcare

The changes on oral health status and oral healthcare behaviors indicated that there is an increase in the demand for oral healthcare after the epidemic. Besides, a large proportion of parents had an increased level of concern on oral health during and after the epidemic according to the results from parental attitudes toward oral healthcare.

However, 53.4% of them still have a tendency to avoid going to the hospital and the proportion of people who had concern on access to treatment after the epidemic was 80.8%. It can be partly explained by the positive correlation between the level of worry on being infected in the process of oral treatment and the attitudes toward dental attendance considering the large proportion of people who had worry on being infected in the process of oral treatment after the epidemic (93.8%).

Taking all these factors into account, more attention should be paid to spread information about the measures that have been taken to reduce the risk of cross-infection during the treatment.

Strengths and Limitations

This study has both strengths and limitations. A major strength of the current study is that it is the first study to report the oral healthcare of school-age children in Wuhan during the COVID-19 outbreak. Wuhan has its specificity for it was the most serious district in China and has been under the strictest management for the longest time. Besides, it has a large sample size and the data was obtained before the epidemic passed.

There are also some limitations. Firstly, selection bias exists because of the snowballing sampling strategy and the use of an online survey. Secondly, recall bias exists as the oral health condition was reported by the parents. Thirdly, to attract more subjects to fill the questionnaire, the number of the questions was limited. As a result, many items were not able to have a further discussion.

CONCLUSIONS

In conclusion, children's oral health status was affected by the epidemic, especially 6–9-year-old children. More attention should be paid on the eating habits of children aged 6–9 and toothbrushing habits of boys. Parents in Wuhan had more concerns on oral healthcare during and after the epidemic than before the epidemic state. Besides, the findings from this study show a high amount of dental treatment needed among school-age children in Wuhan after the epidemic. However, the worry on being infected in the process of oral treatment after the epidemic might be a major factor which would stop people from dental attendance. Effective measures should be taken to meet people's demands of oral healthcare. What is more, age-specific strategies in prevention are necessary for school-age children.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the School & Hospital of Stomatology of Wuhan University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Remote Management of Prosthodontic Emergencies in the Geriatric Population During the Pandemic Outbreak of COVID-19

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The global pandemic outbreak of coronavirus disease 2019 (COVID-19) has put the world in a panic situation. It has been evident that the geriatric population is more susceptible to acquire this infection. Thus, due to this ongoing crisis, geriatric individuals cannot visit a dental operatory, and there is the possibility of their dental needs and emergencies to remain unattended. Partial or complete edentulism is very prevalent among the geriatric population, and prosthodontic management of these patients is essential for their well-being. However, the prosthesis can lead to various emergencies of the oral and its supporting structures. There are currently no available recommendations to address these prosthodontic emergencies in geriatric individuals during this pandemic period. Hence, the aims of this minireview were to discuss the common prosthodontic emergencies in the geriatric population and provide recommendations to manage these issues during the COVID-19 pandemic outbreak.

Keywords: COVID-19, geriatric dentistry, prosthodontics, portable equipment, teledentistry

INTRODUCTION

The public health crisis has evolved rapidly with the outbreak of novel coronavirus disease 2019 (COVID-19) in Wuhan, China (1), and exponentially, it has spread to all parts of the world. Healthcare providers are at a higher risk of transmission susceptibility of COVID-19 (2, 3); among them, oral healthcare professionals are at the front line. Oral health problems are more likely to be seen in the geriatric age groups than in the other age groups (4, 5). The geriatric population is prone to increased risk from COVID-19 because of psychological and pathological changes, decreased immune function, and existing comorbidity making them more susceptible to COVID-19 (6, 7). The geriatric population and people with severe underlying medical conditions such as diabetes and cardiac or respiratory diseases are at higher risk of developing symptoms of COVID-19 (1, 6). A Chinese study reported that a case fatality was more in older adults of 50 years of age or above (8). Similarly, an Italian study (9) reported that case fatality was more in geriatric patients (36%) compared with younger patients (15%). On the other hand, Ningthoujam and Khomdram (10) postulated that people with chronic health conditions are at the highest risk from COVID-19 and stated that immunity is the key to defense against COVID-19. According to the Malaysian national oral health survey of adults, it has been reported that 50.8% of the elderly aged 60 years and older geriatric patients had some form of oral prosthesis (11). The

majority of prosthodontic procedures require direct contact with the patients and indirect contact with dental technicians and dental laboratories for the procedures which include dental casts, dental impressions, fabrication of removable prosthesis, and mock trials (4, 5). The provision of prosthodontic care in geriatric patients could be urgent and/or emergency, depending on the procedure. Some of the emergencies in prosthodontics include provisional restoration debonding, denture adjustments or repairs, prosthetic fractures, and screw loosening in implant prostheses (12–14). There is an impending need to formulate specific guidelines/protocols for managing the geriatric population in the backdrop of COVID-19, considering the physiological, psychological, and treatment needs of geriatric patients, which are unique (4, 5). Nonetheless, the aims of this minireview were to gain an overview of prosthodontic emergencies in the geriatric population and provide recommendations for their management during this pandemic outbreak of COVID-19.

PATIENTS' CLINICAL HANDLING PROTOCOLS

The emergency dental intervention for a COVID-19 suspected patient, when warranted, is that the clinical setup should have negative pressure treatment rooms. The prosthodontist should be aware of the American Dental Association (ADA) recommendations (15). It is mandatory to follow standard airborne and contact protocol by appropriate use of personal protective equipment (PPE) and hand hygiene practices[1]. Prior to the beginning of prosthodontic treatments, 0.23% of povidone-iodine solution mouth rinse for at least 15 s is recommended, and this will help in the reduction of viral load in the patient's saliva (16). The use of single-use and/or disposable instruments and devices is recommended to minimize the cross-contamination of COVID-19 in the dental operatory. The use of a rubberdam will significantly reduce the spread of microbes. Radiographs are generally avoided, and if mandated, the sensor should be double covered to prevent cross-contamination (17). The emphasis on minimally invasive and non-aerosol generating procedures is recommended wherever possible in the dental operatory. The commonly seen prosthodontic emergencies in the geriatric population areas are represented in **Table 1**.

EMERGENCIES RELATED TO PROSTHESIS

Removable Partial Prosthesis

The partial prosthesis can either be made of acrylic resin, cobalt chrome, or a combination. Dentures can fracture in various ways, including the acrylic part, metal substructure, and/or clasps. The patient might present with emergencies when the broken prosthesis causes noticeable discomfort and impingement to the underlying tissues upon wearing. Prosthodontists are recommended to repair the fracture components by laboratory technicians (previous dental master casts if available or with the help of digital impressions); otherwise, the use of prosthesis is suspended if extensive work is required during this pandemic outbreak of COVID-19 to avoid any further emergency (**Table 1**).

Complete Denture Prosthesis

Complete dentures are the most common prosthesis offered to edentulous geriatric patients worldwide (18). Acrylic resin (polymethylmethacrylate) is the material of choice used to manufacture complete dentures, and fracture of the denture is the most common complication associated with it (19). Fracture complete partial dentures may occur due to various reasons such as ill-fit, poor fabrication and design, accidental dropping, parafunction leading to unfavorable stresses, and lack of balanced occlusion (20). Depending on how and where the denture has fractured, the emergency can be managed in various ways. The use of a prosthesis that can cause complications might be avoided till the end of the pandemic period. The virulent effect on acrylic components of the prosthesis is not clearly understood; however, it is better to avoid collecting the prosthesis from the affected geriatric people, and dentists are recommended to send it directly to the dental laboratory for repair. If the denture has a clean break with proper fit and fracture segments are well-located, a laboratory-based repair can be undertaken, provided that the denture is thoroughly disinfected. Sodium hypochlorite exhibited to be the most superior to all the other denture cleansers, and it was suggested that the soaking period is not more than 10 min (21). The dental laboratory technicians should strictly follow the laboratory biosafety protocols (18, 21) and guidelines related to biosafety in surgical pathology (22) while receiving the prosthesis.

Fixed Partial Denture

Cantilever bridges and resin-bonded fixed partial denture (FPD) that are loosened or dislodged can be managed after the pandemic period if the patient is asymptomatic. The hypersensitivity of exposed abutment tooth can be governed by the self-application of silver diamine fluoride (SDF) or casein phosphopeptide amorphous calcium phosphate (CPP-ACP) to the exposed vital abutment tooth (23). Conventional fixed bridge designs that have dislodged on one abutment or one retainer are challenging to diagnose. The patient is aware of the prosthesis movement, but clinically, it is not easy to diagnose for that reason for dislodgement can be parafunction, poor retention form, resistance form and framework design, and incorrect cementation procedure. If one abutment gets dislodged, it can be assessed by informing the patient and caretaker through video communication to gently tie floss underneath the bridge and pull the prosthesis away from the individual abutment teeth. If the patient is asymptomatic, removing the prosthesis can be made after the pandemic period. If the patient is symptomatic, this condition needs to be attended to, and the patient may consult the dentist either by going to his dental practice or *via* portable dentistry where the dentist can offer his services at the patient's residence. The fractured fixed partial prosthesis can cause emergency conditions if the geriatric patient presents with underlying tissue impingement and pain (24). It leads to disturbance in sleep, anxiety and

[1]https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html.

TABLE 1 | Prosthodontic emergency scenarios in the geriatric population and recommendations.

Type of prosthesis	Prosthodontic emergencies	Recommendation
Removable partial denture	If broken or does not fit	• Triaging and teledentistry and suspend the use of the prosthesis to avoid future emergencies
Complete denture	A clean break with reasonably fitting fracture segment	• Triaging and teledentistry and laboratory-based repair by strictly following laboratory biosafety guidelines related to COVID-19
Cantilever bridges resin-bonded fixed partial denture	• Dislodged prostheses usually come out in the hand of a patient • Patient symptomatic with hypersensitivity	• Teledentistry and management after the pandemic period • Application of silver diamine fluoride (SDF) to the exposed vital abutment tooth using the applicator tip
Conventional fixed prosthesis	• Fractured and asymptomatic • Fractured and impinging underlying tissue	• Teledentistry and if asymptomatic the situation can be managed after a pandemic period • Adhering to the American Dental Association, interim guidance for managing emergency dental care and careful removal of the bridge with crown remover
Single or multiple implants supported fixed prosthesis	**Biological emergencies**	
	• Acute peri-implantitis • Asymptomatic failed implants • Symptomatic failed implant	• Pus drainage and debridement under local anesthesia • Managed therapeutically by the AAA protocol (advice, antibiotic, and analgesic) • If symptoms remain, use a local anesthetic to prevent any infection and further bone loss
	Mechanical emergencies	
	Screw loosening and screw fracture	• Retightened with the corresponding screwdriver to the correct torque and retrieving the fractured screw portion is laborious and if possible should be postponed till the deferment period
Implant-supported removable prosthesis	**Biological emergencies**	
	Gingival hyperplasia beneath a bar	• Triaging and teledentistry • Temporarily topical astringents in combination with anesthetic can be used for local application and discontinuation of denture until definitive treatment is done
	Mechanical emergencies	
	• Loosening of attachments • Fracture of acrylic denture	• Can be retightened with specific screwdrivers at the appropriate torque • A fractured acrylic denture is temporarily repaired with repair resins until a new prosthesis can be fabricated later on

depression, a decrease in socialization, cognitive dysfunction, multimedications, malnutrition, and increased healthcare costs that affect the quality of life. If the decision to remove the fracture prosthesis is made, the patient should be informed of the findings and discussed options. An appropriate plan should be put in place to ensure the replacement of the fractured prosthesis with temporization. The dental setup should strictly adhere to the ADA interim guidance to manage emergency dental care (24). The precautionary measures that can be taken when dealing with a prosthodontic emergency are as follows:

- Use of anti-retraction functional dental handpiece, four-handed dentistry with high vacuum saliva ejectors.
- Cleaning of handpieces after each patient to remove debris followed by autoclave.
- Prior to treatment, mouth rinse with 0.2% povidone-iodine or 1.5% hydrogen peroxide.
- Frequently clean and disinfect the reception areas, including waiting rooms, door handles, chairs, and washrooms.
- Accompanying persons of the patient should be made to wait outside the reception area or in the car parking.
- Clinic staff should maintain a list of patients who are suspected of COVID-19 infection.
- The following techniques can be used for removing fracture FPD or partially dislodged bridges causing tissue impingement:
- Gentle tapping of the fractured prosthesis using crown removers and avoid using ultrasonic scalers or WAM key to loosen the cement as it generates aerosol.
- Partially dislodged resin-bonded FPD can be removed by placing the sharp chisel's tip.
- The prosthesis should be secured with dental floss held outside the dental assistant's mouth to reduce the risk of inhalation or swallowing the prosthesis.
- FPD can be sectioned with an anti-retraction functional dental handpiece using special diamond cutting burs and removed.

Before planning for removing the fractured prosthesis, the putty index is made to facilitate the fabrication of temporization. Once the dislodged prosthesis is removed, the underlying abutment tooth and tissue are assessed to ensure they are sound and suitable for temporization.

Single or Multiple Implant-Supported Fixed Prostheses

The often occurring biological emergency after prosthesis fabrication includes peri-implantitis and mobile implant fixtures. Acute peri-implantitis usually presents as painful and fluctuant swelling in the dental implant region, which is an emergency and often is managed by careful debridement under local anesthesia and antibiotic coverage (25, 26). Asymptomatic failed implants can be managed primarily by the AAA protocol (advice, antibiotic, and analgesic) until a substantial diagnosis, and treatment planning should be formulated in the clinical setup after the pandemic period (27, 28). Symptomatic failed implants are recommended to be removed under local anesthesia to prevent further infection and bone loss (29). The common mechanical emergencies include suprastructure prosthesis components such as fixed restorations including lost access cavity restoration and loose implant-supported crown/bridge. In lost access cavity restoration, the patient complains of food entrapment, halitosis, and unesthetic appearance of the prosthesis. Although this situation does not warrant an immediate dental clinic visit, especially during a pandemic outbreak, it can lead to much discomfort to the patient. The patient can procure a temporary restoration on an e-commerce platform such as Amazon, which still allows fast shipment or can be supplied by the dentist. Utilizing teledentistry, the patients' accompanying person can be guided by the dentist. Loose implant-supported crown/bridge mainly happens most commonly because of screw loosening and screw fracture (30). It is classified under emergencies as the patient experiences functional impairment and pain due to the impingement of underlying tissues. Screw loosening can be retightened with the corresponding screwdriver. Worn-out screws are a frequent problem with a screw-retained prosthesis; hence, it is advisable to use a new screw to reduce further fracture risk. The process of retrieving the fractured screw portion is laborious (29) and, if possible, should be postponed. In the event of failure of a luting agent, the previous cement from the crown and abutment can be removed, and the abutment' screw hole can be protected with polytetrafluoroethylene (PTFE) tape or cotton wool, followed by recementation of the crown (30).

Removable Implant-Supported Prosthesis

Prosthodontic complications commonly occur with a removable implant-supported prosthesis, ranging from loss of retention of attachment systems to loosening of screws (31). Biological emergencies usually include gingival hyperplasia beneath a bar, which can lead to failure of the denture to the seat. It often requires a comprehensive clinical and radiographical examination followed by removal of excessive soft tissue surgically. However, for a temporary measure, topical astringents combined with anesthetic can be used for local application and discontinuation of denture until definitive treatment is done. Mechanical emergencies prevent a patient from using their prosthesis due to loss of retention of the attachment system (25) caused by problems with the components in the denture and fracture of the acrylic denture base. Loose attachments present with significant discomfort for the patients due to the attachment system's mobile male counterpart. It can be simply managed by retightening with specific screwdrivers at appropriate torque. Loss of retention due to worn-out female counterparts of the attachment system usually requires replacing the female component. The replacement procedure is not an emergency and can be postponed until normalcy returns in dental practice. A fractured acrylic denture is another complication that commonly occurs and can be temporarily repaired with repair resins until a new prosthesis can be fabricated later.

Maxillofacial Prosthesis

Geriatric patients using maxillofacial prosthesis are relatively less compared with other age groups (32). However, the maxillofacial prosthesis significantly impacts the quality of life in the geriatric population (33). The common complications with such prosthesis are loss of retention and prosthesis ill-fit due to surgical site remodeling. Patients who have recently undergone maxillofacial surgery usually have a prefabricated obturator or get a temporary obturator immediately after the surgery in the hospital setup. Such patients can be advised to continue using the same until the pandemic ends (34). A recently inserted definitive obturator may cause discomfort; in such cases, a telephone consultation can help. If the problem persists, it is advised limiting the use of prostheses only while eating. In severe discomfort, it is advised to discontinue the use. Maxillofacial prosthesis requires adhesives for retention, and it can be purchased online. Any other issue related to wear and tear of the prosthesis can be addressed after the pandemic.

Role of Teledentistry for the Management of Dental Problems in Geriatric Patients

It is essential to use a teledentistry model prior to planning an appointment with geriatric patients. A choice can be made to postpone the routine prosthodontic appointment, but the patient needs to be assured and followed up for experiencing discomfort or problems related to their prosthesis. The first step of managing prosthodontic problems encountered in geriatric emergencies during these COVID-19 situations should always be virtual assistance by "WhatsApp" or "Messenger" or "Instagram" or "Skype." A message with photographs, a video recording, or a video call could be the best option for an initial evaluation in the present COVID-19 pandemic situation (**Figure 1**). This model was adopted and developed base don using a model proposed recently by Nuvvula and Mallineni (35). The healthcare provider should be trained to use modern web-based communication with patients' assessment using a teledentistry model to avoid potential transmission of COVID-19 (15). After the geriatric patients' virtual screening, it is planned to divide the patients into five groups based on COVID-19 and five groups based on treatment needs. Based on signs and symptoms, patients are divided into five groups (See Footnote 1) [(i) asymptomatic/unsuspected/unconfirmed COVID-19 cases, (ii) symptomatic and suspected/unconfirmed COVID-19 cases, (iii) stable confirmed COVID-19 cases, (iv) unstable confirmed COVID-19 cases, and (v) recovered confirmed COVID-19 cases].

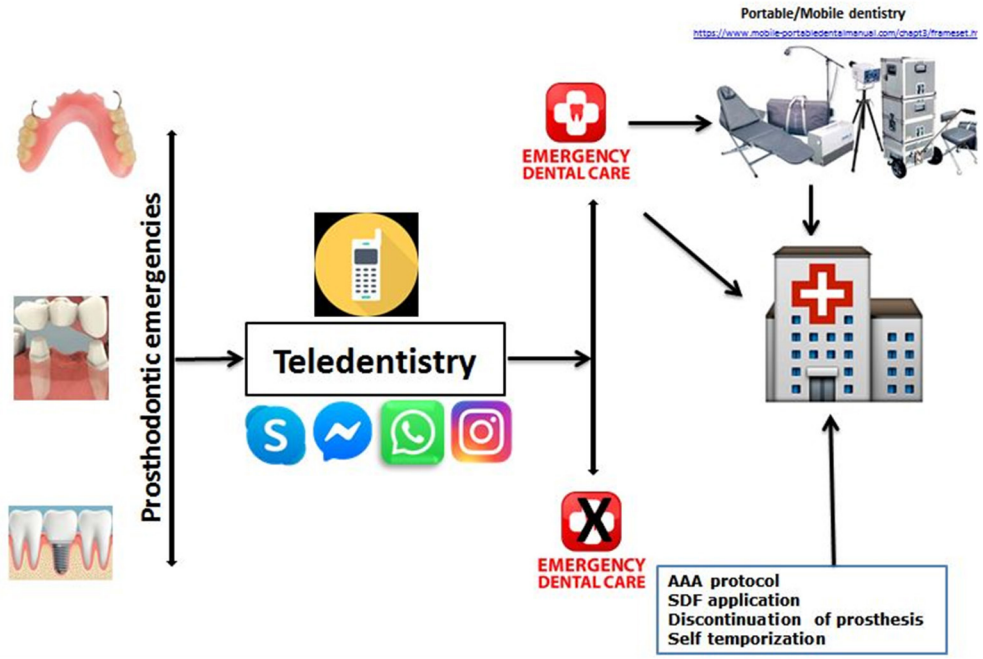

FIGURE 1 | Proposed model for the management of prosthodontic problems in geriatric patients.

DISCUSSION

The global pandemic outbreak of COVID-19 has increased the likelihood that the dental care professional should also take precautionary measures to minimize the spread. These measures include careful prescreening of the patient in a confirmed COVID-19 patient is highly obligatory. The common complications are discomfort due to faulty or fractured prosthesis in geriatric patients. On appointments, there may be a higher chance that clinicians might encounter asymptomatic/symptomatic patients. To assess and manage such patients, it might be possible to use a teledentistry model with the suggested questions as described in this short communication. Advancement in technology and social media has made communication easy, and it can be used as an appropriate tool in such pandemic outbreak situations to manage geriatric patients. Furthermore, the use of the recommended questionnaire *via* the teledentistry model has a vital role in approaching geriatric patients (**Figure 1**). The incubation period of COVID-19 ranges from 2 to 24 days, and most of the patients develop only mild symptoms (15). Consequently, all patients visiting for the management of such emergencies are potential carriers, and the clinicians are advised to follow standard infection control protocols. Radiographs are essential aids in diagnosing dental problems along with clinical examination (36). Radiography should be kept very simple to diminish patient-to-staff contact while providing diagnostic quality radiographs[2] Intraoral radiographs could be avoided to prevent potential aerosol exposure, and extraoral bitewings were suggested to be appropriate substitutes to the sectional panoramic radiographs as they offer quality images with low radiation (36). However, the authors opine that radiographs are based on essential, but the majority of the emergencies in prosthodontics other than the emergencies related to implants could be solved with recommendations discussed in this minireview. The teledentistry approach plays an essential role in the management of prosthodontic emergencies.

Geriatric patients staying in nursing homes, private homes, or institutions have practical difficulties in reaching the dental office. Henceforth, domiciliary dental care services like mobile dentistry could be used for treating such patients (37–39) by following PPE guidelines (2, 7). In mobile dentistry, the instruments, materials, and equipment can be transferred from the dental office to the patients' location to offer timely care (38). This approach, coupled with meticulous attention to instrument disinfection and application of barrier protection, can be considered a viable treatment option for handling dental emergencies in the geriatric population. Care can be limited to the basic requirements to ensuring that the patient should be pain- and infection-free, which includes treating the emergency, affecting their quality of life (40, 41). Management of biological emergencies, as discussed, can be managed with the help of this portable dentistry approach. Similarly, denture repairs, adding teeth to existing complete or partial dentures, and relining of dentures do not require extensive equipment and can be performed at the patient's residence (40, 41). In this work, the guidelines put forward are general, prosthodontic recommendations, and

[2]https://www.fgdp.org.uk/implications-covid-19-safe-management-general-dental-practice-practical-guide.

the final decision will always be the critical insight into the practitioner's judgment to manage geriatric patients during this pandemic outbreak. On the other hand, treatment can be postponed, and pharmacologic management (AAA protocol) for the pain (27, 28) and infection can always be considered (42). The practitioner should always consider the case and treatment categorization based on the recommendations that were suggested. The prosthodontic emergencies in the geriatric population cause an additional burden to those who are already suffering from one or other comorbidities. It is always advisable for the prosthodontist to evaluate these emergencies case by case and use the clinical acumen to aid in decision-making. Therefore, these recommendations help oral healthcare providers treat prosthodontic emergencies in geriatric patients during this pandemic period. Negative ion generators and high-efficiency particulate air (HEPA) filters have also shown a potential reduction of viral load in the dental operatory. The use of these two aids in dental practice may not reduce 100% of the risk of COVID-19 disease transmission in the dental operatory. However, it can assuredly minimize the chance of aerosols generated by dental procedures. In comparison with other dental clinical specialties, very nominal emergency situations occur in the prosthodontics department, and specific treatment could be delayed and does not necessarily need hurried attention. Therefore, the recommendations that are provided in this paper could serve as a guide for older adults with prosthodontic problems and also for general dental practitioners that practice prosthodontics. Consequently, the prosthodontist must visualize the clinic's protective needs as a general dentist and not just as a specialist. This present review gives awareness to the dentists to provide recommendations to prepare them with PPE and the provision of essential emergency treatments to geriatric populations with prosthesis issues.

CONCLUSIONS

The prudent method to manage prosthodontic emergencies in geriatric individuals during a pandemic is to reassure, comfort, motivate, and follow the patient remotely while they are in their home through web-based communications.

Teledentistry and/or mobile dentistry could be considered in the remote management of all prosthodontic non-emergency and emergencies. In emergency cases, teledentistry, along with portable or mobile dentistry, can be recommended with PPE managing geriatric individuals during this pandemic to avoid potential transmission of COVID-19.

AUTHOR CONTRIBUTIONS

SA and SS developed the concept. MM, AT, and SM wrote the first draft. SM designed the figure. All authors were involved in reviewing and editing the manuscript.

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Management of the Oral Health of Children During the COVID-19 Pandemic in Poland

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Managing the oral health of children during the time of a health emergency linked to the current COVID-19 pandemic presents specific problems. A high number of non-specific effective infection control protocols are available in dental settings. It is of fundamental importance to implement specific protocols relating to those clinical situations that normally do not represent an emergency but which now fall into that category. The aim of this study was the comparison of data obtained from the Regional National Health Fund (NFZ) relating to the number and the type of procedures in the oral health management of children aged 0–18 years from the Wielkopolska region, with the months of March and April of 2019 being compared with those of the, respective, pandemic period of 2020. The results showed statistical differences in the number of performed procedures when comparing 2019 and 2020; especially in April (n = 53,077 in 2019 but only n = 2,287 in 2020), when lockdown restrictions reached their highest level and when only 30% of the dental clinics for children were open for patients in the Wielkopolska region of Poland. Regarding surgical cases, there were no differences in percentage frequency between April 2019 and 2020 in terms of extractions. However, an increase was observed in abscess incisions (3.5–17.8%) and surgical dressings (1.5–10.07%). There was a decrease in the total number of performed conservative dentistry procedures in April 2020, but temporary fillings in primary and permanent teeth showed a prominent increase: from 6.4% in 2019 to 19.3% in 2020; and 5.8–11.4%, respectively. Pulp treatment and mucosal lesions therapy fall into the dental emergency category during this COVID-19 pandemic. These cases have shown an increase from 3.2% in 2019 to 12.8% in 2020 for pulp treatment, and from 2.3 to 4.3% for the treatment of oral mucosal lesions. As suspected, after the lockdown was implemented, the number of pediatric dental cases were low. Moreover, the analysis revealed differences in the profile of clinical situations that represented the emergency cases and the pandemic treatment protocols. Future implications suggest that dental prophylactic procedures be included in pandemic protocols with even dental services being limited to a form of urgent treatment. New approaches and treatment models should be implemented in the control of the infectious spread of the disease in the management of the oral health of children in this pandemic period.

Keywords: oral health, children, COVID-19 pandemic, dentistry, protocols

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INTRODUCTION

During the new SARS-CoV-2 virus pandemic, countries implemented different measures for the delivery of dental care for adult and pediatric patients (1). Many dental procedures have been associated with the transmission of SARS-Cov-2 via droplets and splatter from blood and saliva through direct and indirect contact. Direct transmission occurs through respiratory droplets by coughing or sneezing, or in the course of dental procedures between the dentist, the assistant, and the patients. The risk of indirect transmission can occur when a patient or the dental team are in contact with surfaces contaminated with the virus (dental chair, spittoons, floor, etc.). Some procedures, such as using a high-speed turbine, ultrasonic scaler and spray gun, produce a large amount of aerosol, which can remain suspended in the air for long periods of time, increasing the risk of transmission (2, 3).

Because children can be asymptomatic or present with non-specific symptoms, it has been recommended that all pediatric patients and their parents/caregivers should be considered as possible carriers of SARS-CoV-2. This potentially puts pediatric dentists at a high risk of infection (4–7). The management of pediatric patients can also be influenced by behavioral problems connected with greater dental anxiety due to the use of personal protective equipment (mask, goggles, face shield) which makes conversation and adaptation to the dental environment very difficult (8).

During the COVID-19 epidemic (March/April 2020), according to the national recommendations for medical specialties, the routine dental treatment for children in Poland was suspended and limited to emergency cases only. It was reported that only 30% of the dental clinics for children were open for patients in the Wielkopolska region of Poland.

Therefore, the objective of this study was to compare a number dental cases performed in both children and adolescents with national insurance before (March and April 2019 y) and during the actual phase of COVID-19 (March and April 2020 y).

MATERIALS AND METHODS

Approval by the Ethics Committee has been revised by the project protocol at the Poznan University of Medical Sciences (9/06/2020). The analysis was based on data from dental offices in Wielkopolska, which have signed a contract for medical services agreed to be performed in dental care in pediatric dentistry. The data collection was obtained from the National Health Fund (NFZ) under its administrative agreement as well as freedom in access to information guaranteed by national law regulations. The patient status was obviously kept anonymous. One of the examiners involved in data extraction holds the function of a qualified consultant in pediatric dentistry (A.O.). A comparison of the dental service from March/April 2019 vs. March/April 2020 was conducted. The above-mentioned period of time was chosen as a blow up of the first SARS-CoV-2 pandemic lockdown in relation to community activities. Dental service procedures for surgery (S) and conservative dentistry (CD) were divided into the following categories: tooth extraction: single-root (category S), tooth extraction: multiple-root (S), surgical dressing (S), abscess incision (S) and temporary filling of secondary teeth (category CD), temporary filling of primary teeth (CD), restoration of primary teeth (CD), restoration of secondary teeth (CD), post-trauma reconstruction of tooth (CD), trepanation (CD), devitalization (CD), and other procedures (CD). It is noteworthy that during the severe phase of the SARS-CoV-2 pandemic, regular prosthodontic, orthodontic, and periodontal procedures were suspended and they were not considered as marginal in the analyzed period of time.

In 2019, 97 dental clinics in Wielkopolska provided dental services for children and adolescents up to the age of 18. In 2020, this number increased to 99 offices that were dedicated to treating children.

The dental offices are required to submit a report each month for counter-work. The work done during the pandemic period did not release these dental offices from the obligation to submit these reports.

Only correctly filled forms of the reports were accepted in the study and these served as a sources of data. In this study, we have not analyzed data according to age, sex, location of dental practice, specialty of dental practitioners, or any level subject to satisfaction with the provided dental services.

According to the information provided by the Central Statistical Office (GUS), the population of children and adolescents (up to 18 years of age) in Wielkopolska in 2019 stood at 744,228.

Statistical Analysis

The data are presented as absolute numbers and/or percentages, as appropriate. The categorical data (2×2 or larger contingency tables) were analyzed using the Chi-squared test for independence and/or as the difference between the two proportions. All results were considered significant at $p < 0.05$. All statistical analyses were performed with InStat 3.06 (GraphPad Inc.) and Statistica 13.0 (StatSoft Inc.).

RESULTS

The results showed statistical differences in the number of performed procedures when comparing 2019 and 2020; especially in April ($n = 53{,}077$ in 2019 but only $n = 2{,}287$ in 2020), when lockdown restrictions reached their highest level and when only 30% of dental clinics for children were open for patients in the Wielkopolska region of Poland (**Table 1**).

The statistical analysis revealed changes in the profiles of clinical situations that represented emergency cases and pandemic treatment protocols (**Figures 1**, **2**).

Regarding the surgical cases, there were no differences in percentage frequency between April 2019 and 2020, in terms of extractions.

No correlation was seen between the month/year and the number of extractions in both single-rooted and multi-rooted teeth, and the distribution of services was similar in all the periods analyzed, namely March 2019, April 2019, March 2020, and April 2020 ($p = 0.9186$), despite the fact that fewer surgical procedures were performed in 2020.

TABLE 1 | The statistical comparison in the number of dental service procedures for surgery and conservative dentistry (primary and secondary dentition) performed in March and April 2019 and 2020 y.

	2019	2019	2020	2020	Differences between months*
	March	April	March	April	Multiple comparisons (*p*-value)
Dental surgery procedures	***n* = 1,440**	***n* = 1,283**	***n* = 564**	***n* = 112**	
Tooth extraction: single-root	556	487	204	31	April 19 vs. April 20 ($p = 0.031$)
Tooth extraction: multi-root	829	731	326	49	April 19 vs. April 20 ($p = 0.007$) March 20 vs. April 20 ($p = 0.007$)
Surgical dressing	28	19	17	12	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p = 0.001$)
Abscess incision	27	46	17	20	April 19 vs. April 20 ($p < 0.001$) March 19 vs. April 19 ($p = 0.009$) March 20 vs. April 20 ($p < 0.001$)
Conservative dentistry procedures	***n* = 8,127**	***n* = 7,517**	***n* = 3,501**	***n* = 352**	**Multiple comparisons (*p*-value)****
Temporary filling of secondary teeth	462	433	199	40	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)
Temporary filling of primary teeth	525	480	205	68	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)
Restoration primary teeth	4,074	3,847	1,709	12ggz6	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)
Restoration of secondary teeth	1,999	1,840	915	50	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)
Post-trauma reconstruction of tooth	70	62	36	2	ns
Trepanation	265	241	100	45	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)
Devitalization	236	169	99	15	April 19 vs. April 20 ($p = 0.016$) March 19 vs. April 19 ($p = 0.048$)
Other procedures	496	445	238	6	April 19 vs. April 20 ($p < 0.001$) March 20 vs. April 20 ($p < 0.001$)

*n, number of total procedures; *statistical significance difference using the χ^2-test $p < 0.05$; **statistical significance difference using the χ^2-test except post-trauma reconstruction of toot; non-significance $p > 0.05$ (ns).*

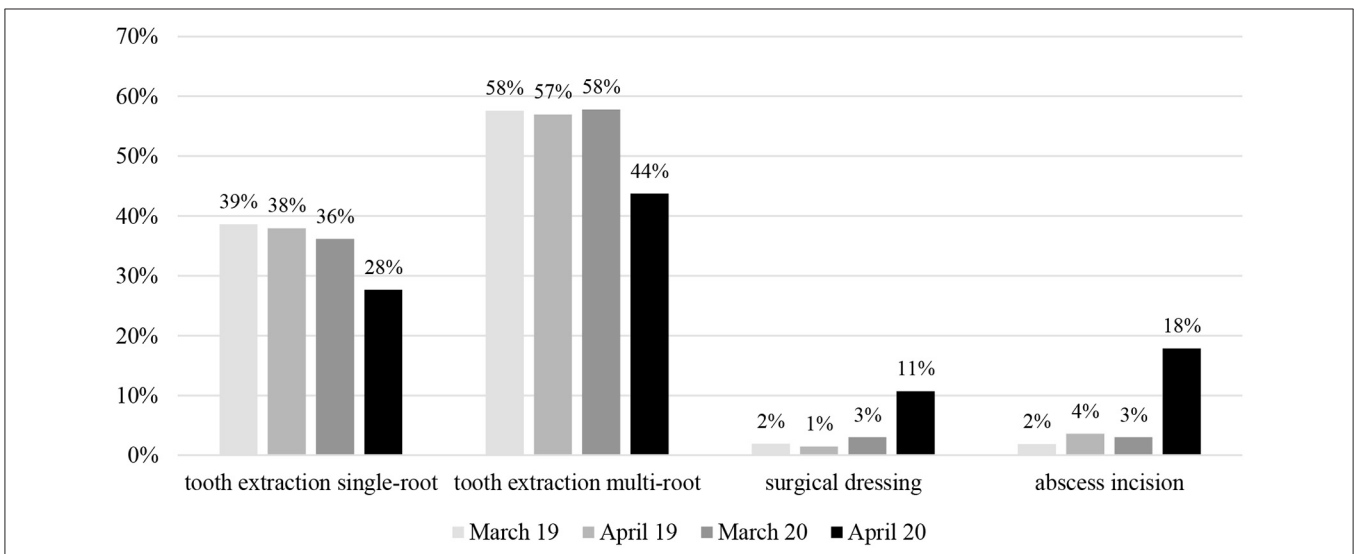

FIGURE 1 | The Statistical comparison showing the percentage of the dental service procedures for surgical procedures (primary and secondary dentition) conducted in March and April 2019 and 2020 y.

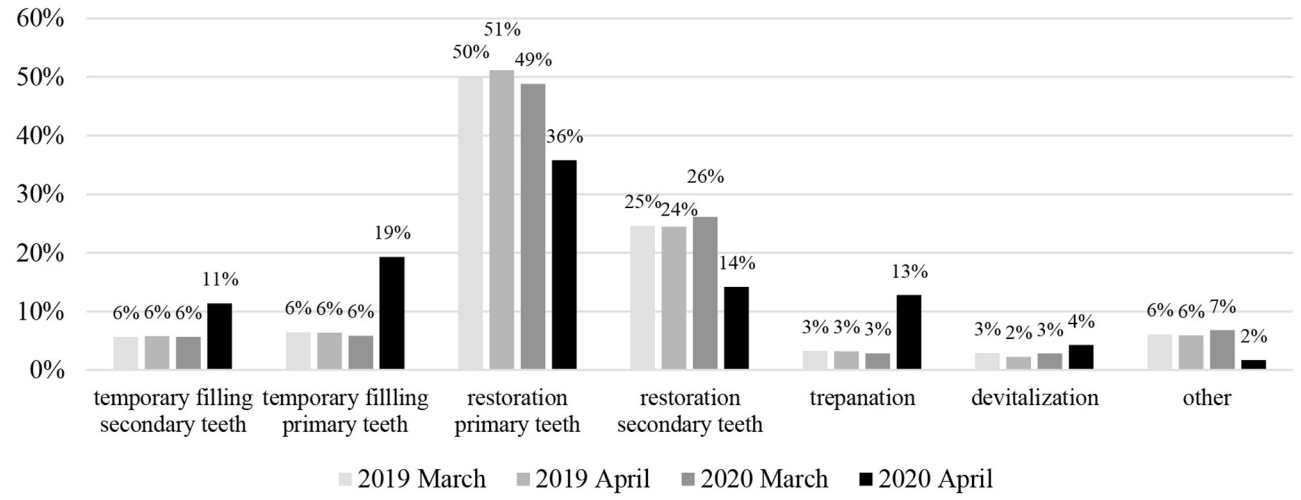

FIGURE 2 | The Statistical comparison showing the percentage of dental service procedures for conservative dentistry (primary and secondary dentition) performed in March and April 2019 and 2020 y.

However, an increase was observed in abscess incisions (3.5–17.8%) and surgical dressings (1.5–10.07%) (**Table 1**, **Figure 1**).

There was a decrease in the total number of performed conservative dentistry procedures in April 2020, but temporary fillings in primary and permanent teeth showed a prominent increase: from 6.4% in 2019 to 19.3% in 2020; and 5.8–11.4%, respectively.

For deciduous and permanent teeth, in March 2019, April 2019, and March 2020, the distribution of the number of therapeutic dressings and fillings was similar and there were no statistical differences. Only April 2020 was different, where the number of fillings decreased in relation to an increased number of dressings ($p < 0.0001$) (**Table 1**).

Taking into consideration the relationship between the time period (month/year) and the performance of the trepanation/devitalization procedures, there was a different distribution of trepanation/devitalization in the month of April 2020 when compared to the other months analyzed ($p < 0.002$): more trepanation was performed in relation to devitalization, with the ratio changing to 75/25% (previously it was 52.9/47.1%; 58.8/41.2%; 50.3/49.7%) (**Figure 2**).

Pulp treatment and mucosal lesions therapy fall into the dental emergency category in this COVID-19 pandemic. These cases showed an increase from 3.2% in 2019 to 12.8% in 2020 for pulp treatment and from 2.3 to 4.3% for the treatment of oral mucosal lesions.

DISCUSSION

As suspected after the lockdown was implemented, the number of pediatric dental cases were low. Moreover, the analysis revealed differences in the profile of clinical situations that represented emergency cases and pandemic treatment protocols.

During the first phase of the COVID-19 pandemic, restricting dental interventions to urgent and emergency cases showed that pediatric dentists have to reassess the benefits of treatment and the risks for the patient associated with potential infection. In this context, good cooperation with the parents/guardians of the child with regard to assessing the health condition and the observed symptoms as well as the measures that can be taken if a visit to the office of the dentist is not essential, as minor issues can be managed at home, makes it possible for pediatric dentists to effectively diagnose and treat patients through the use of "teledentistry."

Based on information from the literature, clinical conditions that are not classified as urgent dental interventions and can be managed by parents/guardians at home include, among others, loss of temporary fillings in deciduous and permanent teeth which is not accompanied by pain; delayed exfoliation of deciduous teeth; and pericoronitis around the erupting permanent molars (2).

The new experience of the COVID-19 pandemic shows how important the roles played by the development of information and communication technology and the ability to remotely solve dental problems that do not require a visit to a dental office are in doctor–patient communication (9).

Considering the effects of the pandemic-related restrictions on the provision of dental services, it seems that when the pandemic is over it will be necessary to adapt to preventive and therapeutic procedures in pediatric dentistry based on the new challenges and greater treatment needs. The effects of abandoning preventive treatment in children is likely to result in a rapid increase in the need for therapeutic intervention, and reinstating regular preventive visits ought to be the first stage in the post-pandemic resumption of operations of pediatric dental offices.

During the SARS-CoV-2 pandemic, the new epidemic situation requires the implementation of special protocols and precautions, in line with the recommendations and the guidelines issued by local and global health authorities.

The safety and health of children is always a priority, especially in the dynamic conditions of the pandemic. The concerns of parents on the potential risks associated with the visit of their child to the office of the dentist can often be the reason for refraining from making an appointment, which in turn may lead to the worsening of the original problem accompanied by complications and severe pain (2).

A child who comes to the dentist with severe pain, especially during the pandemic, is at a high risk of internalizing the unpleasant sensations associated with a dental visit. In the future, this may lead to anxiety that may make it impossible for them to cooperate during dental treatment, requiring sedation via inhalation or general anesthesia.

The role of a pediatric dentist is to educate the parents/guardians of the children about the safety of the procedures performed at the office of the dentist during this particularly difficult pandemic period, while at the same time making them aware of the risks associated with abandoning or delaying dental interventions (10).

It is noteworthy that regular prosthodontic, periodontal, and orthodontic procedures were suspended due to risk of bioaerosol contamination risk at the dental clinics and, hence they were not performed. The reason for this decision lies in significant exposure to infection to pathogens from the mouth and respiratory tract of the patients (11). When working with rotary burs that require water cooling, bioaerosol is formed and the water drops act as carriers of infectious microorganisms. In 2020, the Ministry of Health completed the group of the highest risk factors for infection with biological material by including the Sars-CoV-2 virus transmitted by droplets on the list. The dynamic COVID-19 pandemic forced changes in the organization of work in dental offices based on infection prevention protocols. It is assumed that the longer bioareosol treatment, the higher the risk of COVID-19 infection in the operating areas in dental clinics. Therefore, it is believed that exposure is one of the highest cause of infection among all medical professions. Additionally, if the patient is a child who cries or screams, the risk increases significantly due to the speed of the bioaerosol trajectory. The present COVID-19 time has forced the implementation of safe work procedures with the recommendation to use effective personal protective equipment. For example, use of disposable PPE kits, face shields, masks, caps, protective materials in clothing resistant to fluids, and moisture with hermetic eye protection are recommended for dental personnel.

The recommendations of dental teams with regard to the dental visits of children during the pandemic include the presence of only one parent/caregiver in the office of the dentist; the use of oxidizing rinses (H_2O_2) or chlorhexidine (CHX) before examining the mouth of the child; isolating the treatment area with rubberdam; four-handed work; and the use of high-power suction systems.

The procedure should include all the necessary interventions aimed at relieving the pain of the patient at the given moment, as well as those aimed at preventing the development of other potential ailments; therefore, it is recommended that a dental clearance examination of the mouth of the child should be performed during the same visit (12).

Similar approaches to dental patients may include rinsing with commercial mouthrinses to reduce oral viremia from saliva and oral mucosa. There are several active ingredients of mouthwash that have been tested for their anticovid efficacy. These include chlorhexidine gluconate, cetylpyridine chloride, povidone iodine, hydrogen peroxide, cyclodextrin, and essential oils (13). Other reports confirm the effective protection against the transmission of SARS-CoV-2 due to the content of zinc and stannous fluoride in mouthrinses and toothpastes. In all cases, it is indicated that the exposure to the oral cavity of the patient and the concentration of an active ingredient may have a crucial role in reducing virus transmission (14).

Work safety against the spread of infectious bioaerosols has significantly increased the amount of medical wastes. Currently these materials are not biodegradable, not recyclable, and require radical disposal by complete incineration. This form of waste reduction is not ecological and burdens our environment with harmful gas compounds. Therefore, there is a need to improve protective materials, both for the safety of the natural environment and to provide better protection for medical personnel as well. The search for new solutions will also ensure a sense of security and verify the readiness of stationary dental care. Moreover, it is important for the academic education in all medical professions, which is currently a great challenge (15–19).

To assume, the end of the pandemic will have to mean the beginning of new methods of management in pediatric dentistry. Intelligent technology systems would prefer a remote dentist–patient communication as a standard tool for projecting oral health education in children, especially in the school age. Virtual contact as teleprophylaxis or dental tele-advice will be helpful in strengthening healthy habits and motivating children to follow hygienic and dietary recommendations. As recommended, minimally invasive procedures should be employed, but also strenuous efforts should be made to promote preventive measures.

The pandemic has exacerbated inequalities in health care access. Changing the financing of services for children and adolescents and shifting funds from the model of reimbursement of reconstructive treatments to prophylaxis are currently the expected models in dental care.

CONCLUSIONS

During the first phase of the COVID-19 pandemic, restricting dental interventions to urgent and emergency cases showed that pediatric dentists had to reassess the benefits of treatment and the risks for the patients associated with potential infection.

The analysis revealed changes in the profile of clinical situations that represented emergency cases and pandemic treatment protocols. Future implications suggest that dental prophylactic procedures be included in pandemic protocols with even dental services being limited to a form of urgent treatment.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

MR is responsible for statistics analyzes. AC-J for ideas and revisions of the research. All authors contributed to the article and approved the submitted version.

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