



# Association Between Malocclusion and Academic Performance Among Mongolian Adolescents

Nomin Badrakhkhoo<sup>1</sup>, Yusuke Matsuyama<sup>2</sup>, Miyu Yoshizawa Araki<sup>1</sup>, Yuko Unnai Yasuda<sup>1</sup>, Takuya Ogawa<sup>1</sup>, Tsasan Tumurkhoo<sup>3</sup>, Ganjargal Ganburged<sup>3</sup>, Amarsaikhan Bazar<sup>4</sup>, Takeo Fujiwara<sup>2\*</sup> and Keiji Moriyama<sup>1\*</sup>

<sup>1</sup> Department of Maxillofacial Orthognathics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan, <sup>2</sup> Department of Global Health Promotion, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan, <sup>3</sup> Department of Prosthodontics and Orthodontics, School of Dentistry, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia, <sup>4</sup> Section of Research and Development, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia

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### \*Correspondence:

Takeo Fujiwara  
fujiwara.hlth@tmd.ac.jp  
Keiji Moriyama  
k-moriyama.mort@tmd.ac.jp

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**Objective:** Malocclusion has been reported to affect the daily lives of schoolchildren adversely, but little is known regarding the association between malocclusion and academic performance. We aimed to investigate the association between malocclusion and academic performance among adolescents in Mongolia.

**Methods:** We conducted a cross-sectional study of 767 students aged 7–16 years from two public schools in Ulaanbaatar, Mongolia. Three orthodontists evaluated the need for malocclusion treatment in the participants and determined the type of malocclusion using the Index of Orthodontic Treatment Need and dental casts. The academic scores of study participants in 20 subjects were provided by their schools. Z-scores within subjects were calculated and aggregated into both overall and in six groups of subject categories comprised of mathematics, science, social science, language, arts, and physical education. A multiple linear regression analysis was performed to determine the association between malocclusion, malocclusion type, and academic score adjusted for gender, age, school, and family income.

**Results:** Of the 767 students, 32.6% had malocclusion, and dental crowding was the most prevalent type (162 cases, 21.1%). Malocclusion was not significantly associated with the z-score of overall academic score [coefficient: 0.04, 95% confidence interval (CI): –0.11 to 0.19]; however, dental crowding was significantly associated with the overall academic score (coefficient: –0.19, 95% CI: –0.35 to –0.03), after adjusting for covariates. Other types of malocclusion were not associated with academic scores. Among the six subject categories, arts (coefficient: –0.20, 95% CI: –0.36 to –0.04) and physical education (coefficient: –0.24, 95% CI: –0.42 to –0.07) were significantly associated with dental crowding.

**Conclusions:** Schoolchildren in Mongolia with dental crowding may be prone to poor academic performance, particularly in arts and physical education classes. Further randomized controlled trials are needed to determine whether the treatment of crowding boosts academic performance.

**Keywords:** malocclusion, academic performance, epidemiology, orthodontics, quality of life, Mongolia

## INTRODUCTION

Higher academic performance predicts socioeconomic status in adulthood (1). Various factors determine the academic performance of students; these factors can be divided into three categories: socioeconomic, environmental, and the student's individual factors (2). Health status is included in the student's individual factors (2), and a significant body of research has demonstrated that student health determines academic achievement in school (3, 4). Student health factors, such as body mass index (BMI) (5), quality and duration of sleep (6), diabetes (7), consumption of sweets (8), and depression (9), have been found to be associated with academic performance.

Oral health is also associated with academic performance. Dental caries, being the most prevalent dental disease (10), impair the daily lives of schoolchildren by causing problems with eating, smiling, and sleeping (11). As such, dental caries may be an oral health problem affecting the academic performance of students (12). A previously published literature review of 17 studies showed an inverse association between the number of days absent from school due to dental problems and academic performance (13). Another study found associations between dental problems and psychosocial outcomes, such as shyness, unfriendliness, feeling worthless, and unhappiness, in adolescents (14). A cross-sectional study of 2,871 schoolchildren in North Carolina suggested that the improvement of children's oral health may be a way to improve their educational experience (15).

Despite many studies focusing on dental caries as a determinant of academic performance (14, 16), to our knowledge, only one study has focused on the association of malocclusion with academic performance (17). It is well-known that some types of malocclusion lead to functional and, most importantly, esthetic limitations (18). Esthetic problems can lead to psychological discomfort of the patient, including tenseness, and self-consciousness (18); thereby, it may influence academic performance of children. A study conducted in India reported that severe malocclusion, as evaluated by the dental aesthetic index (DAI), influenced the psychosocial well-being of adolescents, who may avoid participating in social activities and tend to underperform academically (17). However, the DAI is unable to individually assess some occlusal traits, such as a deep overbite (19). Specific types of malocclusion were proven to affect different aspects of adolescents' life, including oral symptoms, functional limitations, and social well-being (20). Therefore, additional studies using other valid orthodontic indices to explore further the pathway of association between malocclusion types and academic performance are required. Also, the above study suggested that students with malocclusion academically underperformed, but the study failed to assess academic performance thoroughly by each subject category (17). As not all classes require students' interactions, more investigation with the academic subject category is needed.

Mongolia obtained democracy in 1990 and gradually transitioned into the market economy. At the same time, drastic changes also occurred in the education system as it changed from the 10-years school system to a 12-years school

system (21). According to the Education Law, a citizen of Mongolia must obtain basic compulsory education and has a right to access general secondary education free of charge. Governmental funding for education increased by a factor of 1.54 from 1992 to 2002, and by a factor of 1.76 from 2003 to 2013 (22). The market economy also led to lifestyle and dietary changes. Brushing habits, the intake of sweets, and prolonged breastfeeding resulted in significant odds ratios for the development of caries (23), with an average of more than one-third of primary teeth decayed or filled in 5-year-old children (10). Consequently, preliminary primary teeth loss due to severe caries can cause malocclusion to develop in Mongolians (24). It was previously reported that the prevalence of malocclusion among Mongolian adolescents was 35.2% (25). Because the prevalence is low compared to that of other countries (26), the number of adolescents receiving orthodontic treatment is much smaller (1.2%) (25). Thus, the investigation is needed to understand better the association between malocclusion and academic performance among adolescents in East Asian populations, including developing countries like Mongolia, where the malocclusion is emerging, and few children are being treated.

## MATERIALS AND METHODS

### Study Participants

This cross-sectional study used data from a longitudinal population-based epidemiological investigation. The study field was Ulaanbaatar, the capital city of Mongolia. The population of Ulaanbaatar was ~1,372,000 at the time of data collection, representing almost half of the country's population (46.8%) (27). Participants were recruited from two public schools that agreed to participate in the survey, with one located more centrally in the Bayanzurh district and the other in the suburban Songino Khairhan district. Two classes were randomly selected from grades 4 to 10 (i.e., aged 7–16 years old) in each school. Exclusion criteria were the presence of orthodontic treatment history. The detailed methods of the survey have been published elsewhere (25).

This article is structured according to STROBE guidelines for cross-sectional studies. Written informed consent was obtained from the caregivers through the classroom teachers. The study was approved by the Ethical Review Board of the Mongolian National University of Medical Science (No. 13-12/1A) and Tokyo Medical and Dental University (No. D2013-071).

### Measurement of Academic Performance

Academic performance was evaluated by the final grades of the students at the end of the school year, provided by the schools. Public schools have the same criteria for the academic assessment of their students, which are established by the municipal secretary of education. Academic performance in Mongolia is graded by percentage (ranges from 0% to 100%; 60% is the passing grade). A total of 20 school subjects were classified into six groups following the ministerial decree and regarding the type of science (28) as follows: math group (mathematics subject only), natural science group (chemistry, biology, science, and physics

subjects), social sciences group (health, geography, history, civil education, and social science subjects), language group (English language, Mongolian language, literature, Mongolian script, and Russian language subjects), arts group (craft, arts, music, and drafting subjects), and physical education group (physical education subject only). All academic performance scores were standardized (i.e., converted to z-score) within the grade. The mean score for each group of subjects and overall subjects was calculated and used as the dependent variable in subsequent analysis.

## Measurement of Malocclusion

Three orthodontists (TT, GG, TO) evaluated the need for malocclusion treatment and type of malocclusion using the Dental Health Component of the Index of Orthodontic Treatment Need (IOTN) (29) and dental casts of the participants. Calibration of the investigators showed high inter-rater reliability ( $\kappa = 0.68$ , 96.7% agreement) (25). IOTN grades range from 1 to 5, and grades 1–3 are considered as “no treatment needed,” while grades 4 and 5 are considered as “needs treatment.” Malocclusion type was diagnosed by the following criteria: increased overjet (>6 mm overjet) and reverse overjet (<-1 mm overjet), deep bite (>3.5 mm overbite), and crowding ( $\geq 5$  mm crowding), which were recorded as “need for treatment.” Anterior and posterior cross bite, scissor bite, and hypodontia were also recorded if present.

## Statistical Analysis

Multiple linear regression analysis was applied to investigate the association between malocclusion, malocclusion type, and academic performance. Sex, age, school, and family income were adjusted because a previous study among adolescents with malocclusion reported gender differences in academic performance (17), and another study reported the association of family income with the academic performance of adolescents (30) and malocclusion severity (31). The school variable was controlled as two public schools in our study are from centrally and suburban areas of Ulaanbaatar, which could have differences in average academic performance and malocclusion treatment needs. Family income level was assessed by the questionnaire and categorized into low (<500 thousand tugriks), average (510 thousand –1,000 thousand tugriks) and high (>1,001 thousand tugriks; 1 USD  $\sim$ 1,437 tugriks).  $P < 0.05$  was considered statistically significant. All analyses were performed using the Stata 15 SE software program (StataCorp LP, college Station, TX, USA).

## RESULTS

**Table 1** describes the demographic characteristics of the participants. Of the 767 participants [mean age: 11.3; standard deviation (SD): 1.9; 43.8% male], 250 adolescents (32.6%) had a need for orthodontic treatment. Overall, the families of 131 (17.1%) adolescents had a high family income, 395 (51.5%) had average income levels, and 213 (27.8%) had low income levels. A chi-squared test revealed no significant association

between the above demographic characteristics and the presence of malocclusion with the need for orthodontic treatment.

As **Table 2** shows, the most common malocclusion type was dental crowding (21.1%) and the least common was reverse overjet (1.6%). Meanwhile, anterior (9.4%) and posterior (6.8%) crossbites were the second and third most abundant types of malocclusion, respectively. Hypodontia (4.6%), scissor bite (4.2%), and increased overjet (3.8%) had approximately equal rates of occurrence.

**Table 3** shows both the overall academic score and the score within each group of subjects after standardizing by malocclusion treatment needs and dental crowding treatment needs. Students with malocclusion had higher scores overall ( $z = 0.06$ ;  $z = 0.03$ ), and in science ( $z = 0.10$ ;  $z = 0.00$ ), language ( $z = 0.05$ ;  $z = 0.03$ ), arts ( $z = 0.12$ ;  $z = 0.02$ ), and physical education ( $z = 0.07$ ;  $z = 0.02$ ) than students without malocclusion. In contrast, students with dental crowding had lower academic scores than students without crowding in all subject categories.

**Table 4** shows the association between malocclusion treatment need, malocclusion type, and overall academic score. Malocclusion treatment need was not associated with the overall academic score in the crude model [coefficient: 0.04; 95% confidence interval (CI):  $-0.11$ – $0.19$ ] or the adjusted model (coefficient: 0.08; 95% CI:  $-0.06$ – $0.22$ ). Among malocclusion types, only dental crowding exhibited a significant association with academic performance [coefficient:  $-0.23$ ; 95% CI:  $(-0.40)$ – $(-0.06)$ ], and it remained significant in the adjusted model [coefficient:  $-0.19$ ; 95% CI:  $(-0.35)$ – $(-0.03)$ ].

The association between crowding and each subject group was further evaluated to determine which groups of subjects were associated with crowding (**Table 5**). The arts subjects group [coefficient:  $-0.20$ ; 95% CI:  $(-0.36)$ – $(-0.04)$ ] and physical education subject group [coefficient:  $-0.24$ ; 95% CI:  $(-0.42)$ – $(-0.07)$ ] had significant associations with dental crowding after adjusting for covariates. Mathematics, science, social science, and language subject groups were not significantly associated with dental crowding.

## DISCUSSION

We employed objective measurements of malocclusion and academic performance to reveal that malocclusion was not significantly associated with academic performance in schoolchildren in Mongolia. However, dental crowding was significantly associated with lower overall academic performance, particularly in arts and physical education subjects.

To our knowledge, only one study in India (17) has evaluated the association between malocclusion and academic performance in children; this study reported that students with severe malocclusion are more likely to exhibit poor academic performance (17). In contrast, we did not find a significant difference in academic performance depending on the need for malocclusion treatment. The inconsistency of these findings might be explained by the severity of the condition, given that the previous study focused on the academic performance of adolescents with severe malocclusion. They

**TABLE 1** | Demographic characteristics of the participants, by presence of malocclusion.

	All (N = 767)		No malocclusion (N = 517; 67.4%)		Malocclusion (N = 250; 32.6%)		P-value
	N	%	N	%	N	%	
<b>Sex</b>							
Male	336	43.8	217	42.0	119	47.6	0.141 <sup>a</sup>
Female	431	56.2	300	58.0	131	52.4	
<b>Age (years)</b>							
7	1	0.1	1	0.2	0	0.0	0.904 <sup>b</sup>
8	18	2.4	12	2.3	6	2.4	
9	101	13.2	73	14.1	28	11.2	
10	118	15.4	80	15.5	38	15.2	
11	174	22.7	120	23.2	54	21.6	
12	144	18.8	94	18.2	50	20.0	
13	92	12.0	60	11.6	32	12.8	
14	97	12.7	65	12.6	32	12.8	
15	20	2.6	11	2.1	9	3.6	
16	2	0.3	1	0.2	1	0.4	
<b>School</b>							
Outside of the city center	358	46.7	252	48.7	106	42.4	0.099 <sup>a</sup>
Within the city center	409	53.3	265	51.3	144	57.6	
<b>Family income level</b>							
High	131	17.1	83	16.1	48	19.2	0.743 <sup>a</sup>
Average	395	51.5	271	52.4	124	49.6	
Low	213	27.8	144	27.9	69	27.6	
Missing	28	3.7	19	3.7	9	3.6	

<sup>a</sup> chi-square test was applied.

<sup>b</sup> Fisher's exact test was applied.

evaluated malocclusion with the DAI, which scores malocclusion on a continuous scale and differentiates cases within severity levels. Our measurement, the IOTN, evaluates orthodontic treatment needs but does not rank cases with greater or lesser need for treatment within grades (32). Instead, we evaluated the type of malocclusion, which was not evaluated in the previous study, and found that dental crowding was significantly associated with academic performance.

Social and biological pathways might explain the link between malocclusion and low academic performance of children. Malocclusion is associated with the emotional well-being and self-esteem of school children (33, 34). Poor oral condition results in an impaired smile and these children are likely to be socially excluded and perform poorly at school (12). Dental crowding, which showed association with overall, arts, and physical education performance, often presents in the anterior portion and can induce gingivitis (35). Symptoms such as gum bleeding and bad breath were associated with lower self-esteem and academic performance in children (12).

As for biological pathways, dental crowding is associated with headache (36), resulting in poor academic performance (37). Occlusal contact decreased by dental crowding (38) might reduce trigeminal nerve stimulation (39). Sensorimotor signals from the trigeminal nerve activate specific brain areas

**TABLE 2** | Malocclusion type distribution.

Type of malocclusion	All (n = 767)	Male (n = 336)	Female (n = 431)
	n (%)	n (%)	n (%)
Increased overjet	29 (3.8)	10 (3.0)	19 (4.4)
Reverse overjet	12 (1.6)	8 (2.4)	4 (0.9)
Deep bite	13 (1.7)	6 (1.8)	7 (1.6)
Anterior crossbite	72 (9.4)	39 (11.6)	33 (7.7)
Posterior crossbite	52 (6.8)	24 (7.1)	28 (6.5)
Scissor bite	32 (4.2)	20 (6.0)	12 (2.8)
Crowding	162 (21.1)	76 (22.5)	86 (20.1)
Hypodontia	35 (4.6)	18 (5.4)	17 (3.9)

and, as a consequence, improve cognitive performance (40); a lack of signals from the trigeminal nerve causes cognitive impairment (41). Dental crowding as a chronic stressor might enhance the secretion of stress-activated neuronal responses in the hippocampus area. Thereby, it may suppress learning and memory ability (42, 43). Another study has proven that occlusal condition can influence the increase in cerebral blood flow generated by a motor task involving the fingers (44).

**TABLE 3 |** Mean of academic score (Z-score) by malocclusion status and crowding.

	Malocclusion		Crowding	
	No	Yes	No	Yes
Overall score	0.03	0.06	0.09	-0.14
Mathematics	0.02	0.00	0.06	-0.12
Science	0.00	0.10	0.07	-0.09
Social science	0.05	0.03	0.07	-0.09
Language	0.03	0.05	0.08	-0.11
Arts	0.02	0.12	0.10	-0.13
Physical education	0.02	0.07	0.10	-0.18

**TABLE 4 |** Association between malocclusion type and overall Z score.

	Overall score			
	Crude		Adjusted <sup>a</sup>	
	β	95% CI	β	95% CI
Malocclusion	0.04	-0.11, 0.19	0.08	-0.06, 0.22
Increased overjet	0.02	-0.35, 0.39	-0.07	-0.41, 0.28
Reverse overjet	-0.15	-0.72, 0.41	-0.05	-0.58, 0.49
Deep bite	0.22	-0.32, 0.77	0.20	-0.31, 0.72
Anterior crossbite	-0.02	-0.26, 0.22	0.05	-0.18, 0.27
Posterior crossbite	0.11	-0.17, 0.38	0.13	-0.13, 0.40
Scissors bite	0.07	-0.28, 0.42	0.23	-0.10, 0.57
Crowding	-0.23	-0.40, -0.06	-0.19	-0.35, -0.03
Hypodontia	0.18	-0.16, 0.52	0.20	-0.11, 0.52

CI, confidence interval.

<sup>a</sup> Adjusted for gender, school, family income level and age.

This result is consistent with that of previous studies that have found occlusion to be important for maintaining and/or enhancing motor function (45). Further, a recent functional magnetic resonance imaging (fMRI) study revealed that molar biting was positively associated with the blood oxygenation level-dependent (BOLD) signal and electromyogram (EMG) activity of the masseter and temporal muscles, while incisal biting was negatively correlated with them (39). Their finding suggests molars engage in powerful chewing given that the brain areas related to powerful motor control are activated, whereas brain areas related to fine motor control are activated by incisor biting (39). According to the evaluation criteria of school subjects in Mongolia, the art subject category requires drawing skills, playing musical instruments, learning precision in drafting class, and handcrafting in crafts class (46). Such tasks might require fine motor skills, potentially explaining why dental crowding was associated with reduced scores in arts and physical education subjects in the present study.

Our study has several limitations. First, when evaluating the association of malocclusion treatment need and academic performance, only the worst occlusal trait was used to diagnose the malocclusion. However, we additionally evaluated all malocclusion types that meet the criteria. Second, only

**TABLE 5 |** Association between crowding and Z-score on each subject group.

	Crude		Adjusted <sup>a</sup>	
	β	95% CI	β	95% CI
OVERALL SCORE				
Crowding	-0.23	-0.40, -0.06	-0.19	-0.35, -0.03
MATHEMATICS				
Crowding	-0.18	-0.35, -0.01	-0.15	-0.32, 0.03
SCIENCE				
Crowding	-0.16	-0.33, 0.01	-0.13	-0.30, 0.03
SOCIAL SCIENCE				
Crowding	-0.16	-0.33, 0.02	-0.12	-0.28, 0.05
LANGUAGE				
Crowding	-0.20	-0.37, -0.03	-0.15	-0.31, 0.02
ARTS				
Crowding	-0.23	-0.40, -0.06	-0.20	-0.36, -0.04
PHYSICAL EDUCATION				
Crowding	-0.28	-0.45, -0.11	-0.24	-0.42, -0.07

CI, confidence interval.

<sup>a</sup> Adjusted for gender, school, family income level and age.

two public schools were recruited into the study, which can be a potential source of sampling bias. The findings might not be directly applicable to children living in rural areas in Mongolia. Third, our *post-hoc* power calculation showed that the statistical power to detect the overall academic score difference by malocclusion treatment need was 6.8%. Thus, we might have failed to detect the difference in population means. Fourth, due to the cross-sectional design of our study, no cause-and-effect relationship can be inferred from our data. The biological mechanism requires investigation through future studies, and a randomized controlled trial is also necessary to determine if the treatment of crowding increases academic performance.

In conclusion, we found that dental crowding is significantly associated with the academic performance of Mongolian adolescents. Our findings suggest that schoolchildren with dental crowding tend to show poor academic performance. Due to the rapid economic and social changes in Mongolia, our findings are important for comparison with future studies. Promoting oral health in school settings might improve children's academic performance. For example, regular dental health checkups in schools, which has not been previously implemented in Mongolia, might contribute to the early detection of malocclusion.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of privacy or ethical restrictions. Requests to access the datasets should be directed to Keiji Moriyama, k-moriyama.mort@tmd.ac.jp.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Review Board of the Mongolian National University of Medical Science (No. 13-12/1A) and Tokyo Medical and Dental University (No. D2013-071). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

NB contributed to conception, design, data acquisition, analysis, and interpretation and drafted and critically revised the manuscript. YM contributed to design, analysis, and interpretation and critically revised the manuscript. MA, YY, and TO contributed to conception, design, data acquisition, and

interpretation and critically revised the manuscript. TT, GG, and AB contributed to data acquisition and critically revised the manuscript. TF contributed to design, data acquisition, analysis, and interpretation and critically revised the manuscript. KM contributed to conception and design and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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