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The importance of visual acuity screening in dental education amongst undergraduate dental students: a straightforward method

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Background: Visual acuity plays a pivotal role in a dental professional's daily performance and screening the students' field of vision in their early formative years ensures successful undergraduate programmes.
Aims: To compare near and distance visual acuity and stereopsis in first-year and final-year dental students and investigate students' perception of their vision.
Method: This was a cross-sectional study involving 100 KCL first- and final-year dental students that underwent assessment of their vision and completed a self-perception questionnaire. Near visual acuity was assessed using a standardised near vision test chart, distance visual acuity using COMPlog (Clinical Vision Measurement Systems Ltd, London, UK) computerised software and stereopsis using the Frisby stereotest. On the basis of the Mann−Whitney test, no statistical differences were found between the first-year and final-year students' near and distance visual acuity, nor in stereopsis difference at a significance level of $\alpha = 0.05$. The null hypothesis was accepted.
Results: 84% of first-year students and 94% in final-year students attained the highest binocular near visual acuity score of 0.50M. Distance visual acuity scores showed a median ETDRS (Early Treatment Diabetic Retinopathy Study) Letters score 94 in the first-year group and 95 in the final-year group. 8% of students were found to have correctable refractive errors in distance visual acuity. The majority of students across both year groups were able to discern 20 s arc of smallest disparity. Final-year students reported worrying about their eyesight significantly more than the first-year students.
Conclusions: No statistically significant differences were found in near and distance visual acuity, and stereopsis, between first-year and final-year dental students. However, 8% of students were identified with undiagnosed, correctable refractive errors. The importance of students' vision in clinical dentistry is highlighted and regular eye examination is recommended.

KEYWORDS
dental undergraduate, dental student, visual acuity, haptic training, virtual reality simulator, visual-motor skills

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1 Introduction

The dental profession, in general, requires the acquisition of numerous skills including good patient management, good communication and very precise manual dexterity, amongst others. A fundamental skill required for any dental professional is the ability to carry out optimal clinical work by having unimpaired vision. Dental surgeons are required to accurately distinguish shapes, dimensions, colour, distances and depth. Motor skills are often tested on entry to dental school, however, currently there is no established requirement or assessments of dental students' vision on admission nor during their training programme. This research is particularly valuable as virtual reality simulators are becoming increasingly popular in dental education (1), and where visual acuity is key in having successful training outcomes.

The faculty of sight is very complex and its different attributes include, but not limited to, colour vision, visual acuity and binocular vision. Concurrently, many factors influence visibility including illumination, distance and angle of object viewed, size of object. High hand-eye coordination requires good visual acuity as well as other psychological and neurological qualities such as stereopsis (2).

Visual acuity is a measure of the ability of an eye to distinguish shapes and details of objects at a given distance (clarity and sharpness of vision). Dentistry, with its small operating field, requires visual control of small structures which is also known to decrease throughout life (3). Stereopsis can be defined as "the information regarding three-dimensional object structure which is made available through retinal image differences" (4). These differences arise because the eyes are horizontally separated by approximately 6 cm in humans. Previous studies have shown that: (i) horizontal disparities can provide information about the slant, curvature and depth of proximally fixated objects (5–7); (ii) humans use this information (8–10); (iii) the use of stereopsis (and other "cues") is task dependent (11, 12).

Studies have repeatedly shown that dentists' self-assessment of their visual performance is unreliable. Responses to the questionnaires used in previous studies have shown a poor correlation with objective findings of the visual tests, with dental surgeons not being aware of their visual deficiencies (13, 14).

The current body of evidence looking at visual acuity and stereopsis in dental students is very limited. Most studies have small sample sizes and/or incorporate inherent biases. One study showed that dental students exhibited difficulty estimating depths and distances early on in their programme and that visual accuracy increased with clinical experience (15). Another study adopted a successful method at screening dental students for visual defects including squints, limits of convergence, and defective stereopsis (16). In a similar study a simple eyesight screening method led to identification of defective colour-vision with implications on shade taking during prosthetic treatments (17). The aim of this study was to test an association between visual training effects and dental undergraduate training. The justification was obtained as there has been no testing and no results have been published testing this.

2 Aims

The aim of this cross-sectional study was to compare near and distance visual acuity and stereopsis in first-year and final-year dental students. The secondary aim was to investigate first-year and final-year undergraduate dental students' perception of their vision.

3 Materials and methods

3.1 Study participants

This was a cross-sectional observational study comparing first-year and final-year dental students at King's College London University, London, United Kingdom. All voluntary participants were recruited consecutively by the principal researcher (JP) between September 2018 and February 2019. Asample size of 47 was calculated using G*Power 3.1.9.7, Universität Düsseldorf, Düsseldorf, Germany for a significance $\alpha = 0.05$, power = 0.8 and a medium effect size = 0.6. To allow for drop-outs 50 students were recruited in each year. students were obtained in each of the year groups. The criteria for inclusion in the study were:

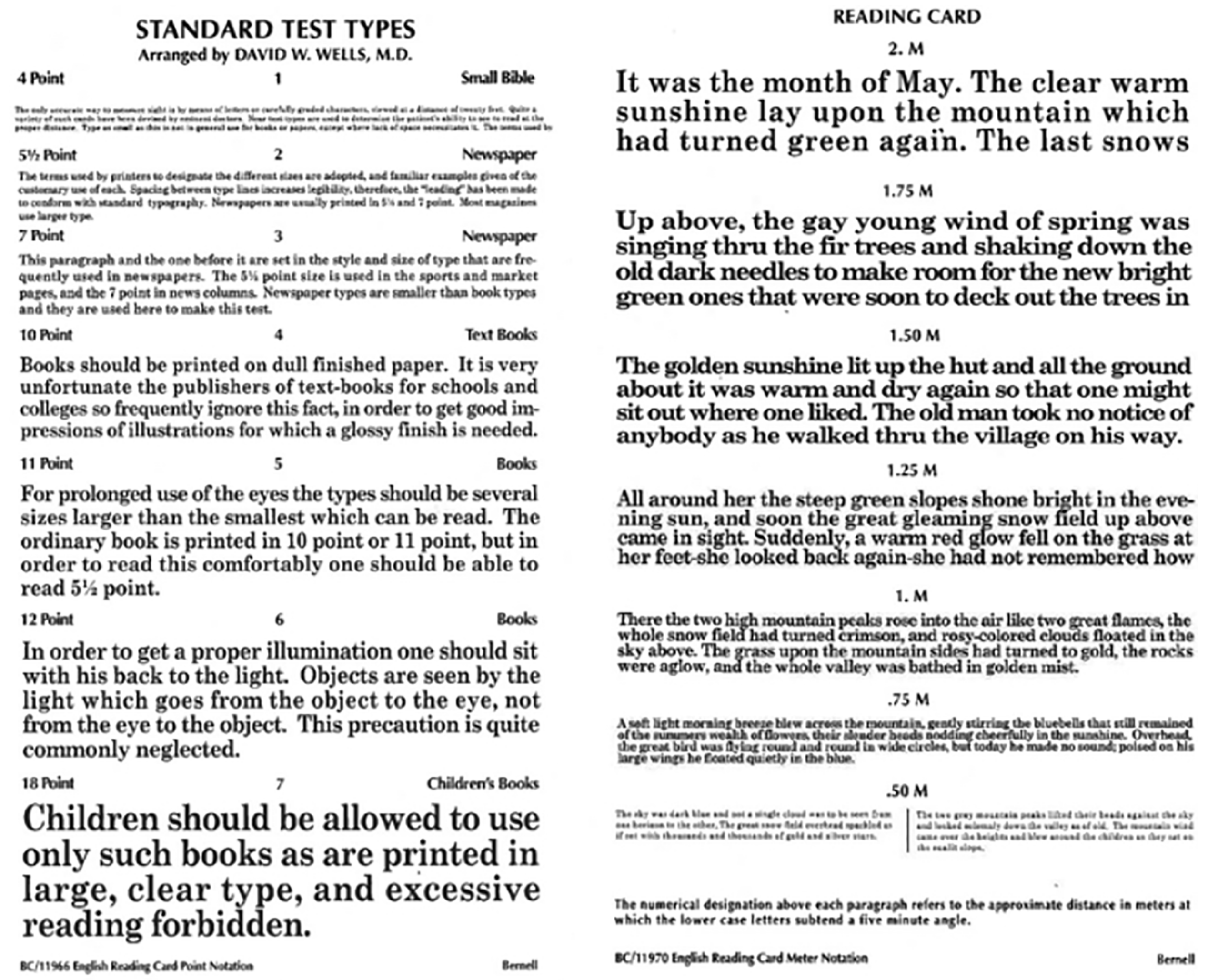
- Dental students at King's College London University, London, United Kingdom in the first year and final year of the dental undergraduate programme
- Above 18 years of age
- No previous eye surgery

3.2 Method

Participants were given an information sheet, written consent form to complete, and a self-perception visual functioning questionnaire (Supplementary Material S1). A data capture form was used by the researchers to record anonymised participant demographics, date of birth, gender, and verify whether visual aids were worn at the time of the study. In cases where students wore glasses or contact lenses in everyday tasks, they were asked to wear these for the visual tests, thereby testing corrected vision. The same form was also used to record the findings from visual tests.

3.2.1 Near visual acuity

To assess near visual acuity, a standardised near vision test chart approved by the Faculty of Ophthalmologists, was used (Figure 1). This test was carried out by one trained assessor for all participants for accuracy and repeatability. The reading chart uses Times New Roman font with sentences at varying sizes of print with logarithmic progression. The smallest print size that each student could read with fluency was recorded for each eye independently, right and then left, with the contralateral eye completely obscured using an occluder. The test was then repeated for binocular vision, both eyes unobscured. The test distance was standardised and measured to 40 cm in each case.


STANDARD TEST TYPES
Arranged by DAVID W. WELLS, M.D.

4 Point 1 Small Bible

5½ Point 2 Newspaper

The terms used by printers to designate the different sizes are adopted, and familiar examples given of the customary use of each. Spacing between type lines increases legibility, therefore, the "leading" has been made to conform with standard typography. Newspapers are usually printed in 5½ and 7 point. Most magazines use larger type.

7 Point 3 Newspaper

This paragraph and the one before it are set in the style and size of type that are frequently used in newspapers. The 5½ point size is used in the sports and market pages, and the 7 point in news columns. Newspaper types are smaller than book types and they are used here to make this test.

10 Point 4 Text Books

Books should be printed on dull finished paper. It is very unfortunate the publishers of text-books for schools and colleges so frequently ignore this fact, in order to get good impressions of illustrations for which a glossy finish is needed.

11 Point 5 Books

For prolonged use of the eyes the types should be several sizes larger than the smallest which can be read. The ordinary book is printed in 10 point or 11 point, but in order to read this comfortably one should be able to read 5½ point.

12 Point 6 Books

In order to get a proper illumination one should sit with his back to the light. Objects are seen by the light which goes from the object to the eye, not from the eye to the object. This precaution is quite commonly neglected.

18 Point 7 Children's Books

Children should be allowed to use only such books as are printed in large, clear type, and excessive reading forbidden.

BC/11966 English Reading Card Point Notation Bernell

READING CARD

2. M

It was the month of May. The clear warm sunshine lay upon the mountain which had turned green again. The last snows

1.75 M

Up above, the gay young wind of spring was singing thru the fir trees and shaking down the old dark needles to make room for the new bright green ones that were soon to deck out the trees in

1.50 M

The golden sunshine lit up the hut and all the ground about it was warm and dry again so that one might sit out where one liked. The old man took no notice of anybody as he walked thru the village on his way.

1.25 M

All around her the steep green slopes shone bright in the evening sun, and soon the great gleaming snow field up above came in sight. Suddenly, a warm red glow fell on the grass at her feet-she looked back again-she had not remembered how

1. M

There the two high mountain peaks rose into the air like two great flames, the whole snow field had turned crimson, and rosy-colored clouds floated in the sky above. The grass upon the mountain sides had turned to gold, the rocks were aglow, and the whole valley was bathed in golden mist.

.75 M

.50 M

The numerical designation above each paragraph refers to the approximate distance in meters at which the lower case letters subtend a five minute angle.

BC/11970 English Reading Card Meter Notation Bernell

FIGURE 1
Near vision test chart, standard test types.

3.2.2 Distance visual acuity

Distance visual acuity was evaluated using COMPlog (Complog Clinical Vision Measurement Systems Ltd., London, U.K.) computerised software (18). The software program was run on a laptop PC (control monitor) with a 24-inch widescreen secondary monitor (Figure 2). One assessor carried out all the assessments at a set distance of 3 m under consistent lighting conditions. When a participant is unable to identify all five letters on a row the test is terminated and the visual acuity recorded in ETDRS (Early Treatment Diabetic Retinopathy Study) letters. Each eye was assessed individually, right and then left, with the contralateral eye completely obscured using an occluder. Each eye, right and left, was then tested individually using a pinhole occluder (Figure 3). The pinhole test allows a single ray of light from a point on an object to pass through the centre and is a useful method of determining reduced visual acuity due to refractive error (19). That is, vision which can be corrected with glasses or contact lenses. The test was then repeated for binocular vision, both eyes unobscured.

3.2.3 Stereopsis

The Frisby stereotest (Figure 4) was used to measure stereopsis which consists of three plates of varying thickness (6 mm, 3 mm, 1.5 mm). Each of the plates has four random texture patterns, with a hidden circular shape in one. With unobscured binocular vision, the student was asked to decide in which pattern the hidden shape lay. The stereotests were performed in random sequence in order to control for fatigue and learning effects. Using a tape measure, the viewing distance was increased incrementally per plate thickness to give the stereo threshold in units of seconds of arc. The lowest disparity which the student could reliably discriminate was calculated using Table 1 and recorded on the data capture form. All stereopsis tests were carried out by co-researcher MM who is trained in carrying out these tests.

3.2.4 Self-perception questionnaire

Each student was asked to complete a shortened and adapted version of the self-perception visual functioning questionnaire

FIGURE 2
COMPlog distance visual acuity measurement system (14). Control monitor (top) and secondary monitor (bottom).

FIGURE 3
Pinhole occlude.

(20), comprising of a total of 18 questions in two domains; general health and difficulty with daily activities. The questions assessed the students' perceived views about their eyesight, and difficulties encountered with daily activities as well as an additional question about accurately in a dental task of drilling a 1 mm cavity. The questionnaire used a Likert scale and ranges from none of the time 1; a little of the time 2; some of the time 3; most of the time 4; and all of the time 5. For the daily activity questions the scale ranges from no difficulty at all 1; a little difficulty 2; moderate difficulty 3, extreme difficulty 4; stopped doing this because of your eyesight 5; stopped doing this for other reasons or not interested in doing this 6. As different scales were used, a composite score calculation could not be used, and each answer was to be assessed individually.

3.2.5 Statistical Analysis

All the data analysis was conducted, analysed and processed using Stata Software, version 17, StatCorp, Texas, USA. The null hypothesis was that there is no statistically significant difference in near and distance visual acuity, and stereopsis between first and final-year dental students. All statistical significant differences for near, distance visual acuity and stereopsis for the two cohorts were assessed using Mann–Whitney test at a significance level of $\alpha = 0.05$.

Responses from the questionnaire were analysed using an ordered logistic regression model when the data was ordered, and with a multinomial logistic regression analysis model where the responses had more than two discrete answers and were non-ordered. The reporting of this study conformed to the STROBE statement (Supplementary Material S2) (21).

4 Results

4.1 Sample characteristics

Table 2 illustrates participant demographics with regards to gender, age, and use of visual aids.

4.2 Visual test results

4.2.1 Near visual acuity

The majority of dental students in year 1 (84%, $n = 42$) and in year 5 (94%, $n = 47$) had a binocular near visual acuity score of 0.50 M; the highest attainable score using our methods (Figure 5). Eight first year students scored 0.75 M whereas three final-year students scored 0.75 M. Ordered logistic regression showed no statistically significant differences between the year groups in binocular near visual acuity. This was also true when the right eye and left eye were tested independently. There was no correlation found between age and near visual acuity.

4.2.2 Distance visual acuity

Binocular distance visual acuity was similar between groups with a median score of 94 ETDRS in the first-year group and 95 ETDRS letters in the final-year group (Figure 6). Mann–Whitney test was used to test for differences between the year groups and the results showed no statistically significant differences in binocular distance visual acuity. A closer evaluation of individual participants revealed that eight students ($n = 4$ year 1, $n = 4$ year

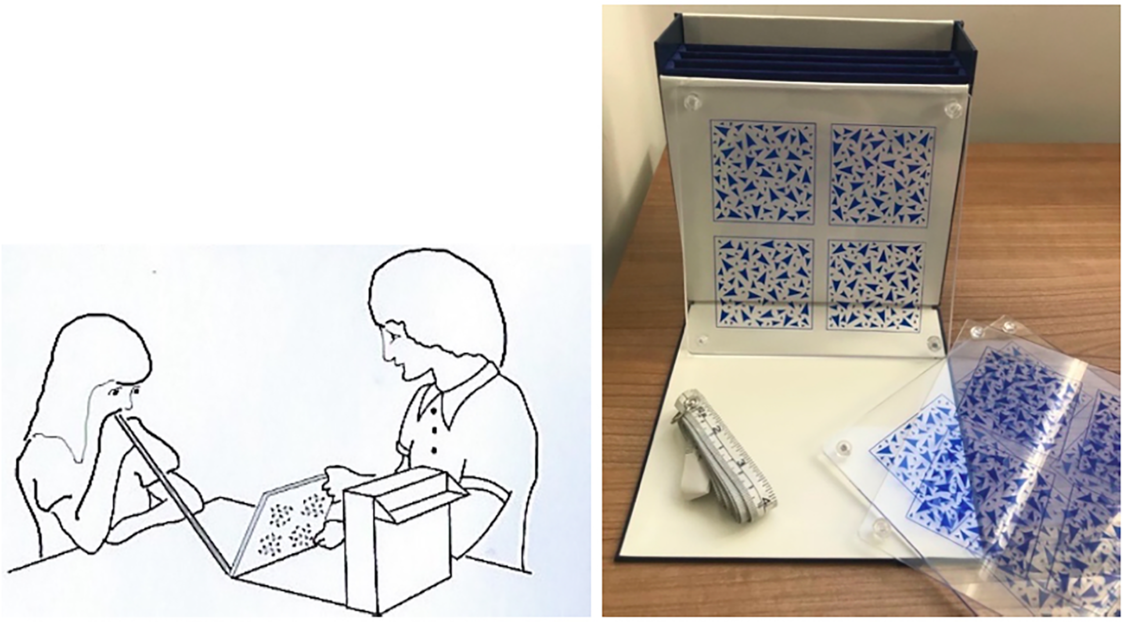


FIGURE 4
Diagram (left) of frisby stereotest and photo (right).

TABLE 1 Disparities for stereoacuity assessment.

Viewing Distance Cm	Plate thickness		
	6 mm	3 mm	1.5 mm
30	600	300	150
40	340	170	85
50	215	110	55
60	150	75	40
70	110	55	31
80	85	40	21
100	55	25	15
120	40	20	10
150	25	10	5

TABLE 2 Sample demographics.

Year Group	1	5	Total
Gender (*n*)			
Female	30	34	64
Male	20	16	36
Age (years)			
Mean (sd)	19.3 (1.88)	23.6 (1.47)	
Max	25	27	
Min	18	22	
Visual aids (*n*)			
Unaided	30	26	56
Glasses	13	20	33
Contact lenses	7	4	11

5) displayed a clinically significant improvement in distance visual acuity of more than 10 ETDRS letters with use of the pinhole occluder (Figure 7).

4.2.3 Stereopsis

A comparison of the smallest disparity which the student could reliably discriminate found no significant difference between first-year and final-year students when assessed using the Mann–Whitney test. The majority of students in both year groups scored 20 s arcs. In the first-year group 44% ($n = 22$) of students achieved this score and 48% ($n = 24$) in the final-year group (Figure 8).

4.3 Self-perception questionnaire results

There was a statistically significant difference in the groups when asked "How much of the time do you worry about your eyesight?" ($p = 0.044$) with final-year students worrying more about their eyesight compared to the first-year group.

5 Discussion

The responsibility of good visual health is currently reliant on the individual dental student undertaking independent eye examinations and is by no means essential. From a safety standpoint, when compared to other professions, admission criteria pertaining to visual ability is less stringent in dentistry. In the UK aviation industry for example, eye examinations are a mandatory requirement for medical certification, revalidation and renewal of aircrew.

Corrected vision was tested in students who were frequent glasses or contact lens users thus. allowing visual testing vision in

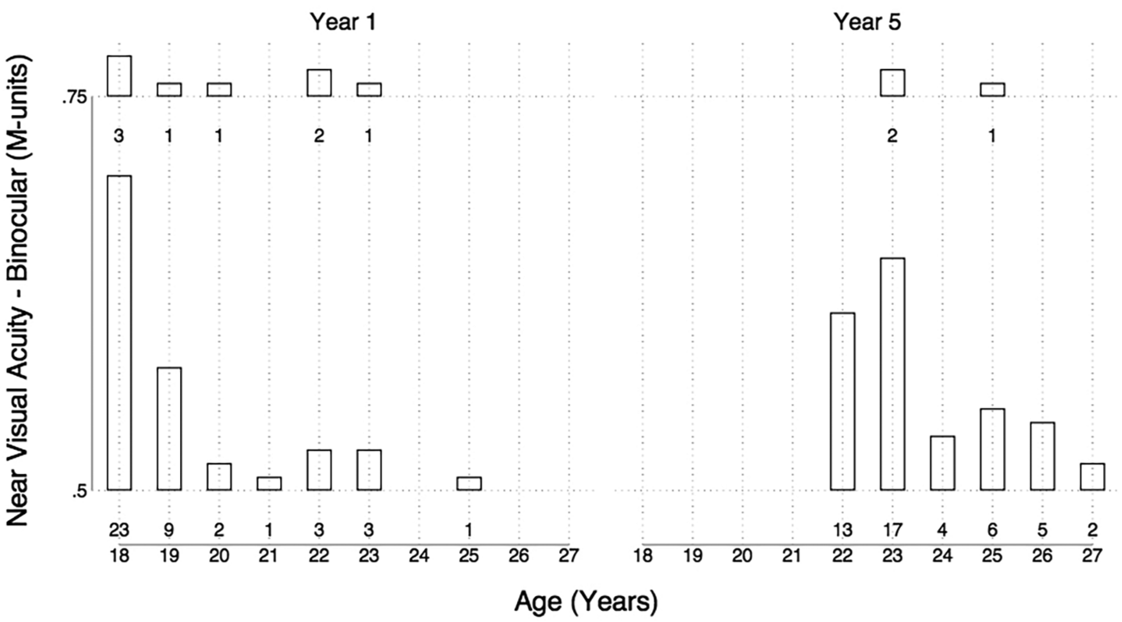


FIGURE 5
Bar chart of age plotted against binocular near visual acuity for year 1 students (left) and year 5 students (right).

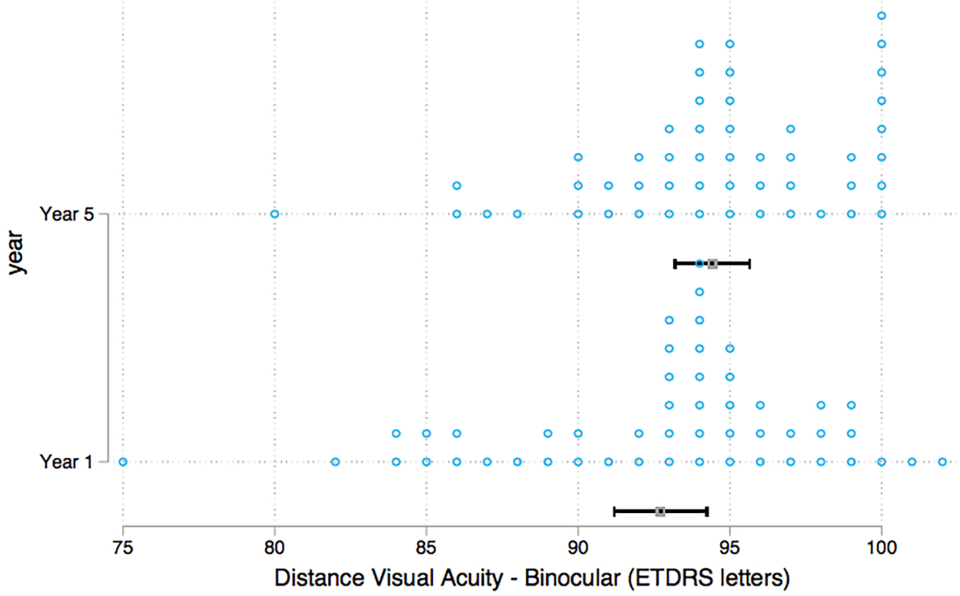


FIGURE 6
Strip plot of binocular distance visual acuity per year group.

an everyday setting. The lighting in the room used for the visual tests was kept at a constant, however in the dental setting an operating light offers more illumination than standard room lighting. The typical working distance of a dentist is 300 mm and whilst the near acuity reading tests were carried out at a range similar to this, the remaining tests were not due to the design of the tests.

All students had a binocular near visual acuity of at least 0.75 M with the majority obtaining 0.50 M (84% in first year, 94% in final year); the highest attainable near visual acuity score with the test type used. Although not statistically significant, this is a noteworthy 10% difference of clinical relevance indicating 1 in 10 final-year students with better near visual acuity compared to first year students. Eight first year students scored 0.75 M

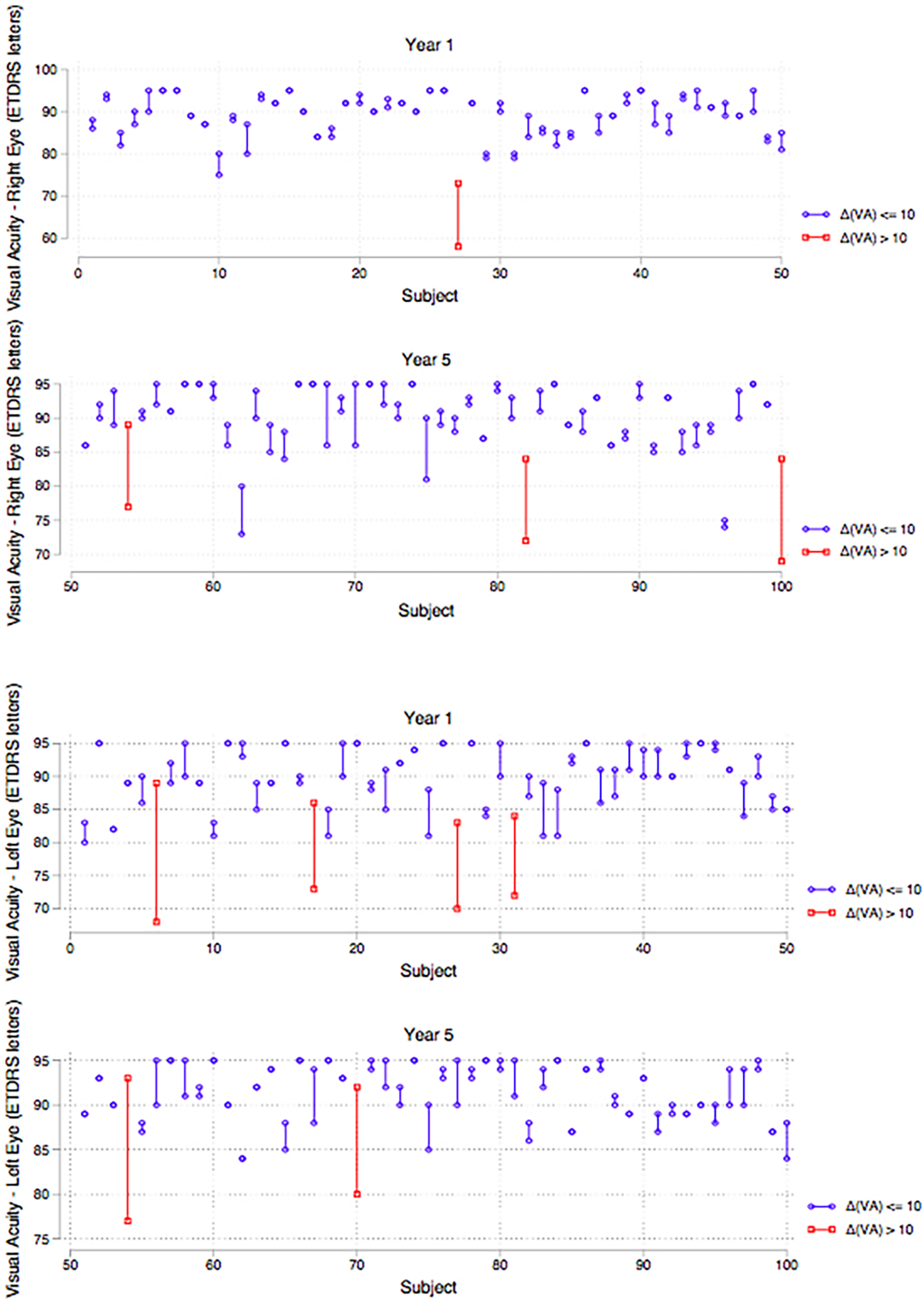


FIGURE 7
Strip plots of distance visual acuity per year group showing students with improvement in distance visual acuity of >10 ETDRS letters with use of the pinhole occluder (highlighted). Top (right eye), bottom (left eye).

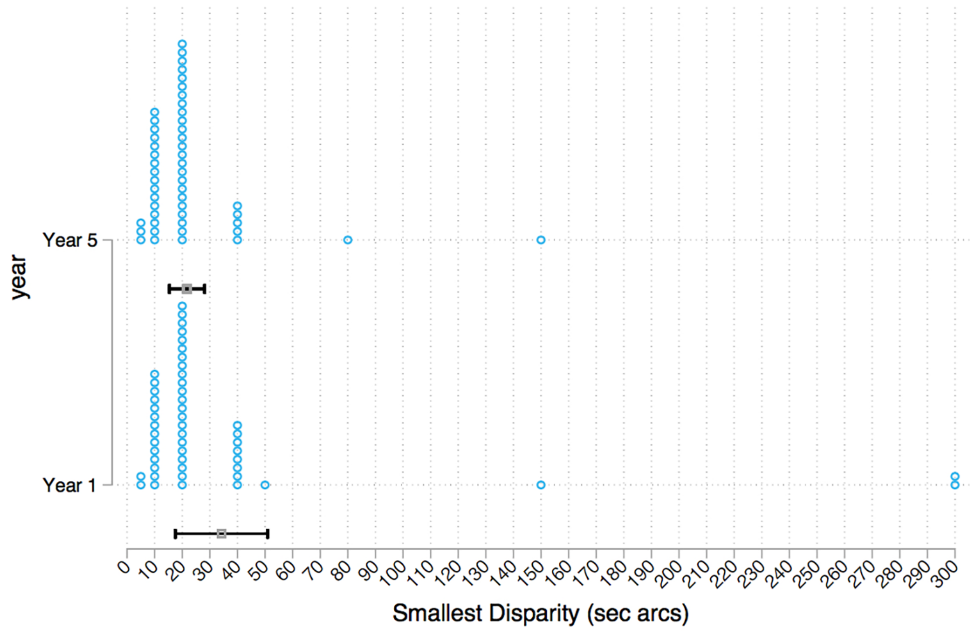


FIGURE 8
Strip plot of smallest disparity per year group.

whereas only three final-year students scored 0.75 M, the remainder scoring 0.50 M. This difference was not statistically significant but illustrated that a greater number of students with better near visual acuity were in the final-year cohort. This trend would be congruous with the findings of Forgie et al. (22) who assessed 46 practising dentists and found them all to have 0.50 M near visual acuity, using a standardised reading type test. A limitation of the test type used was its sensitivity as most students could read the smallest typeface used.

This study found that distance visual acuity was not statistically significantly different between the groups. However, undiagnosed refractive errors were highlighted by use of the pinhole occluder which improved distance acuity by 10 ETDRS letters in 4 students in each group. Undiagnosed refractive errors in working age UK population has been reported at a 1.6% prevalence (23), however this figure was derived from a disparate cohort aged 44/45 years. 8% of dental students with a potential benefit from wearing lenses is a sizeable proportion in a profession that relies heavily on perceptual-motor skills and where optimal vision is essential for patient safety. These students with correctable refractive errors were advised to seek further independent eye tests. Ignoring this may impact on students' clinical progression, and also raises issues pertaining to admission criteria. Currently, occupational health clearance is required to enter dental training within the UK and the authors propose that evidence of a recent eye test also be incorporated to entry requirements as well as regular testing throughout the dental undergraduate training.

The findings of the present study were not in line with a previously-conducted study by Dimitrijevic et al. (15) who found that entry-level dental students performed significantly worse in depth perception and estimation than more senior dental students. In contrast, the results showed that there was no significant difference between the year groups in the smallest disparity of stereopsis. Overall, stereopsis was good for both year groups with median and mode results for both year groups at 20 s arcs. This is in accordance with Bohr and Read (24), who reported median stereoacuity on the Frisby test at 20 s arcs, when assessing a large sample aged 11–49 years old.

The majority of students regarded their eyesight as "very good" or "excellent". There was no statistical difference between self-reported quality of eyesight between the two year groups. Eight students were found to have undiagnosed refractive errors whilst seven reported their eyesight quality as "good"/"very good"/"excellent". The results of this study add to the existing literature that dentist's self-assessment of their vision is unreliable.

When asked how much of the time students worry about their eyesight, there was a significant difference between the year groups, with first-year students reporting worrying less of the time than final-year students ($p = 0.044$). Interestingly this discrepancy in concern over eyesight is not supported by objective test findings. It is possible that with more clinical experience, dental students are conscious of the need for appropriate optical correction. Although there is a large difference in clinical experience, there was no statistical difference between the year groups when asked about accuracy in drilling a 1 mm cavity, with most stating they could complete this task with no difficulty at all.

The use of questionnaires in cross-sectional studies to analyse students' perceptions is a widely-used method and has been used by all the dental specialties (25). The limitations of evaluating self-perception of vision in this study was mainly based on the reliance on the participants' truthfulness completing the questionnaire and the incorporation of subjective bias. Albeit assured anonymity, the students may overestimate their visual capabilities in fear of a detrimental effect on their academic or clinical progression.

6 Conclusions

This study did not show any statistically significant differences between the year groups in near visual acuity and distance visual acuity, nor in stereopsis. Therefore, the null hypothesis could not be rejected and has been accepted. Eight percent of students had undiagnosed, correctable refractive errors with distance visual acuity. Students with visual deficits should be alerted and supported to undergo further eye examinations throughout their training programme.

Dental students' self-assessment of their vision is unreliable and therefore routine testing of all dental students for perceptual and visual difficulties is recommended. This study has a wide range of purpose with the findings being potentially applicable to most universities providing dental undergraduate programmes. Students, as well as practising dentists, should be aware of the importance of their vision in clinical dentistry and regular attendance for an eye examination is to be encouraged and recommended. Screening for visual acuity and stereopsis is easily implemented and it is hard to justify overlooking a potential impairment to clinical dentistry.

7 Future research

This study was a cross-sectional study with measurements of two different cohorts taken at one point in time. A future prospective longitudinal study design would be more accurate in assessing changes in vision throughout dental training. The influence of loupes on visual acuity and stereopsis and their effect on compensation on visual deficits could be a very useful study as loupes are being increasingly used by dental professionals.

There is also a need for an investigation into the effect of students' vision on the educational performance, and whether compensatory learning can occur in the presence of visual impediments. The interaction of visual acuity and stereopsis on operative procedures of varying specialties within dentistry also remains the subject of further studies.

As virtual reality and augmented realities are becoming more commonplace in dental undergraduate programmes, with potential implications on visual acuity and stereopsis, increased trials, investigations and validation of these systems will be crucial in delivering effective dental programmes (26).

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.

Ethics statement

Ethical approval was obtained on 17th September 2018 from the King's College Research Ethics Committee: project reference LRU-18/19-6835A. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JP: Data curation, Formal analysis, Investigation, Writing – original draft. SA: Formal analysis, Writing – review & editing. MM: Methodology, Writing – review & editing. MS: Data curation, Formal analysis, Writing – review & editing. DB: Methodology, Supervision, Validation, Writing – review & editing.

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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.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fdmed.2023.1337909/full#supplementary-material

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