The Accuracy of Dental Students and Dentists Assessing the Total Occlusal Convergence of Crown Preparations

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ABSTRACT

This study examined the ability of dental students and qualified dentists to visually assess the total occlusal convergence of clinical crowns. 10 working casts of maxillary molar crown preparations were installed in phantom heads in a clinical skills laboratory. 87 participants assessed the buccolingual and mesiodistal total occlusal convergence of the casts. 2nd-year students with no experience in fixed prosthodontics served as a control group with 3rd, 4th and 5th-year students and qualified dentists including specialists in restorative dentistry involved. Differences were calculated between the measured angles and the subject's estimate to assess accuracy. For 8 of the 20 surfaces measured there were significant differences. ($p < 0.05$). Differences were not standardized between the groups, with no clear patterns of difference in tooth type or aspect assessed. Differences were primarily between the control group and the more experienced groups. The remaining groups were of similar ability. A minority of participants in each group were highly divergent from their peers. This study found significant differences between participants with no experience of fixed prosthodontics and those with experience, however, the ability to assess total occlusal convergence does not appear to improve significantly with experience.

INTRODUCTION

The taper of a crown abutment is an essential part of creating the retention and resistance form needed to prevent displacement of the restoration.[1] Taper is defined as "the angle, measured in degrees as viewed in a given plane formed between one external wall and the path of placement of a tooth preparation or machined surface on a metal or ceramic material when prepared for a fixed dental prosthesis". The convergence of these two opposing external walls of a tooth preparation as viewed in a given plane is the total occlusal convergence [TOC] angle.[2]

Creating adequate retention and resistance form improves the clinical success of the restoration.[3] Producing acceptable retention and resistance form requires assessment of the preparation as it is being created and making any necessary corrections; key to this process is continuously reviewing the preparation including assessing the TOC. Within the literature on crown preparation there is an underlying assumption that clinicians

can accurately assess the preparations they create, yet Cho *et al*.[4] found that the least able clinicians were also the least able to assess crown preparations

There are few papers in the literature examining the visual assessment of TOC. Nick *et al*.[5] tested the ability of dental students and faculty to assess the TOC of typodont teeth prepared to a known TOC: they found that overall staff and students had similar abilities. Mays *et al*.[6] compared the accuracy of dental school faculty with Computer aided design / Computer aided manufacture [CAD/CAM] systems for the assessment of dental student crown preparations. They found that visual assessment by staff was less reliable than CAD/CAM systems but there were no statistically significant differences between the clinicians. Esser *et al*.[7] compared dental tutors with a digital measuring system and found a high correlation between the tutors and the digital system when evaluating TOC.

In studies of visual assessment of crown TOC, Marghalani[8] examined the visual acuity of prosthodontic specialists and found that some were able to assess TOC consistently to within +/- 6°, whereas others were consistently significantly wrong. Ahmed *et al*.[9] found a statistically significant correlation between students' and clinical supervisors' ability to assess TOC during a clinical examination. However, the study only assessed TOC as overprepared, underprepared or correct.

The aim of this paper is to examine the ability of dental students, general dental practitioners [GDP] who supervise dental students on clinics and Specialists / Consultants in Restorative Dentistry to visually assess the TOC of crown preparations in a simulated clinical setting. Furthermore, this study sought to investigate whether there was an improvement in accuracy of visual assessment as experience levels increased.

AIMS AND OBJECTIVES

This study tested two null hypotheses.

- There would be no difference in ability between qualified dentists and dental students in visually assessing crown TOC angles.
- Each cohort would accurately assess the TOC of crown preparations on the mesial-distal [MD] and buccal-palatal [BP] aspects of the preparations.

MATERIALS AND METHODS

The study was carried out at the Institute of Dentistry, University of Aberdeen (IoD). The undergraduate Bachelor of Dental Surgery [BDS] degree course is a 4-year graduate entry program. Students are given prior credit for their previous degrees and start in the 2nd year (BDS2).

The University of Aberdeen ethics committee gave permission for the study to be undertaken. There were 5 cohorts within the study. Cohort 1, BDS2 students who had received no teaching in fixed prosthodontics were used as a control group. The 2nd year control group did not contain any students resitting the year, any students that had transferred from another dental school and may have had prior experience, or any students that had qualified overseas. Students were not given time to practice assessing crown occlusal convergence angles prior to taking part in the study.

Cohorts 2, 3 and 4 were BDS3, BDS4 and BDS5 respectively: these groups of students had completed the fixed prosthodontic program and were currently treating patients. Cohort 5 was comprised of postgraduate trainees, clinical supervisors and restorative specialists. All the dental students and clinical supervisors in IoD and the Restorative Dentistry staff of Aberdeen Dental Hospital, including specialists and postgraduate trainees, were invited to take part in the study. Due to the small sample available for some types of specialist, all qualified dentists were included in one group

Ten working casts of maxillary 1st or 2nd molar crown preparations made clinically by students and clinicians at IoD were selected. The preparations were assessed by two of the authors, LH and RI, to ensure the preparations were of suitable quality. A cast and die were rejected if the dies showed: a) a preparation of poor quality b) markedly divergent angles, c) had preparations of less than 4mm crown height, d) were of two or more crown preparations adjacent to each other and e) the cast could not be installed in the phantom head in a clinically realistic manner,

Excess stone was removed from the dies apical to the crown preparations to allow a clear view of the margins. The working casts were mounted in dental plaster in the base plate of a Frasaco typodont jaw in order to standardize the presentation and then placed in the maxillary arches of ten Frasaco phantom heads. This was carried out to simulate the clinical environment in a controlled manner.

87 volunteers attended one of five data collection sessions. Participants were given a standardized verbal briefing and an information sheet prior to assessing the preparations. A definition of TOC was provided during the briefing and a labelled projected image showing an example of TOC was available. Participants were provided with the standardized tray of operative hand instruments used in the clinical skills laboratory at IoD including a mirror, No.6 straight probe, Basic periodontal exam [BPE] and University of North Carolina [UNC]-15 probes but no handpieces or burs were made available. Participants were not supplied with a silicon matrix for assessing TOC as the models used within the study were working models of clinical crown preparations that had been carried out on patients and the focus of the study was on visual assessment of TOC. By not supplying a matrix to aid in TOC assessment, the participants were following the protocol used at IoD when marking crown preparations carried out by students under exam conditions.

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Participants were instructed that they could assess the convergence angles visually and use any of the instruments provided. They were asked to assess the TOC of each preparation between a) the midpoint of the buccal and palatal surfaces and b) the midpoint of the mesial and distal surfaces. Answers were recorded to the nearest whole degree on a data collection form. There was no time limit for the subjects to carry out the assessments.

Participants could move freely around the phantom head as with a real patient, but instructions were given that the models were not to be removed from the phantom head. An overhead surgery light was used for illumination. Participants were prevented from using magnification or a headlamp. Each subject was given a reference number that identified the individual and the cohort they belonged to.

MEASUREMENT OF DIE TOC

Each preparation was photographed using a Nikon D90 with a Sigma 105mm 1:2.8 DC macro lens with a Sigma EM-140DG ring flash. The camera was set up on a Hama Profil duo 2 tripod. All images were taken using centre-point manual focus. The camera was set up in the horizontal plane and perpendicular to the surface of the tooth being photographed using spirit levels built into the tripod and an external spirit level. The models were mounted on the surveying table of a Dentalfarm Paral B dental surveyor, 20cm from the ring flash. The occlusal surface was placed in the horizontal plane using a spirit level and the axial wall was placed at 90o to the camera lens. Images were captured from the buccal aspect and the mesial aspect of the preparations to allow measurement of the MD and BP TOCs respectively. Figure 1 illustrates the camera set up and the image used within the SDEO application. Images were then cropped using Apple Photo V1.5 with the centre of the preparation in the middle of the image.

The TOC of each preparation was measured once all the data collection sessions had taken place. This ensured that participants and researchers were blinded to the actual values during data collection. To measure the actual [MD] and [BP] TOC angles, a newly developed web application from Scottish Dental Education Online (SDEO) was used.[10] This allows TOC to be measured after uploading a crown preparation image. The measurement tool was developed as a rapid teaching aid to be used in clinical skills laboratories. The SDEO application allows teachers and students to quickly assess TOC and can be easily incorporated into undergraduate teaching. Users place 4 markers at desired points on the preparation image to create two lines on opposing axial walls. The program calculates the angle between these lines (TOC). Figure 1 shows the tool measuring the bucco-palatal TOC of a die. The marker co-ordinates within the program used to assess TOC can be recorded for reproducibility.

To avoid intra-operator variability a single operator carried out the measurements and to ensure reproducibility, the TOC measurement for each surface of each preparation was undertaken multiple times. The results produced a mean value with a standard deviation of approximately 1.5°.

The gingival 1/3 of the preparation has been shown to be most important for retention and resistance form.[11,12] Therefore, the TOC was measured in the gingival 1/3 and from the point at which the finish line joined the axial wall to the most occlusal point of the first plane of reduction.

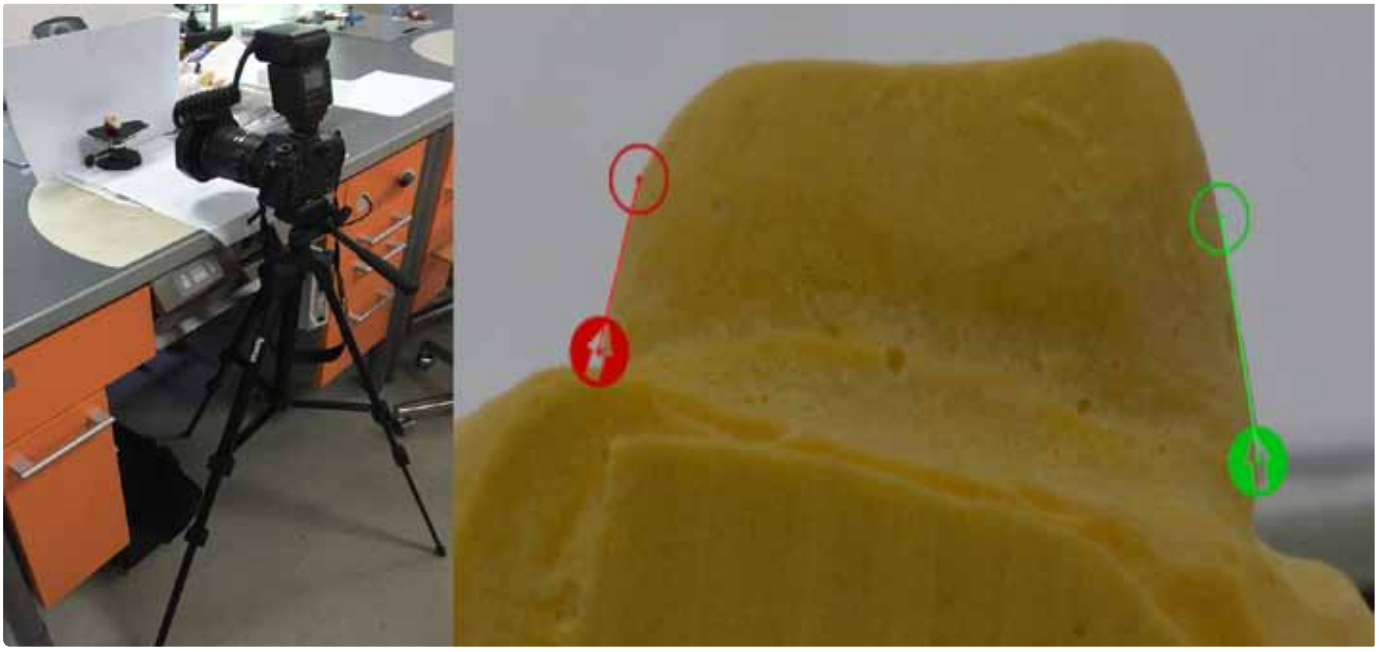

Figure 1: Photographic set up for preparation image capture and SDEO measuring tool

RESULTS

Table 1 contains details of the models used in the study. Data provided include details of maximum and minimum values for TOC.

To determine the ability of each clinician to assess TOC, the difference between the SDEO measured TOC and the subject's assessment was calculated. SPSS V.24 was used to analysis the differences between the actual and assessed values. A difference of 0 equalled a correct estimation. Figure 2 gives details of the median difference for each group between the assessed and measured values. Distributions of scores for differences between SDEO measured values and the visually assessed values were similar for all groups following visual assessments of boxplots. Within each cohort, a minority of participants was responsible for values that were 1.5 to 3 times the interquartile range for the entire cohort.

Following visual inspection of histograms and boxplots, the data were judged to be non-parametric. Therefore, a Kruskal-Wallis test was carried out to test for significant differences between each cohort. P values and the $X^2(4)$ statistic for each surface were calculated. Median differences were statistically significant between the groups for 8 of the 20 surfaces in the study ($p = < 0.05$). For these surfaces pair-wise post-hoc Dunn's tests with Bonferroni adjustments for multiple comparisons were carried out to detect statistical differences between groups. The tests revealed statistically significant differences in the median difference between SDEO measured values and visually assessed measurements for 5 MD assessments and 3 BP assessments. Only three dies had statistically significant differences for both the MD and BP measurements. However, these differences were not standardized between the groups with no clear pattern between them. Therefore, it cannot be inferred that they were clinically significant. There were no obvious similarities between the dies on which these differences were found.

Table 1. Model number, tooth type [Federation Dentaire Internationale (FDI)] and Bucco-palatal [BP] and Mesio-distal [MD] total occlusal convergence [TOC]

Model Number	1	2	3	4	5	6	7	8	9	10	Median value	Minimum value	Maximum value
Tooth Type [FDI]	26	16	16	26	26	27	16	26	17	26	-	-	-
Bucco-palatal TOC [Degrees]	16	12	9	12	13	7	13	12	20	17	13	7	20
Mesio-distal TOC [Degrees]	17	25	26	11	10	34	28	14	-27	25	21	-27	34

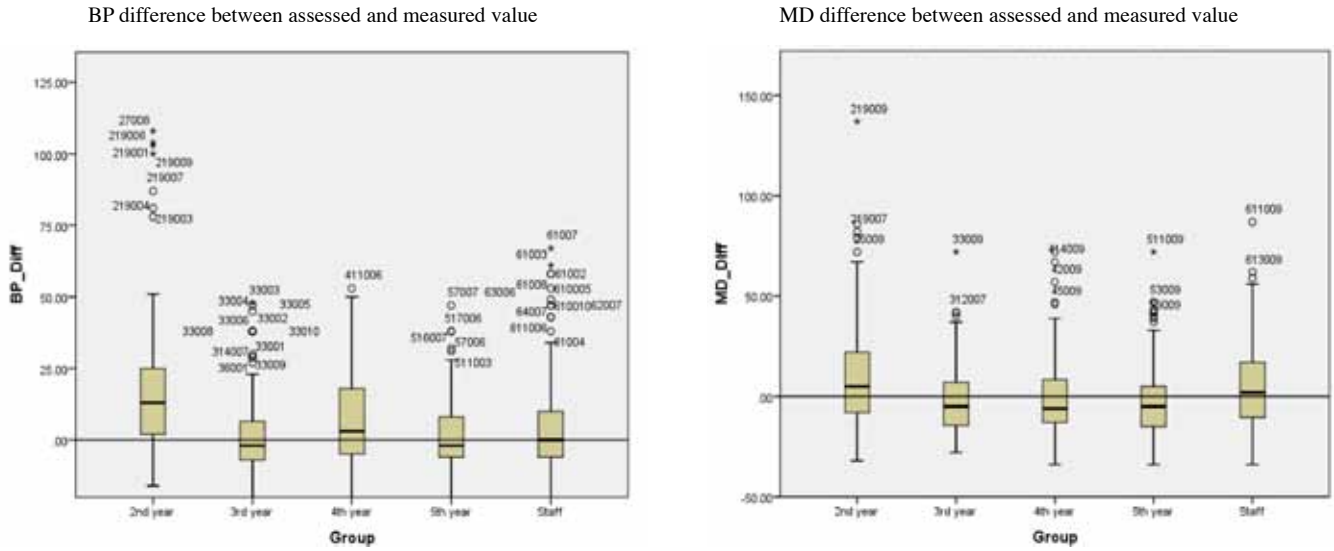

Figure 2. Mean difference between assessed values and measured values for each group for Bucco-palatal [BP] and Mesio-distal [MD] total occlusal convergence.

The first null hypotheses were therefore rejected. There were significant differences between the BDS2 cohort with no training in fixed prosthodontics and the other cohorts. However, there were no statistically significant differences between the other student cohorts and the qualified clinicians.

Table 2 provides the median assessed values, standard deviations and interquartile ranges for each cohort. The median visually assessed values of the BP TOC for the 3rd, 4th and 5th year students and the staff were all within 3° of the SDEO application measured median value [12.5° median TOC, 3.6° SD]. The BDS2 cohort were unable to achieve this level of accuracy with a median value over 12° greater than the measured value: for the MD TOC the situation was reversed. The BDS2 cohort were closest to the SDEO application measured value [21° median TOC, 16.3° SD] with a median visual assessment of 20° [SD 21.1°]. The 3rd, 4th, 5th year students and staff cohorts all estimated lower values with median values ranging from 11.5° [SD 11.1] for 5th year students to 15° [SD 18.4] for staff.

Due to presence of outliers within the data, the interquartile ranges were examined to assess the variability within the cohorts and to assess if there was less variability within more experienced groups. There were differences for the amount of variability between the groups. For the BP assessments the interquartile ranges in degrees were BDS2= 25, BDS3 = 14, BDS4 = 21.7, BDS5 = 13.7 and the staff result was 19.8. For the MD assessments the values were BDS2= 21.3, BDS3= 14, BDS4= 14, BDS5= 13 and the staff was 26. Therefore, the second null hypothesis was rejected, there were statistically significant differences between the BDS3, 4 and 5 students and the staff: the latter were better at BP assessment whereas the 2nd year cohort were best at assessing the MD TOC.

Table 3 gives data on the accuracy of the cohorts. Details are given for varying levels of accuracy up to and including estimates that were over 20° more than the SDEO measured value.

DISCUSSION

Significant differences were primarily detected between the BDS2 cohort who essentially were the controls and the more experienced groups. The BDS3, 4 and 5 cohorts were of similar ability in estimating the TOC within +/-5° and +/- 10° of the correct angle. These results are similar to those of Nick *et al.*[5] who carried out a bench-top exercise with typodont teeth. Within this study, individuals with no training or experience of visually assessing crown TOC were statistically significantly worse than subjects with experience. Students with experience can achieve results similar to qualified clinicians however there appears to be no clear pattern of continuous improvement as experience is gained.

Table 2. Visually assessed median total occlusal convergence [TOC] value per group with standard deviations [SD] and interquartile ranges

Visually assessed median TOC value in degrees, standard deviation and interquartile range

Group	Bucco-palatal	Standard deviation	Interquartile range
2nd year	25	21.9	15 to 40
3rd year	10	13.8	6 to 20
4th year	15	15.3	8.3 to 30
5th year	12	11.4	6.3 to 20
Staff	13.5	16.5	5 to 24.8
Measured Median using SDEO (SD)	12.5	3.6	12 to 16
Group	**Mesio-distal**	**Standard deviation**	**Interquartile range**
2nd year	20	21.1	10 to 31.3
3rd year	11.5	12.5	6 to 20
4th year	12.5	13.6	6 to 20
5th year	11.5	11.5	7 to 20
Staff	15	18.4	6 to 32
Measured Median using SDEO (SD)	21	16.3	11 to 26

Table 3. Total occlusal convergence estimation accuracy for Bucco-palatal [BP] and Mesio-distal [MD] TOC

	Number of correct estimates		% of estimates within 5 degrees of measured TOC		% of estimates 6-10 degrees different from measured TOC		% of estimates 11-20 degrees different from measured TOC		% of estimates >20 degrees different from measured TOC	
Group	BP	MD	BP	MD	BP	MD	BP	MD	BP	MD
2nd year	2%	3%	19%	24%	24%	15%	35%	21%	27%	33%
3rd year	3%	0%	43%	26%	27%	21%	26%	21%	11%	25%
4th year	4%	3%	35%	21%	29%	23%	27%	24%	19%	24%
5th year	3%	2%	42%	28%	31%	18%	32%	21%	11%	19%
Staff	3%	2%	38%	19%	28%	23%	24%	23%	16%	28%

Students at IoD are required to place a minimum of 6 indirect restorations as part of their training, this being similar to other UK dental schools. Therefore, even the most experienced students within the study had limited experience of crown preparation and assessment. Within this study, experience above a basic level did not appear to influence the ability of clinicians to assess TOC.

It would be expected that there will be some variability within each cohort given that visual acuity has been found to vary between dentists[13] and indeed this was the case in this study. However, within each cohort, and in a finding that replicates the work of Nick *et al*,[5] a small number of individuals skewed the results with estimates that were much greater than the SDEO measured TOC. This finding, which has been replicated in other studies,[4,5] found that the most able clinicians were also the most critical of their clinical work with the least able being least capable of accurately assessing their preparations. Cho *et al*.[4] argued that the ability to critically appraise clinical work is not fixed but can be improved through education and training. Constant feedback and self-assessment have been shown to be crucial to improvements in performance.[14,15] It is important that dental educators make efforts to identify those who are less able, as the work of Dunning and Kruger[16] has shown. not only do less competent individuals perform poorly but they often lack the meta-cognitive skills to recognize this.

Woolliscroft *et al*.[17] demonstrated a similar effect in medical students, lower performing students tended to overestimate their abilities with higher performing students underestimating them. Papinczak *et al*.[18] found that medical students were poorer at assessing their own performance compared to assessing their peers. A 2016 systematic review[19] examining self-assessment in pre-clinical and clinical dental education found a tendency for poorer performing students to over-estimate their performance and the inverse for higher performing students. Other studies within the literature have confirmed this tendency.[20-24]

A focus within clinical skills training must be to ensure that individuals needing extra help with TOC assessment are identified and supported to ensure they develop this skill. Ericsson[14] demonstrated that elite performers within fields such as surgery often have more detailed mental representations of the outcomes they are trying to achieve. Spending additional time with less able students and making use of digital technology to improve their mental representations of acceptable crown form would be time well spent for dental educators.

For the 3rd, 4th, 5th and staff groups, the BP surface was more accurately assessed than the MD *(Table 2)*: for the 2nd year cohort, this was reversed. Theoretically the MD TOC angle should be the easiest to assess as the preparation should be a uni-planar surface. It is possible that the presence of adjacent teeth makes estimating the TOC angle more difficult. Further research would need to be carried out to assess how the presence of adjacent teeth affects MD TOC assessment.

It was interesting to note that in respect of the MD TOC, there was a general trend amongst the student and staff cohorts to under-estimate the TOC, whilst this was not evident on the BP. This might have been a visibility issue given the presence of teeth adjacent to the prepared proximal surfaces.

Fewer than 50% of the subjects within each cohort were able to estimate the TOC within 5° of the correct angle. This shows that accurate assessment of crown TOC is difficult to achieve even for experienced clinicians. This is an interesting finding as experienced clinicians are expected to be able to accurately assess a TOC as part of their clinical work and clinical supervisors are expected to do this when assessing the clinical work of dental students.

The on-going improvement in intra-oral scanning technology may prove beneficial with a number of systems having been proposed to assist with feedback during training and assessment, such as the SDEO measuring tool, PREPR[25] or within the software for intra-oral scanning devices. Syed[15] and Ericsson[14]

have demonstrated that immediate and tailored feedback is effective at improving performance. Buchanan[26] demonstrated that students progressed quicker and asked for more feedback when using dental simulators compared with traditional teaching methods. Tiu[25] demonstrated that students were able to improve their crown preparations at a quicker rate when given oral feedback combined with the use of computer simulation software. Accelerated learning with the use of visual and digital teaching aids has been demonstrated in the literature.[20,27]

In-vitro studies suggest a maximum retention of a crown is achieved at a 5° taper or 10° TOC[28]. Subsequently numerous recommendations have been made within the literature and the current consensus is that whilst 4 - 10° is an ideal total convergence angle, 10 - 20° is clinically acceptable.[3,29–32] At the Institute of Dentistry, University of Aberdeen students are taught to prepare tapers of 5-10°, giving a total convergence angle of 10-20°. This aims to balance the theoretically desirable with the clinically achievable.

Numerous methods for assessing crown TOC have been described in the literature and Tiu *et al.*[33] reviewed these. However, there is no standardized agreement on where to measure TOC between preparation surfaces. The problem is not just an issue for this type of study but also within clinical teaching and everyday practice. Further research on this key aspect of assessing preparations is required. Mack[31] and Shillingburg[29] describe visual methods for assessing crown TOC using monocular vision and a mirror. Alternatives have been described where instruments are in effect used as surveying rods but it is likely that as intra-oral scanning technology improves this aspect of clinical dentistry will undergo further development while also allowing for greater collection of data on the "real world" TOC of crown preparations.

CONCLUSIONS

This study has shown that there was a statistical difference between the accuracy of TOC angles assessments made by dental students with no experience of fixed prosthodontics and those cohorts which had experience. However, there were no significant differences between the cohorts of clinicians with varying levels of experience. The results show that assessing crown TOC visually is unreliable even by experienced clinicians as less than 50% estimated the TOC within 10°. There was also a minority of clinicians who tended to be particularly poor at estimating TOC angles and were highly divergent from their peers: effective education of these clinicians is an important consideration. It may be that the use of aids such as intraoral scanners to provide immediate feedback might be explored further. In particular, students and dentists who struggle with this key skill need to be identified and time and resources dedicated to helping them improve.

DECLARATIONS OF INTEREST

None

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