Computer-Aided Measurement of Total Occlusal Convergence of Teeth Preparations for All-Ceramic Crowns by Dental Students

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Abstract

Objective: This study was based on the evaluation the degree of total occlusal convergence of teeth prepared for all-ceramic crowns which is the main factor that retention and resistance form of indirect restorations depended on. Teeth preparation done by 3rd year dental students at Al-Esraa university collage, Iraq in 2019.

Materials and method: Eighty typodont teeth, maxillary central incisor(n=40) and first premolar teeth (n=40) were prepared for all-ceramic crowns by preclinical dental students under examination condition. The prepared teeth were scanned and digitized using the laser scanner 3Shape D710 (SculptCAD, Texas, USA). The datasets were evaluated using inspection software (shaper 3D zrt. Hungary, 2020) that used for the assessment of the total occlusal convergence. Each tooth was virtually sectioned by four vertical planes: buccopalatal, mesiodistal, mesiobuccal–distopalatal and distobuccal– mesiopalatal and for each plane the total occlusal convergence angle (degree) was measured by drawing lines along the two opposing axial walls from the finish line extended coronally. The data were analyzed with appropriate statistical tests using analysis of variance (ANOVA) and unpaired t-tests. Differences between groups were tested for significance at 95% confidence interval.

Results: The results revealed that the students prepared the central incisor teeth with average TOC values of 11.46° ± 6.81°, 9.91° ± 4.92°, 10.54° ± 7.05° and 12.06° ± 6.71° respectively, from the buccopalatal, mesiodistal, mesiobuccal–distopalatal and distobuccal– mesiopalatal planes. Concerning first premolar teeth, students prepared them with average TOC values of 12.03° ± 6.63°,11.57° ± 6.34°, 14.3° ± 6.94° and 12.55° ± 6.6° respectively.

The findings revealed that the approximated average TOC values for all the measured planes were greater than the optimal TOC range 4 to 6 ° but stayed within the TOC acceptable range 4 to 14 °.

Ordinary one-way ANOVA test showed no significant (P >0.05) differences in the average TOC between the different four planes within each tested group of teeth. The average value of overall total occlusal convergence (TOCs) in the first premolar teeth= 12.61°± 6.63°was higher than for the central incisor teeth= 10.99°±6.4°. Unpaired t-test for the two tested groups revealed significant ($p < 0.05$) differences.

Conclusions: The presented study found that about 85%, 65.83% respectively of upper central incisor and first premolar teeth prepared for all-ceramic crowns by pre-clinical dental students with acceptable recommended convergence angle range 4-14°.

Keywords: Total occlusal convergence, teeth preparation, All-ceramic crowns.

Introduction

Preparation of teeth for full coverage crowns play a crucial role in preclinical training and subsequently enhance the dental treatment. One of the fundamental principles of tooth preparations for indirect restoration is the retention and resistance form. Number of factors that affect the retention and resistance of a full coverage

crown involve the degree of taper, surface area, height of the preparation, diameter of the tooth and type of cement used [1].

Taper or more precisely known as total occlusal convergence (TOC) is the most challenging part of the preparation to assess by inspection only. TOC has been defined as the angle of convergence formed by the two opposing prepared axial walls in each plane [2,3,4]. It is one of the factors which determine the amount of axial and non-axial forces which can be tolerated without degrading retention and loosening of the crown [5].

Studies by Jorgensen [6] and Kaufmann et al. [7] have found an inversely proportional between (TOC) and the retention and stability of complete coverage crowns on the prepared teeth; increasing the convergence angle from 5° to 10° reduces the retentive force by as much as 40-50%. They concluded that maximum retention with a 5° taper angle. Another study by Wilson and Chan in 1994 [8] recommended that maximal tensile retention occurred between 6° and 12°degrees (TOC). Further researchers found that by increasing the angle of convergence from 0 to 6 or 12°, no major change was observed in crown retention. They concluded that increasing this angle from 18 to 24° reduced retention significantly [9]. Another study found that 12° total occlusal convergence angle in teeth prepared for zirconia copings resulted in the best precision of fit and had no influence on marginal adaptation compared to 4° or 8° axial walls tapers [10]. Textbooks of crown and bridge prosthodontics advocate that in full crown preparations axial walls should be as parallel as possible, often recommend a convergence angle of approximately 5° (4-6°) as the ideal, but with a range of (4-14°) as acceptable [2,4,11].

Earlier, many researches have been directed to ascertain the optimal TOC value. later, studies were done to evaluate whether operators could achieve these values. Visual preclinical assessment of (TOC) have traditionally been accomplished but are of limited value for determining the actual convergence angle formed [12,13]. The increasing spread of digital technology in dentistry, specifically direct digital approach for obtaining dental impressions that are capable of capturing and storing high quality 3-dimensional (3D) virtual images of tooth preparations or dental casts, it is become easier to assess the prepared tooth. and to improve undergraduate compliance to the recommended degree of taper. Various studies have contrasted the (TOC) of the tooth preparation in both the Faciolingual and Mesiodistal plane. While, the oblique planes have not been included. Measurement of the TOCs in the oblique planes is important due to the lateral forces during excursive movements which might influence the retention of the indirect restoration [14].

This study was done to evaluate the (TOC) of the prepared teeth by dental students wouldn't vary from the recommended optimal range to provide maximum retention of the crown by measuring TOC in 4 different planes for each tooth, (1) buccopalatal (BP), (2) mesiodistal (MD), (3) mesiobuccal–distopalatal (MB-DP) and (4) distobuccal– mesiopalatinal (DB-MP). Also, to assess the effect of the tooth position (maxillary central incisor and maxillary first premolar) on the degrees of Convergence angle of the prepared teeth.

Materials and Methods

A total of 80 typodont teeth (40 samples for maxillary central incisor and 40 samples for maxillary first premolar) were prepared for all-ceramic crown by the 3rd year preclinical dental students under examination environment. Manikins (Nissin Dental Products) were mounted onto the phantom head to simulate real clinical situation. All the students were given equal and enough time to accomplish each tooth preparation. students were instructed to the ideal preparation considerations including a smooth, 1.0 mm shoulder finishing line that follows the level of gingival margin using tapered diamond burs with flat end. The samples were randomly selected then divided into two groups of teeth. Special plastic squares were fabricated and used as a bases to position the typodont teeth vertically with its long axis.

The typodont teeth were scanned using laser scanner of the CAD/CAM digital impression system and digitized with the computer-aided design software (3Shape D710; SculptCAD, Texas, USA) according to the manufacturing instruction of full crowns by CAD/CAM system. The STL datasets for the prepared teeth were measured by the inspection software (shaper 3D zrt. Hungary, 2020). Each tooth was virtually sectioned by four vertical planes from the: buccal view the mesiodistal (MD) plane, proximal view the buccopalatal (BP) plane, lateral view the mesiobuccal–distopalatal (MB-DP) and

(distobuccal– mesiopalatal (DB-MP) planes. All these planes crossed one virtually central long axis (Figure 1).

For each tooth, the four planes were imaged and filed and for each plane the TOC angle was measured and recorded separately by drawing lines along the two opposing axial walls from the finish line extended coronally (Figure 2).

The data subjected to statistical analysis using GraphPad Prism 8.0.2 software. The relationships and differences of total occlusal convergence angle (degrees) among four different cross-sectional planes for each group of teeth type (upper central incisor and first premolar) Also, the differences among upper central incisor and upper first premolar teeth were tested for significance. One-way, two-way analysis of variance (ANOVA) with Sidak's multiple comparisons test and unpaired t test were used to indicate the significant differences. Data have been shown as Means ± Standard Deviation (SD). Differences between groups were tested for statistical significance at a 95% confidence interval.

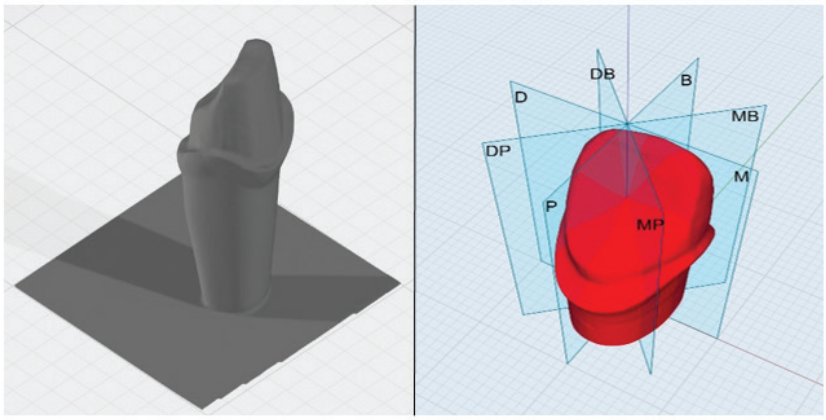

Fig. 1 Sectioning of STL dataset for each tooth into four vertical planes: buccal (B), palatal (P), mesial (M), distal (D), mesiobuccal (MB), distopalatal (DP), distobuccal (DB), mesiopalatal (MP).

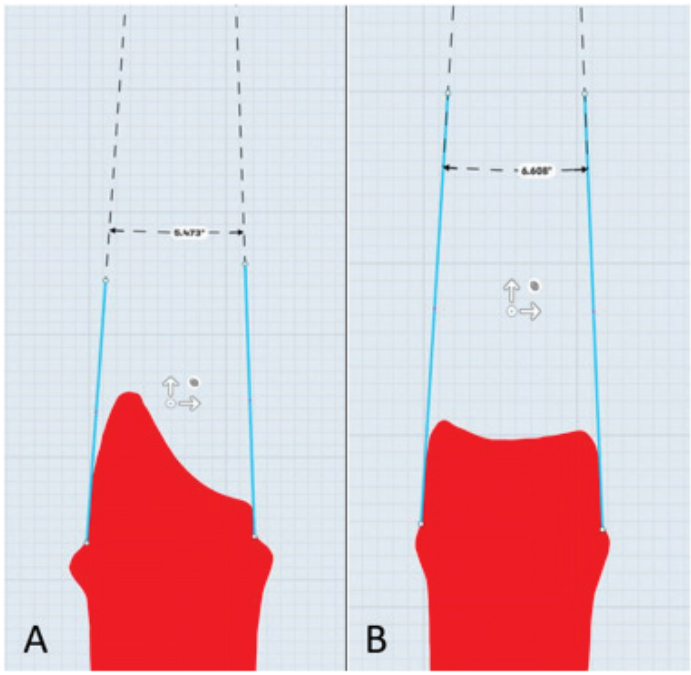

Fig. 2 Measurement of total occlusal convergence in A-BP plane (5.47°), B- MD plane (6.60°).

Results

Table 1 shows the distribution of average TOC (degrees) of different four planes (BP, MD, MB-DP, and DB-MP) for each group of teeth prepared for all-ceramic crowns , upper central incisor (n=40) and upper first premolar teeth (n=40). The highest mean TOC values were observed with first premolar for MB-DP plane (14.3°±6.94°). The mean TOC values for MD plane of upper central incisor were consistently the lowest for all parameters of convergence angle degrees (9.91°±4.92°).

The results of one-way ANOVA test with Sidak's multiple comparisons test showed statistically non-significant ($P > 0.05$) differences with the mean TOC (degrees) between different four planes for each group [Table 2]. Two-way ANOVA test with Sidak's multiple comparisons analysis of average TOC (degrees) of different four planes between two groups. The data has showed there was no significant differences among groups except for MB-DP plane, there was significant ($P = 0.037$) differences between upper central incisor tooth and first premolar tooth [Table 3].

Furthermore, Unpaired t test was used to make comparison of Average TOCs (degrees) between teeth preparation for crowns of upper central incisor and upper first premolar. The results showed that the mean TOCs degrees for first premolar was statistically higher as compared with central incisor teeth ($P < 0.05$) [Table 4].

Table 1: Summary statistics of TOC (degrees) of different four planes for two tested groups of teeth prepared for all-ceramic crowns.

Planes (TOC)	Upper Central incisor				Upper First premolar			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
BP	11.46	6.81	4.16	26.58	12.03	6.63	4.89	26.31
MD	9.91	4.92	2.57	22.45	11.57	6.34	5.8	25.57
MB-BP	10.54	7.05	4.85	28.93	14.3	6.94	6.94	28.67
DB-MP	12.06	6.71	6.3	29.41	12.55	6.6	5.92	26.26

BP:buccopalatal; MD: mesiodistal; MB-DP: mesiobuccal–distopalatal; DB-MP: distobuccal– mesiopalatal; TOC: total occlusal convergence; SD: Standard deviation; min: minimum value; max: maximum value.

Table 2: Comparison of mean TOC (degrees) between different four planes for each tested group of teeth prepared for all-ceramic crowns by one-way ANOVA test.

Planes (TOC)	Central Incisor		First Premolar	
	Mean diff.	P-value	Mean diff.	P-value
BP vs. MD	-1.549	0.8639 ns	0.4565	0.9998 ns
MB-DP vs. DB-MP	1.525	0.8723 ns	-1.747	0.8077 ns

BP: buccopalatal; MD: mesiodistal; MB-DP: mesiobuccal–distopalatal; DB-MP: distobuccal– mesiopalatal; TOC: total occlusal convergence; mean diff: mean differences; ns: non-significant differences (P>0.05).

Table 3: Comparison of mean TOC (degrees) of different four planes between two tested groups of teeth prepared for all-ceramic crowns by two-way ANOVA test.

Central incisor vs. First premolar	Mean diff.	P-value
BP Plane	-2.114	0.4620 ns
MD Plane	-0.1083	>0.9999 ns
MB-DP Plane	-3.763	*0.0374
DB-MP Plane	-0.4905	0.9950 ns

BP: buccopalatal; MD: mesiodistal; MB-DP: mesiobuccal–distopalatal; DB-MP: distobuccal– mesiopalatal; TOC: total occlusal convergence; mean diff: mean differences; ns: non-significant differences (P>0.05); *: significant differences (P<0.05).

Table 4: Comparison of mean TOCs between two tested groups of teeth prepared for all-ceramic crowns by Unpaired t test.

Tooth type	Mean (TOCs)	SD	Mean Diff. ± SEM	P - Value
Central incisor	10.99	6.4	1.619 ± 0.7307	*0.0274
First premolar	12.61	6.63		

(TOCs): overall convergence angles; SD: Standard deviation; mean diff: mean differences; SEM: standard error of mean; *: significant differences (P<0.05).

Discussion

In the presented study about 85 % of the upper central incisor teeth preparations and 65% of the upper first premolar teeth prepared by 3rd year pre-clinical dental students revealed a convergence angle between acceptable TOC range as mentioned in fixed prosthodontics textbooks 4° to 14°. The average TOC values of all assessed planes exceeded the optimal 4° to 6° TOC range. This means that the optimal tapers and Convergence angle degrees mentioned in fixed prosthodontics textbooks and the dental literatures are hard to accomplish by the dental students. The findings of this study were agreed with study by Kirov et al. [15] who found that preclinical students could not finish crown preparations within the 4-6° criteria.

They suggested that a 12º TOC degrees is more realistic and easier to achieve than 6º criterion for full coverage crown preparations. These recommendations balanced with Mack's investigation that a minimum taper of 12° was needed to be visually certain of avoiding undercuts and allow more satisfactory placing of restorations along path of insertion [16].

Patel et al. [17] asked 63 dental students to create convergence angles of 4 to 10°. Only eight students (12%) were able to do so, and the average of the convergence angle was 19°. Although the mean convergence angle found in this study among the two groups was higher than the optimal value, it was still within the recommended acceptable limits. This might be due to the newly picked knowledge by the students of how the ideal preparation is necessary to be performed and the continuously checking and correction by teachers to their students. Also, the students were under final exam's stress and they tried to do the best.

The results of this study showed that was no significant differences after the comparison the mean TOC (degrees) for all planes within each tooth type prepared for all-ceramic crowns evaluated. MB-DP plane in first premolar presented a highest TOC degree (14.3°±6.94°) of all the planes for the two teeth types. It could be supposed that dental students have trouble estimating the right taper of the axial walls in lateral view during preparation, especially in the mesiobuccal to distopalatal directions. Inversely, the MD plane of central incisor recorded the lowest TOC degree (9.91º±4.92º). This could be ascribed to the students who use direct vision and instruments control while preparing the proximal walls of central incisor. Moreover, as compared to other teeth, central incisors have straighter and parallel interproximal walls with a long axis. This finding coincided with the findings of Yoon et al.'s analysis [14] found that the central incisor tooth's MD plane showed at 6.3 degree the least TOC value of all planes for three teeth types.

The results of this study showed that the mean BP Convergence Angle was greater than the mean MD Convergence Angle in the two groups of teeth. This might be attributed to the difficulty to assess the buccal and palatal axial walls of tooth for undercuts and the existence of relatively short palatal surface on the cingulum of central incisor tooth was the reason for increasing taper in the bucco-palatal aspect. Results from studies by Makker et al. [18] and Tiu et al. [19] confirm this inspection with exception the investigation of Convergence angle achieved in clinical settings, displaying that all maxillary anterior samples, premolars and molars had an average faciolingual cross-section with higher TOC values relative to the average mesiodistal cross-sectional TOC values.

Our survey results showed that the average over all convergence for upper teeth preparation done by the third-year dental students were 12.61°±6.63° for first premolars and 10.99°±6.4° for central incisor. After the comparison analysis, the results showed that the mean TOCs for the upper first premolar preparation was significantly higher than the mean TOCs for the upper central incisor tooth preparations ($p<0.05$). The difference in the convergence angle between the two groups that were evaluated could be due to the highest mean TOC (degrees) value of MB-DP plane of first premolar that showed significant higher differences after the comparison with MB-DP plane of central incisor tooth. Also, the difference among upper central incisor and first premolar could be strongly correlated to the difference in the anatomical shape and student's ability to directly visualize the anterior teeth. these reasons could be resulted in better accessibility for one group than for other. This was contrary to expectations as premolars (bicuspids) had the lowest convergence values compared to all the other teeth all of which had similar convergence angles [20]. Many studies explained the difference in convergence angle from tooth to tooth might be correlated to overall variations in anatomy, location of the tooth, visual access and positioning the bur next to the teeth [14,21,22].

The utilization of Digital method to assess students' performance may be a valuable resource for dental education and provide a fair assessment of preparations. Since the STL data type is the root of most computer-assisted

design/computer-assisted manufacturing CAD/CAM systems, thus promote the utilizations of digital methods for the preclinical evaluation of teeth preparations features for proper taper or total occlusal convergence, adequate reduction, marginal design and surface texture. Digital method could give direct feedback to the teaching stuff and dental students on the quality of preparations and possible errors and this direct feedback could be enhance the educational quality and student's skill particularly at a pre-clinical level. Studies by Güth et al. [23] and Mays et al. [13] have established that visual measuring the degree of TOC can be a challenge in clinical assessment while digital approach can determine a numeric value that represents definitely the degrees of taper.

Conclusion

Within the limitations of this study, about 85%, 65.83% respectively of upper central incisor and first premolar teeth prepared for all-ceramic crowns by pre-clinical dental students with acceptable recommended convergence angle range 4-14°. The digital approach presented in this study could be a viable tool to assess the degree of total occlusal convergence for the prepared tooth.

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Conflict of Interest: Non

Source of Findings: Self

Ethical Clearance: taken form dental laboratories and patient

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