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EC DENTAL SCIENCE
Research Article

Digital Assessment of Total Occlusal Convergence during Pre-Clinical Practical Training

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Received: January 16, 2024; **Published:** February 02, 2024

DOI: 10.31080/ECDE.2024.23.02116

Abstract

Introduction: In dentistry, cemented fixed prosthodontics stands as a fundamental pillar, demanding absolute precision and unwavering adherence to preparation principles from practitioners to ensure proper insertion, retention, and mechanical resistance for prosthetic restorations. Retention is a key parameter for the success of a prosthesis. According to the literature, preparations require specific values, initially defined at 6°. Weed demonstrated that it is possible to reach values up to 16°, which are clinically feasible and largely acceptable. Can students replicate the recommended occlusal convergence angles for sealed unit preparations in a preclinical setting?

Objective: A digitized assessment of the total occlusal convergence (TOC) of preparations carried out by 2nd-year students at the Faculty of Dental Medicine at Mohamed VI University of Science and Health in Casablanca during pre-clinical practical activities (APP).

Materials and Methods: A total of 357 dental preparations, performed by second-year students at Mohamed VI University of Science and Health for cast or ceramo-metallic crowns, were digitally scanned using the Smart Optique Scan box scanner. The obtained STL files were imported into the PREFORM FORMLAP software. Tangent lines were drawn at the base of the mesio-distal and buccolingual angles using a screenshot captured with the Paint tool. These tangent lines were subsequently measured using the MB Ruler software. The collected statistical data underwent analysis using SPSS software, and comparisons were conducted using the t-test.

Results: An average TOC of 13.5° +/- 4.92° was recorded for typodont preparations, with specific values of 11.02° +/- 5.31° in the mesio-distal direction and 15.99° +/- 5.81° in the buccolingual direction. No significant differences were observed in relation to students' gender. However, significant variations were noted based on the type of tooth, sector, and preparation method. 59.7% of second-year students achieved results within the 6° to 16° range.

Discussion: The results obtained in our study align with the new recommendations proposed by Weed. These findings are similar to those of studies conducted by the University of Sofia in Bulgaria and those by Yoon., *et al*. Most institutions worldwide have reported higher values than ours.

Conclusion: This study shows that second-year dental students at Mohamed VI University of Science and Health face challenges in achieving the recommended 6° angle for total occlusal convergence (TOC). However, the majority of those students recorded TOC values between 6° and 16°, which is consistent with findings worldwide.

Keywords: *Convergence Angle; Dental Preparation; Total Occlusal Convergence*

Introduction

In dentistry, fixed partial dentures (FPD) is a fundamental discipline that requires precision on the part of the practitioner and adherence to preparation principles. There are two types of FPDs:

- Bonded FPD: A fixed prosthesis that requires minimal preparation and the use of an adhesive system.
- Cemented FPD: A fixed prosthesis that demands specific preparation involving a geometric shape affecting the durability of the prosthesis and requires a sealing mechanism.

The preparation of the tooth for a cemented fixed partial denture involves reducing dental structure on all surfaces: buccal (B), lingual (L), mesial (M), distal (D), and occlusal (O). These reductions must be carried out following specific criteria tailored to the material used for the cemented prosthesis.

Adhering to the fundamental principles of fixed partial dentures (FPD), such as prosthesis stability, insertion, retention, and support, is essential to ensure the success and longevity of the prosthesis.

To properly insert a crown onto a prepared tooth, it is necessary for the axial surfaces to have a taper. Tapering, in the context of a crown, involves angling these two converging outer walls toward the occlusal surface of the tooth. The taper of a tooth preparation (TOC) is the sum of the angles of convergence of the four axial walls of the prepared tooth (buccal, lingual, mesial, and distal).

Nevertheless, achieving the proper fit of the prosthetic element involves creating a taper, represented by the axial walls converging toward the occlusal surface, ideally at an academic recommendation of 6 degrees [1]. However, due to the challenges of achieving such precision in preparation, Weed., *et al*. have accepted a clearance margin ranging from 6 to 16 degrees as clinically achievable while still ensuring adequate retention [2].

This is achieved at the Faculty of Dental Medicine at Mohammed VI University of Health Sciences (UM6SS) through a preclinical teaching of these principles on typodonts, enabling students to develop both theoretical and practical understanding of the desired outcomes. This, in turn, facilitates the learning of clinically relevant techniques.

Pre-clinical practical activities (APP) play a crucial role in the education of fixed partial dentures (FPD) because they provide hands-on initiation to the procedures and enable students to master them.

Aim of the Study

The aim of our study is twofold: first, to determine the total occlusal convergence (TOC) of preparations performed by 2nd year students at the Faculty of Dental Medicine at UM6SS. Second, to evaluate and compare these collected results against established international recommendations. Our goal is to formulate appropriate recommendations based on the obtained results.

Materials and Methods

In total, 357 dental preparations intended for cast or ceramo-metallic crowns, carried out by second-year students at UM6SS, were digitized using the SmartOptique Scanbox scanner. The resulting STL files were imported into the PREFORM FORMLAP software. Using a screenshot captured with the Paint tool, tangent lines were drawn at the base of the mesio-distal and bucco-lingual angles. These tangent lines were then measured using the MB Ruler software. The statistical data collected were analyzed using the SPSS software, and comparisons were made using the t-test.

Results

A total of 357 dental preparations on typodont were analyzed.

Our study reports a total occlusal convergence (TOC) of 13.5 +/- 4.92, with MD convergence of 11.02 +/- 5.31 and VL convergence of 15.99 +/- 5.81 (Table 1).

	MD	VL	TOC
Mean	11.02°	15.99°	13.50°
Standard deviation	5.31°	5.81°	4.92°

Table 1: *The average of total occlusal convergence (TOC).*

The results show that 59.7% of the selected students obtained a TOC value between 6° and 16°. 33.6% of the students achieved a TOC value exceeding 16°, indicating excessive taper. A minority of 6.7% obtained TOC values below 6°, representing insufficient taper and counter-taper (Table 2).

	Global TOC		Premolar		Molar		Incisor	
Ranges of TOC values	**Sample**	**Percentage**	**Sample**	**Percentage**	**Sample**	**Percentage**	**Sample**	**Percentage**
<6°	8	6.7%	18	15.1%	25	21%	6	5%
[6°, 16°]	71	59.7%	56	47.1%	60	50.4%	62	52.1%
16° <	40	33.6%	45	37.8%	34	28.6%	51	42.9%
Total	119	100%	119	100%	119	100%	119	100%

Table 2: *The distribution of students based on the values of total occlusal convergence (TOC).*

For 78 females and 41 males, the research yielded a TOC of 13.72° +/- 5.11° for females, with axial convergence values of 11.27° +/- 5.66° for MD (mesio-distal) and 16.18° +/- 6.05° for VL (vestibulo-lingual). In the case of the male group, the TOC value obtained was 13.10° +/- 4.56°, along with MD values of 10.54° +/- 4.61° and VL values of 15.65° +/- 5.37°. Using the t-test, it was concluded that the difference in convergence angle values between males and females was not statistically significant, with a p-value of 0.26, which is greater than 0.05. For further precision, the t-test was also conducted separately on both axial faces, MD and VL, resulting in p-values of 0.218 for MD and 0.414 for VL (Table 3).

	Sample population	Preparations dentaires	TOC mean (Standard deviation)	MD mean (Standard deviation)	VL mean (Standard deviation)
Female	78	234	13.72° (5,10612)	11.27° (5,65739)	16.18° (6,05476)
Male	41	123	13.10° (4,56275)	10.54° (4,61016)	15.65° (5,36587)
p- value			0.26	0.218	0.414

Table 3: *The average total occlusal convergence by gender.*

A TOC of 13.82° +/- 9.55° was obtained for premolars, 11.64° +/- 8.04° for molars, and 15.06° +/- 6.82° for incisors.

The difference in results based on the type of tooth was statistically significant, as the calculated p-value was 0.005.

47.1% of the students achieved a TOC for premolars that falls within the range of 6° to 16°, 50.4% for molars, and 52.1% for incisors within the same range (Table 2).

The average overall TOC of posterior sector was 12.73° +/- 6.52° and 15.06° +/- 6.82° in the anterior sector. Through a t-test, we observed that the difference was statistically significant, with a p-value of 0.0018 (Table 4).

The mean value of TOC for ceramo-metallic crowns (CCM) was 13.35° +/- 7.33° and 13.82° +/- 9.55° for cast crowns (CC). By using the t-test, a significant p-value of 0.024 was obtained (Table 4).

	Sample	TOC mean	Standard deviation	Variance	P-value
Premolar	119	13.82°	9.55017	91.206	
Molar	119	11.64°	8.03693	64.592	
Incisor	119	15.06°	6.82084	46.524	P-value of the type of tooth = 0.005
Anterior	119	15.06°	6.82084	46.524	
Posterior	238	12.73°	6.52342	42.555	P-value of teeth sector = 0.0018
Cast Crown (CC)	119	13.82°	9.55017	91.206	
Ceramic Metal Crown (CCM)	238	13.35°	7.33334	55.558	P-value of the type of preparation = 0.024

Table 4: *The averages of total occlusal convergence based on the type of tooth, teeth sector and the type of preparation.*

Discussion

The success of retaining a fixed dental prosthesis depends on several factors. Total occlusal convergence (TOC) significantly influences the final prosthesis outcomes.

Ideally, academic recommendations suggest a 6-degree taper, with a clinically achievable value of 12° [1]. However, due to the challenges in achieving such precision, Weed., *et al*. have suggested a maximum TOC of 16 degree as clinically acceptable while still ensuring sufficient retention [2].

Our results fall within the 6 - 16° range with a 13.5° TOC, that aligns closely with the recommended achievable value of 12° [1]. The results indicate that the majority, 59.7% of the selected students, achieved a TOC (tapering) value ranging from 6° to 16°. In contrast, 33.6% of the students recorded a TOC exceeding 16°, indicating excessive tapering. A minority of 6.7% obtained TOC values below 6°, representing shallow tapers and undercut preparations. 59.7% of selected students achieved a TOC (tapering) value between 6° and 16°, which is considered acceptable. However, 33.6% recorded a TOC exceeding 16°, indicating excessive tapering, and 6.7% obtained TOC values below 6°, representing shallow tapers and undercut preparations. In the study conducted at the Faculty of Dentistry in Casablanca (FMDC), a higher percentage, 71.5% of students, achieved TOC values ranging from 6° to 16°, which are also considered acceptable in the literature. Only 8.6% achieved a TOC below 6°, in contrast to just 0.4% of students at the University of Colorado, while 18.5% recorded values exceeding 16° [3,4]. Moreover, the results from King Saud University in Saudi Arabia showed a TOC of 18.56° +/- 10.583°, using a scanner and manual protractor. Interestingly, 32.7% of the students achieved values below 12° [5].

A TOC of 13.10° +/- 4.92° was obtained for males, with axial convergence values of 10.54° +/- 4.61° (MD) and 15.65° +/- 5.37° (VL). Concerning females, the TOC value obtained was 13.72° +/- 5.11°, with MD values of 11.27° +/- 5.66° and VL values of 16.18° +/- 6.05°. It was concluded that the difference in convergence angle values between females and males was not significant. Thamer Y. Marghalani also conducted a study on both axial aspects. The t-test was performed on each axial value, yielding 10.92° +/- 4.03° (MD) and 10.16° +/- 3.90° (VL) for males, and 10.66° +/- 4.45° (MD) and 11.46° +/- 5.06° (VL) for females. The t-test results for both aspects were not significant [6].

The average total occlusal convergence (TOC) in our study varies depending on the type of tooth. A TOC of 13.82° +/- 9.55° was obtained for premolars, 11.64° +/- 8.04° for molars, and 15.06° +/- 6.82° for incisors. The Faculty of Dental Medicine in Sofia, Bulgaria, conducted a study specifically on the vestibulo-lingual aspects, demonstrating that the axial wall convergence of molars was significantly higher than that of premolars, with a vestibulo-lingual axial convergence of 14.68° +/- 2.58 for molars and 11.99° +/- 2.80 for premolars [7]. On the other hand, the article presented by Robia Ghafoor., *et al*. deals with and compares the MD aspect of molars and premolars. In their study, the difference in results was significant [8].

Students achieved values of 12.73° +/- 6.52° in the posterior sector and 15.06° +/- 6.82° in the anterior sector. A study also found, higher TOC values in the anterior sector (20.8°) compared to the posterior sector (16.2°) [9]. The p-value we obtained signifies that the sector significantly impacts the tooth's TOC. This finding is consistent with numerous other studies that have reached a similar significant conclusion [5,8,10].

It appears that preparations for metal-ceramic crowns (CCM) come closest to 12°, which is a clinically achievable TOC according to Shillingburg [1]. The recorded values are 13.35° +/- 7.33° for CCM and 13.82° +/- 9.55° for cast crowns (CC). A significant p-value is obtained, which was similar to the one obtained by FMDC in Casablanca. A TOC value of 9.27° +/- 4.64° was recorded for CCM and 14.7° +/- 5.23° for CC [4].

Improvement in TOC values achieved by students is closely tied to the evaluation by dental training staff. A study compared visual evaluations by instructors to technical assessments using a laser scanner. The article suggests the potential for digitizing student evaluations by instructors, offering a clearer and more objective assessment of dental preparation quality [11].

The use of scanners and angle measurement software (CAM/CAD) has demonstrated significantly higher efficiency and precision compared to traditional visual assessment techniques [12].

Digitization has empowered students to self-assess their preparations and receive immediate feedback, as they tend to visually underestimate TOC values by 5°. This creates a visual connection between TOC measurements and cervical line dimensions related to preparations, enhancing dental students' learning [13,14].

Furthermore, some researchers have proposed incorporating virtual simulations into dental curricula as an educational tool that can complement traditional teaching methods [4,15].

Conclusion

This study has highlighted the gap between theoretical values and the values achieved in clinical practice by second-year dental students at UM6SS. Achieving 6° remains a challenge, as the majority of our students recorded values falling within the range of 6° to 16°, which is consistent with results observed in students worldwide.

There are several complementary methods available to help students optimize their preparation results, such as the use of microscopes. Additionally, the use of a scanner and a simulation model is recommended. The results of this study were obtained from second-year students working on a typodont. Therefore, it is advisable to introduce the use of simulation models as early as the second year, including digital assessment by instructors.

Acknowledgments

The authors would like to extend their gratitude to Sounani Dental Prosthesis Laboratory, which facilitated the scanning of Typodont models and the organized retrieval of STL files for each student. A special thanks to the entire team involved in the study.

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Volume 23 Issue 2 February 2024