

Occlusal Convergence Angles of Teeth Preparation Achieved by Pre-Clinical Dental Students at Umm-Alqura University, Saudi Arabia

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Abstract

Aim: This study aims to determine the mean of convergence angles of each tooth in both aspects MD and BL which is produced by fourth-year dental students at Umm-Alqura University. Then compare it with ideal convergence angles and see which tooth prepared need to improve.

Materials and Methods: A total of 150 prepared teeth: 50 molars prepared to receive full metal crowns, 50 premolars prepared to receive porcelain fused to metal (PFM) crowns, 50 anteriors prepared to receive all-ceramic crowns. All samples were prepared in phantom labs. Images were captured with a digital camera. Mesio-distal (MD) and bucco-lingual (BL) tapers for each prepared tooth was measured by computer program.

Results: The mean BL angle of all preparations was 16.93 ± 6.43 degrees, while the mean MD angle was 15.65 ± 6.26 degrees. The mean BL angle for the molar tooth preparation (20.11 ± 7.65 degree) and the mean BL angle for the premolar tooth preparation (19.19 ± 4.21 degree) was significantly greater than the mean BL angle for the anteriors teeth preparations (11.50 ± 1.95 degree) ($p = 0.000$). On the other hand, no statistical difference was observed between the mean BL angle for the molar and premolar tooth preparation ($p = 0.457$). The mean MD angle for the molar tooth preparation (19.91 ± 7.72 degree) was significantly greater than the mean MD angle for the premolar tooth preparation (16.09 ± 3.98 degree) ($p = 0.002$). And the mean MD angle for the anteriors teeth preparations (10.96 ± 1.63 degree) ($p = 0.000$). The mean MD angle for the premolar tooth preparation was significantly greater than the mean MD angle for the anteriors teeth preparation ($p = 0.000$).

Conclusion: Most of BL and MD total occlusal convergence angles fall within an acceptable range, with low values being undercuts and excessive angles of up to 41.31 degree seen. This means the course did very well, but we need to increase the time of training and make sure the student work with the index to know the ideal amount of reduction.

Keywords: Artificial Teeth; Crown Preparation; Dental Students; Fixed Prosthodontics; Occlusal Convergence Angles; Pre-Clinical Education; Saudi Arabia; Taper

Introduction

Preparation of teeth is an essential technique for dental treatment and plays an essential role in pre-clinical education. There is a general assumption that sufficient tooth preparation is essential for the fit of fixed prosthodontics [1]. The British Society for Restorative Dentistry has outlined the principle considerations in tooth preparation as follows: conservation of tooth tissue then control of the path of insertion, appropriate clearance in occlusion and articulation, optimum retention and resistance form and the removal of adequate tooth tissue to permit the manufacture of restorations with appropriate cosmetic results without the over-contouring of the finished restoration [2].

Convergence angles are the angle formed between opposing axial walls when teeth are prepared for crowns or fixed dental prostheses. Theoretically, ideal convergence angles should range from 4 to 6 degrees, but angles of 10 to 20 degrees are considered acceptable [3]. In the Aga Khan University Hospital, Ghafoor, *et al.* reported in 2012's Assessment of convergence angle of full-coverage porcelain fused to metal crowns. A sample was 197 crown tooth preparation models of molar and premolar teeth, reported convergence angle and axial wall taper values were $23.7^\circ \pm 8.9^\circ$ and $11.3^\circ \pm 7.8^\circ$ and observed Convergence angle values were greater for molars as compared to premolars [4].

According to Aleisa, *et al.* in 2013's at the College of Dentistry, King Saud University. The sample is 355 teeth the overall mean convergence angle was 18.56° . Only 32.7 percent of the preparations were within the recommended convergence angle ($< 12^\circ$). They observed that the mean convergence angle for anterior tooth preparations (15.8°) was significantly less than the mean CA for posterior tooth preparations (20.3°) [5]. According to Kirov, *et al.* in 2014's research at the Faculty of Dental Medicine, Sofia, Bulgaria. The sample was 80 tooth preparations (20 upper premolars, 20 lower premolars, 20 upper molars and 20 lower molars), which prepared by third-year dental students. According to results difference in the mean value of convergence angle between teeth the greatest convergence value (mean 15.44°) was for the lower molar. The smallest convergence value (mean 11.12°) was for the upper premolar [1].

Later investigation in 2014 by Marghalani, the sample was 68 maxillary first premolar made by 38 male and 30 female students. Estimated that the mean bucco-lingual angle was 10.49 ± 3.95 degrees and mean mesio-distal angle of all preparations was 11.11 ± 4.79 degrees. "The mean bucco-lingual angle in teeth preparations by female students was 11.4 ± 5.06 degree, compared with 10.16 ± 3.90 degree in preparations by male students" [6]. Another investigation in Jazan University reported that 4th-year dental students prepared teeth for cast metal crowns (43 male, 46 female), in result showed The mean mesio-distal and bucco-lingual degrees of taper were 19.52 and 23.25 (Male) 19.77 and 22.38 (Female) degree [7].

An *in vitro* study in 2016 in New Zealand, the sample was 371 teeth preparations for metal-ceramic crowns prepared by dental students in the Technical Services Laboratory Database at the University of Otago. According to the result, the convergence angles an acceptable range of 10 to 20 degrees [8]. Another investigation in Syria, this study aimed to compare the convergence angles of metal-ceramic fixed prosthodontics among final-year undergraduate dental students (UG), master prosthodontics students (MS), and general practitioners (GP). In the result show bucco-lingual, mesio-distal angle of the whole samples was 31.1° , 21.2° and 26.3° . On the other hand, GP had always the largest convergence angle in both dimensions (bucco-lingual and mesio-distal) in comparison to the UG and MS students. They observed that a minimal taper of 12 degree was necessary to ensure the absence of undercuts [9].

Objective of the Study

Determine the mean of convergence angles of each tooth in both aspects MD and BL, which produced by fourth-year dental students at Umm Alqura University. Then compare it with ideal convergence angles and see which tooth prepared need to improve.

Materials and Methods

This *in-vitro* study was conducted at the oral and maxillofacial department (prosthodontics division), Faculty of Dentistry, Umm-Alqura University in Makkah. A total of 150 prepared teeth (50 molars prepared to receive full-metal crown, 50 premolars prepared to receive PFM and 50 anteriors prepared to receive all-ceramic). There are 9 sections (3 sections for molar, 3 sections for premolar and 3 sections for anteriors). Each section has 3 hours of training and each student has 2 artificial teeth in each section, except the third section they only have one tooth. We collected the teeth in third sections for each tooth. We only collecting the samples in the last three sections, which may allow them to know the ideal reduction for each tooth.

We determine the size of samples according to the number of students in the phantom lab, each student did 3 prepared teeth (one molar, one premolar and one anterior). No special instructions were given to the students or instructors that we were going to use these preparations for subjective evaluations.

The specimens were collected from fourth-year dental students in the third sections to let the students. All samples are prepared in phantom labs. All the samples were mounted in the Frasaco typodont model; the base holds the tooth in a position with it is long axis perpendicular to the floor of the base (Figure 1). For each tooth, within the typodont 2 completely different pictures from buccal and axial, or proximal views were taken. Images were captured with a digital camera (Nikon digital camera made in Thailand) which is set up on small photographic studio at distance 20 cm for all teeth from the base to maintain stable measurement of angles. A black background is set up to allow the convergence angle to be more easily detected on the computer scan (Figure 1).

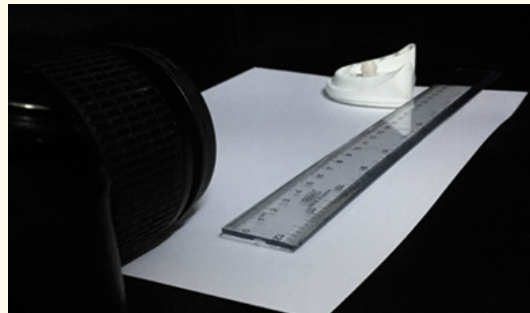


Figure 1: Typodont teeth positioned in the Frasaco typodont model at 20 cm distance from a digital camera.

The images were evaluated by a computer program called on-screen protractor soft-were from Iconico company. This program was used to measure the mesio-distal and bucco-lingual degrees of tapers for each prepared tooth (Figure 2), the convergence angles of each image was recorded by combining of two opposing walls.

The findings were statistically analyzed by comparing the means using an independent t-test. Finally, a one-way analysis of variance was conducted. All the analyses were done using SPSS software package version 21 and a p-value of 0.05 was considered as statistically significant.

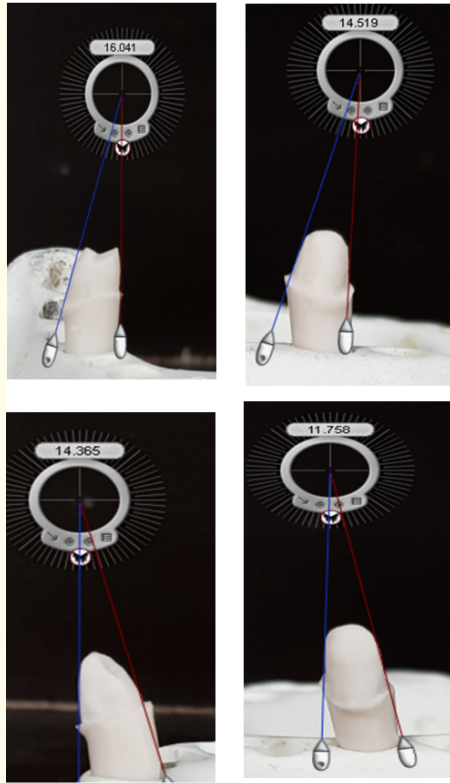


Figure 2: Measurement of convergence angles on computer screen.

Results

In the present study, the occlusal convergence angle of molar, premolar and anterior teeth were evaluated both bucco-lingually (BL) and mesio-distally (MD). The experimental data was statistically analyzed according to the factorial experiment in a completely randomized design to study the effect of the individual factors as well as the effect of their interactions.

Data were computed in order to ascertain that the observed effects were real and discernable from chance effect. In case of significance, the means were compared using the level of significance differences (L.S.D.) at 5%. The statistics of convergence angles (BL and MD) for preparations made by the students were summarized in table 1 and figure 2. The mean BL angle of all preparations was 16.93 ± 6.43 degrees, while the mean MD angle was 15.65 ± 6.26 degrees. The mean BL angle and the mean MD of the three tested teeth were shown in table 2. The mean BL angle for the molar tooth preparation (20.11 ± 7.65 degree) was significantly greater than the mean BL angle for the premolar tooth preparation (19.19 ± 4.21 degree) and the mean BL angle for the anteriors teeth preparations (11.50 ± 1.95 degree) ($p = 0.00$). The mean MD angle for the molar tooth preparation (19.9 ± 6.1) was significantly greater than the mean MD angle for the premolar tooth preparation (16.08 ± 3.9 degree) and the mean MD angle for the anteriors teeth preparations (10.96 ± 1.6 degree) ($p = 0.02$). We choice this comparison to see which teeth have the worst result then decide to increase the amount of training for this tooth in the phantom lab, to improve the quality preparation.

Group	Number	Angle	Mean	S.D
Molars	50	BL	20.113700	7.6486249
	50	MD	19.906740	7.7242366
Premolars	50	BL	19.186320	4.2129075
	50	MD	16.088400	3.9769291
Anteriors	50	BL	11.502660	1.9465623
	50	MD	10.961420	1.6349212

Table 1: Means, standard deviations for mesio-distal and bucco-lingual angles.

BL: Bucco-Lingual; MD: Mesio-distal; S.D: Standard Deviation.

Angles	Number	Mean	S.D	P-value
BL	150	16.934227	6.4277415	0.081
MD	150	15.652187	6.2628259	

Table 2: Difference in convergence angle between all groups of teeth.

BL: Bucco-Lingual; MD: Mesio-distal; S.D: Standard Deviation.

	BL			MD		
	Molar - Premolar	Molar - Anterior	Premolar - Anterior	Molar - Premolar	Molar - Anterior	Premolar - Anterior
P-value	0.454	0.000	0.000	0.002	0.000	0.000
	0.081					

Table 3: P-value of taper falling in the suggested range.

BL: Bucco-Lingual; MD: Mesio-distal.

CA	Number	BL		MD		Total
		Percentage	Number	Percentage	Number	
6° - 12°	45	15%	55	18.33%	100	33.33%
12° - 18°	46	15.34%	51	17%	97	32.34%
18° - 24°	41	13.67%	28	9.33%	69	23%
> 24°	18	6%	16	5.33%	34	11.33%
Total	150	50%	150	50%	300	100%

Table 4: Percentage value of taper falling within the suggested range.

CA: Convergence Angle; BL: Bucco-Lingual; MD: Mesio-Distal.

Degrees	BL				MD				Total
	Molars	Premolars	Anteriors	Subtotal	Molars	Premolars	Anteriors	Subtotal	
6° - 12°	9	2	34	45	12	6	37	55	100
12° - 18°	11	19	16	46	10	28	13	51	97
18° - 24°	17	24	0	41	14	14	0	28	69
> 24°	13	5	0	18	14	2	0	16	34
Total	50	50	50	150	50	50	50	150	300

Table 5: Distribution of examined teeth with relevancy convergence angle (CA).BL: Bucco-lingual; MD: Mesio-distal.

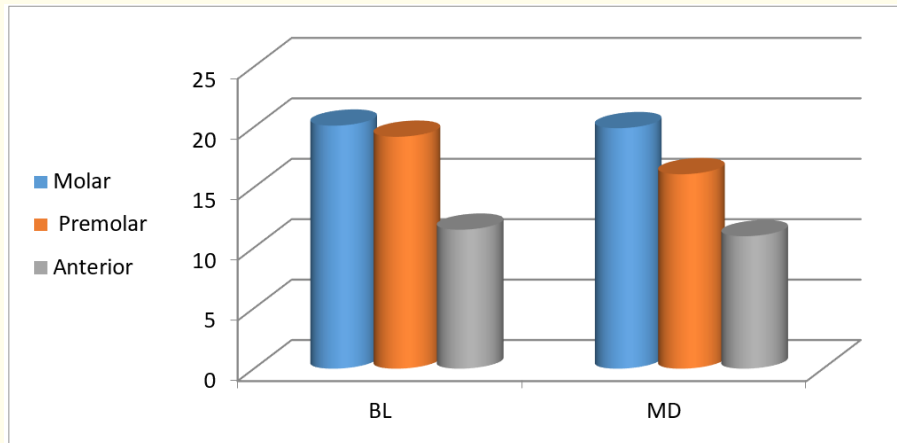


Figure 3: Histogram showing the mean total occlusal convergence (TOC) angles of different tested teeth Bucco-Lingually and mesio-distally.

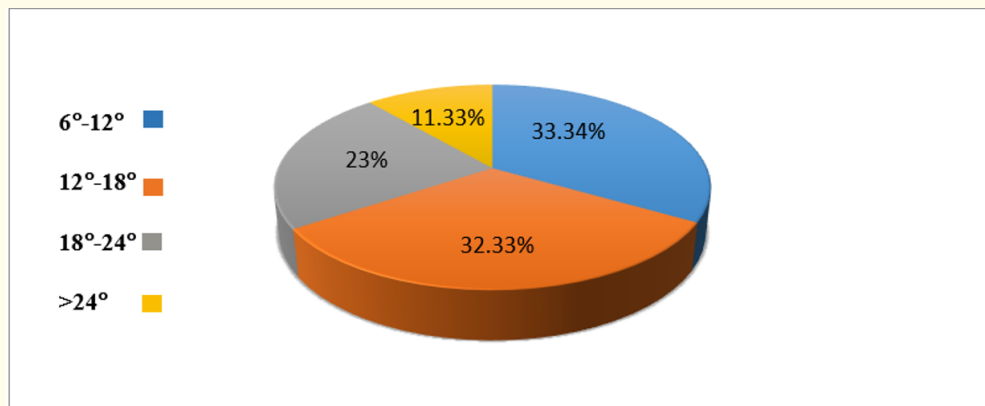


Figure 4: Pie chart percentage value of taper falling in the suggested range.

Discussion

The longevity of fixed restoration depends on many factors, some determined by the operators, and some by the patients. Of these is TOC angles which is an angle formed by opposing axial walls that determine retention and resistance of a restoration. In this study, prepared teeth were collected from 4th-year students, in the academic year 2017 - 2018.

There is a controversy regarding the ideal prepared occlusal convergence angle. Rosenstiel, *et al.* recommends 6- degree TOC, while others recommended that the range between 10 to 22 degree is clinically acceptable [10].

Sato., *et al.* stated that (2 to 5 TOC degree) is ideal and should not be changed although they acknowledged that a 10-degree TOC was more clinically achievable, but Smith., *et al.* thought that a 6-degree TOC criterion to be unrealistic [11].

Studies showed that a TOC of 16 degrees is clinically achievable and it provides adequate retention and resistance [12]. However, the dental school teaches a 12-degree TOC angles to ensure there are no undercuts in preparations. Different methods were previously used to measure convergence angles as microscopy, Photographs, AutoCAD, Lava Design and 3D inspection software, digital laser scanning, Photographs, and visual estimation [13].

Convergence angles of endodontically treated teeth were measured by microscope on stone dies was varied from 12 to 37 degrees, while in vital teeth were from 19 to 27 degrees [14]. Loma Linda University developed a special customs gauge for use in preclinical fixed prosthodontics course, it allows students and faculty members to superimpose the axial walls of dies over lines incorporated into the gauge. These lines represent convergence angles between 5 to 25 degrees. This gauge is only available within Loma Linda School for testing.

In our study, photographs of the prepared teeth were recorded and evaluated by an on-screen protractor soft-were, this method was previously used by Yoon., *et al.* 2014. Our results showed that the percentage of the preparations, which is in the ideal range of 6-12 TOC, angles were 18.33% and 15% for MD and BL respectively. These results are in agreement with OWC., *et al.* who has reported that 38% of students preparing TOC angles greater than 20° [15].

Our finding is in contrast to Rafeek., *et al.* who have achieved 36% (BL) and 62% (MD) taper. Also, El-Mubarak., *et al.* found all measured samples were out of the ideal TOC angles range as it was the first case for students [16].

Moreover, our results showed that the mean TOC angles were found to be higher in the bucco-lingual aspects of molar (20.11 ± 6.38) and premolar teeth (19.18 ± 4.2) than anteriors teeth (11.5 ± 1.9). This indicates that the anatomy of the typodont and anatomic variation in anterior and posterior teeth play a major role in the clinician's ability to reach the recommended narrow range of TOCs to achieve retention and resistance forms. These differences may be due to overall differences in hand skills, operator experience, hand-eye coordination, instrumentation, visual and mechanical access, tooth and oral anatomy, perception skills, magnification, and comprehension of tooth preparation procedures.

A previous study also founds that the TOCs of molars were greater than those of premolars (27.3 degrees versus 17.3 degrees), however, this study did not include the anteriors teeth in the comparison, as in our study [17].

Annerstedt., *et al.* carried a study including general dental practitioners and students. They found a mean TOC angle of 21 degree, which is so close to the maximum angle recorded in the present study. They reported significant differences between premolar and molar preparations made by the same person and that general dentists [18].

There are some limitations to this study as the TOC angles evaluation was limited to a single tooth type, sample size also, these results only demonstrate the *in-vitro* evaluation of angles of tooth preparations, without the clinical perspective of surrounding teeth and other oral structures. So, Additional clinical researches would be a useful.

University	Year of Study	Result
Tehran University of Medical Science	2008	MD 28.81 ± 11.18 degrees, BL 17.20 ± 8.37 degrees.
West Indies University	2010	MD 14.2 ± 5.0 degrees, BL 18.2 ± 7.1 degrees.
Aga Khan University	2012	Convergence angle and axial wall taper values were 23.7 ± 8.9 degrees and 11.3 ± 7.8 degrees.
King Saud University	2013	The overall mean CA was 18.56 degree. Only 32.7% of the preparations were among the suggested CA (<12°).
Governmental and Private School	2014	MD 38.96 ± 11.7 degrees, BL 42.3 ± 10.8 degrees.
King Abdul Aziz University	2014	MD 11.11 ± 4.79 degrees, BL 10.49 ± 3.95 degrees.
Jazan University	2014	The mean MD and BL degrees of taper were 19.52 and 23.25 (Male) 19.77 and 22.38 (Female) degree, for MD and BL respectively.
New Zealand University	2016	The majority of TOC angles fell within an acceptable range of 10 to 20 degree.

Table 6: Relevant literature to compare with the present study results.
 CA: Convergence Angle; BL: Bucco-Lingual; MD: Mesio-Distal; TOC: Total Occlusal Convergence.

Conclusion

This *in vitro* study measured the TOC angles of anterior, premolar and molar teeth prepared by preclinical dental students in Makkah-Saudi Arabia. Most of BL and MD TOC angles fall within an acceptable range, with low values being undercuts and excessive angles of up to 41.31 degree seen. This means the course did very well, but we need to increase the time of training and make sure the student work with the index to know the ideal amount of reduction.

Key Messages:

- To make undergraduate students aware of ideal ranges of Occlusal convergence angles for crown preparations.
- To make readers aware of ideal ranges of Occlusal convergence angles for crown preparations.
- To increase the current competency undergraduate dental students when preparing a crown.
- To find strategies to help undergraduate dental students improving clinical competence.
- To support the development of clinical skills undergraduate dental students as aspects of student education.

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