مجلة الريادة للبحوث والأنشطة العلمية
Al-Riyadah Journal For Researches
And Scientific Activities

العدد الثالث
January 2022 يناير

Convergence angles of Porcelain Fused To Metal Crowns performed in Libyan private dental practice

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Abstract

Back ground: Full coverage porcelain fused to metal crowns (PFM) is commonly recommended for restoration of extensively damaged teeth. Ability of the dentist to adequately prepare teeth is necessary to achieve a proper success and longevity of these restoration.

Aims: This study aimed to determine the degree of axial taper and total occlusal convergence angles (TOC) for Porcelain Fused To Metal crowns (PFM) prepared with clinically practiced values, that carried out by dental practitioners in Tripoli center, Libya.

Materials and Methods: It was a descriptive, cross-sectional study design and held at Alzendah private dental laboratory, Tripoli Libya.

A convenience sample (40) models of Porcelain Fused To Metal Crowns (PFM) preparations carried out by private dental practitioners were scanned by employing a 3D model scanner (Ceramill Map300, Amanngirrbach, Austria). Evaluation of the total occlusal convergence (TOC), bucco-lingual and mesio-distal convergence angles of each abutment tooth was proceeded using B&B dental software (Guide system, B&B, Italy). The degree of taper was measured on the axial walls of each crown preparation and the bucco-lingual and mesio-distal convergence angles subsequently calculated.

Results: A total of 40 casts having crown preparations (15 anterior, 25 posterior). The mean convergence angles mesio-distally for all preparations was 40.29° (sd 21.8°), and for the bucco-lingual was 29.92° (sd 9.3°), with mean of TOC was 35.10°.

In anterior preparations, the mean bucco-lingual convergence angle was 42.32° (sd 12.2°) compared to 24.52° (sd 15.5°) for posterior preparations ($p<0.001$). Mean mesio-distal convergence anteriorly was 20.39° (sd 10.18') compared to 20.01° (sd 12.16°) posteriorly ($p<0.001$). Distal and buccal taper were significantly greater on posterior teeth ($p<0.001$) compared to anterior whereas lingual taper was greater on anterior teeth ($p<0.001$).

Conclusions: The mean convergence angles for porcelain fused to metal crowns produced by private dental general practitioners in Tripoli, Libya, were significantly greater in bucco-lingual dimension than mesio-distal. This results exceeded the recommended guidelines proposed in the literature and it was not easy for them to achieve ideal taper results.

Keywords: Porcelain fused to metal crowns, convergence angles, axial taper,

Introduction

The preparation design is guided by five principles: preservation of tooth structure, retention and resistance, structural durability, marginal integrity, and preservation of the periodontium. For a restoration to have longevity in the oral cavity, a preparation should have retention and resistance form. The concept of retention form refers to the ability of a restoration to resist forces along the long axis, or path of insertion, of the tooth. Resistance form works in tandem with the concept of retention. Resistance form prevents dislodgement of the restoration under occlusal forces directed in an apical or oblique direction (Shillingburg *et al*., 1997).

Convergence angle is one of four operator-controlled factors in tooth preparation that influence retention/resistance. *Taper* is the angle between one axial wall of the preparation and the long axis of the preparation. *Convergence angle* is defined as the angle between two opposing axial walls of a preparation and equals the sum of the taper of two opposing axial walls**.** The degree of taper and the convergence angle are thus interrelated to each other.

The retention of a single crown relies on several factors, such as the height of the preparation, surface texture, the method of placement (cemented or bonded), the closeness of fit, and the axial taper of the preparation walls. The total occlusal convergence angle (TOC), however, represents the most fundamental factor contributing to retention of crownwork and is the angle formed at the intersection of tapers between two opposite axial walls in a given plane (1). Achieving axial preparation walls that are as parallel as possible will enhance retention but this can be hindered by various factors, including visibility, accessibility, location and anatomy of the tooth (Ohm E *et al.*, 1978).

Jorgensen (1955) investigated the relationship between retention and axial wall taper, and noted that retention increased as convergence angle decreased. He recommended an ideal convergence of 5° but also advised some degree of axial convergence was necessary to ensure full seating of cast crowns.

In general, full coverage cast preparations are recommended to have 10° to 20° of total occlusal convergence with a minimal height of 4mm for molars and 3mm for other teeth (Goodacre *et al*., 2001). Further researches led to the conclusion that 16° was the optimal convergence angle, because a 22° convergence provided inadequate resistance

and a 10° convergence did not significantly increase retention (Shillingburg *et al*., 2012; Dykema *et al*., 1986; Dodge *et al*., 1985). These early publications focused on retention of cemented metal-ceramic crowns but with the introduction of all-ceramic crowns that are bonded rather than cemented, a greater degree of taper has been accepted. Thus a total occlusal convergence angle of 20° was found not to affect internal fit of zirconia copings for all-ceramic crowns (Beuer *et al*., 2008). Also a 12° preparation angle, presumably axial taper, for zirconia copings resulted in the best precision of fit compared to 4° or 8° tapers and had no influence on marginal adaptation (Zidan *et al*., 2003). The use of adhesive luting resin enhanced the retention values by 20% at 24° taper compared to the retentive values of conventional cements at 6° taper (Ayad *et al*., 2009).

Crown retention using three different tapers (5°, 12°, 25°) and 4 types of lute: zinc phosphate cement, glass ionomer cement, or adhesive resin (Panavia 21 and C&B-Meta-bond) found that the best retention was obtained when complete metal crowns were cemented with adhesive resin cements, regardless of tooth preparation taper (Ayad *et al*., 2009).

The quality of metal-ceramic crown preparations were assessed by studies that provided privately in the Middle East and found that the TOC angles were higher than recommended with the highest recorded value being 38.2° for mesio-distal convergence on molars (Al-Dwairi *et al*., 2015; Al-Moaleem *et al*., 2015). There have been no studies conducted to assess the convergence angle on PBC preparations in country of Libya.

This study **aimed** to determine the degree of taper and total occlusal convergence angle on casts of teeth prepared for porcelain fused to metal crowns by private dental practitioners in Tripoli center, Libya.

Statistical analysis was performed using SPSS v20, Differences in the convergence angle and axial wall taper values between two groups of teeth (anterior vs. posterior; maxillary vs. mandibular) were tested by independent sample t-test with statistical significance set at $p<0.05$.

Materials and Methods

This was a descriptive, cross-sectional observational study of the convergence angles conducted at Alzendah dental Laboratory, Tripoli, Libya. A sample of 40 crown preparations models of patients were collected in order to achieve the objectives of the study. Data were collected retrospectively using convenient sampling technique from die stone casts after delivering crown to the patients. We included crown preparation models of anterior, premolars, and molars from both arches (maxillary and mandibular) of full coverage crowns prepared by dental practitioners in private practice with at least three years of post-graduate experience under normal clinical condition. The dentists did not know when the casts were to be examined and privacy of patients and dentists was maintained. Local Research Ethics approval from Ministry of health was gained (Ref 345, 2020). The dies models were randomly selected, having crown preparations were obtained in January 2020 from one of the largest dental laboratory, Alzendah dental laboratories in Tripoli center, Libya.

The study was conducted at Alzendah dental Laboratory, Tripoli-Libya. All prepared teeth impressions were poured with Type IV super hard stone, Moldarock Royal, Moldastone (Kulzer , Germany). Then, Master cast models were mounted on square shaped hard wax block to stabilize in a fixed vertical position on horizontal table with white background. Then they were scanned by employing a 3D model scanner (Ceramill Map300, Amanngirrbach, Austria). Evaluation of the total occlusal convergence (TOC), bucco-lingual and mesio-distal convergence angles of each abutment tooth was proceeded using B&B dental software (Guide system, B&B, Italy). In addition, the axial wall tapers for each preparation mesially, distally, buccally and lingually were measured. The standardized reference axes were the mid lines on each surface as determined by the software, which made a plane slice through the image perpendicular to an occlusal grid reference (Figure 1). The formulae to determine the total convergence angle and the axial wall taper are as follows:

1. Total convergence angle, is the angle formed when the two lines along the axial wall inclinations meet, either in bucco-lingual or mesio-distal distal cross sections (Figure 2).
2. Axial wall taper, is the angle of the axial inclination in relation to the horizontal plane - 90°, which represents the point where the taper inclination started from the vertical plane (Figure 3).

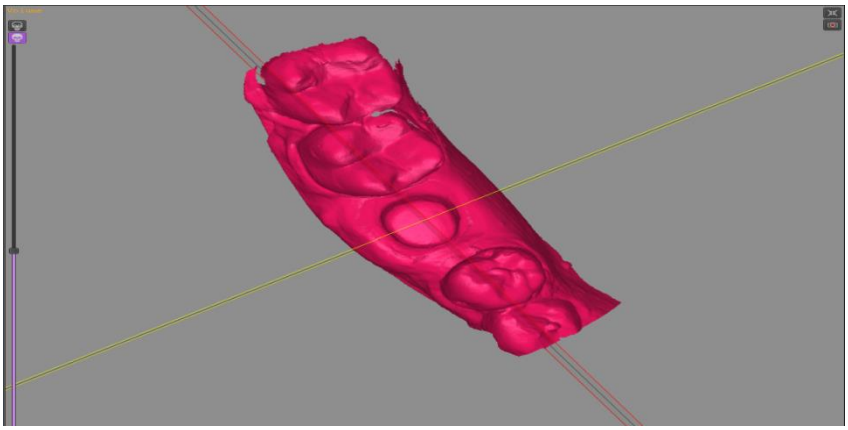

Fig. 1: Scanned image of lower first molar showing mid-bucco-lingual plane for subsequent angle measurement on image as shown in next figures.

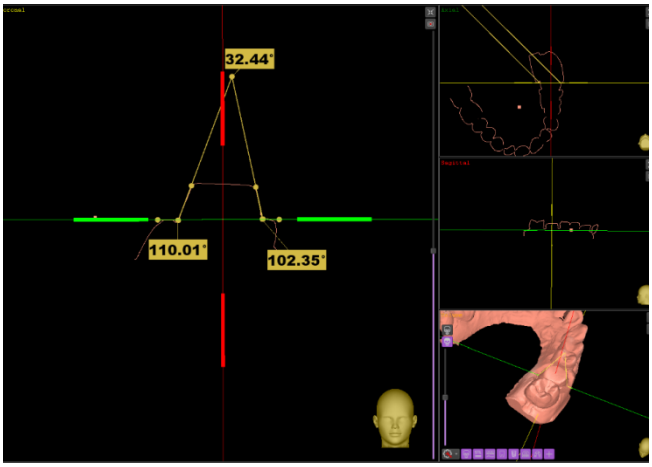

Fig. 2: Determination of total occlusal convergence angle on lower molar. Buccal inclination in relation to horizontal plane= 110°. Lingual inclination in relation to horizontal plane= 102°. Total convergence angle bucco-lingually = 32.44.

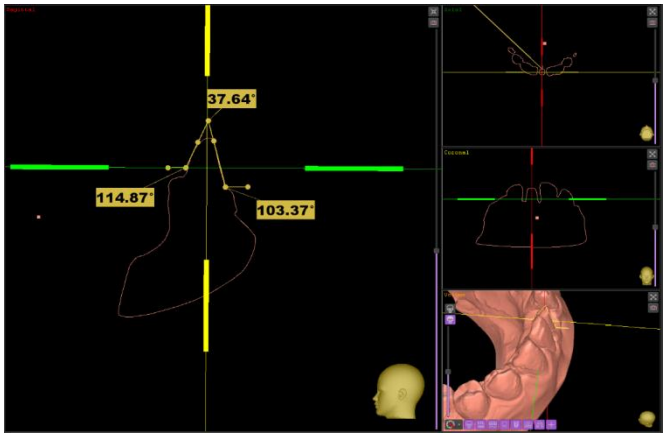

Fig.3: Determination of 37.64°convergence angle on up-per incisor from labial taper at 103° and palatal taper at 114.87°.

Table 1: Mean values for convergence angle and axial wall taper angle on all crown preparations.

Numbers of samples	Tooth		Mesial Axial taper	distal Axial taper	Buccal Axial taper	Lingual Axial taper	BL Convergence angle	MD Convergence angle
1	6		96.49°	95.43°	99.29°	108.08°	27.41°	24.53°
2		1	100.33°	101.29°	97.15°	142.16°	53.62°	27.85°
3	2		98.11°	103.35°	97.34°	99.11°	20.71°	25.76°
4		2	97.66°	95.43°	98.57°	89.92°	21.62°	16.84°
5		5	98.12°	101.86°	102.53°	95.76°	22.20°	24.04°
6	6		107.99°	106.26°	100.08°	103.66°	28.83°	39.25°
7	6		92.71°	102.59°	109.13°	84.19°	16.01°	19.01°
8	4		99.76°	98.27°	84.85°	97.88°	10.74°	17.95°
9	6		100.35°	117.31°	95.96°	95.78°	17.75°	37.88°
10	4		96.79°	95.84°	97.64°	103.72°	18.60°	18.66°
11	5		100.41°	93.52°	102.35°	107.75°	23.81°	18.25°
12		2	97.65°	97.26°	102.48°	117.55°	39.45°	17.41°
13	5		96.72°	95.82°	100.12°	101.46°	23.22°	11.90°
14		4	89.01°	104.74°	101.79°	105.41°	28.66°	14.06°
15	4		96.56°	105.36°	96.16°	114.90°	31.18°	22.42°
16		5	97.59°	95.38°	99.04°	99.63°	21.37°	16.66°
17	4		94.41°	98.22°	105.56°	107.71°	32.61°	15.21°
18		6	88.25°	97.27°	101.86°	108.60°	28.14°	12.31°
19	3		91.95°	112.28°	121.61°	143.10°	84.81°	27.51°
20		2	93.44°	101.28°	96.68°	119.19°	40.94°	17.67°
21	2		91.95°	101.98°	92.10°	123.94°	34.28°	15.30°
22	5		102.67°	97.98°	103.86°	117.53°	42.59°	20.60°
23		6	105.68°	102.83°	110.80°	100.28°	30.78°	30.75°
24	6		107.82°	116.51°	99.55°	96.74°	20.47°	45.93°
25	2		95.23°	94.95°	100.26°	129.95°	49.02°	12.56°
26		6	89.89°	96.93°	95.21°	106.77°	20.56°	14.99°
27		1	109.64°	102.24°	101.77°	148.89°	66.53°	33.22°
28	1		100.34°	106.62°	105.53°	143.96°	70.48°	26.05°
29		1	100.34°	91.00°	97.07°	115.20°	34.58°	14.70°
30	1		108.48°	102.10°	105.15°	118.72°	44.91°	32.87°

31	7		94.50 O	100.79 O	103.83O	94.58 O	20.21 O	18.02O
32			97.41 O	91.10 O	102.89O	95.39 O	23.36 O	13.51O
	7							
33			100.44 O	100.56 O	103.37 O	114.87 O	37.64 O	18.03O
	1							
34		4	99.07O	103.60 O	105.06 O	112.48 O	41.05O	27.68O
35	4		103.22 O	100.05 O	110.61 O	108.23 O	40.35O	28.10O
36		1	100.83 O	82.45 O	95.55 O	143.26 O	57.99O	6.60 O
37			103.04 O	96.82 O	115.85 O	98.31 O	32.23 O	19.63O
		6						
38		3	102.38 O	95.19 O	92.00 O	124.31 O	39.40 O	18.39O
39		6	103.80 O	87.95 O	102.35 O	110.01 O	32.44 O	11.32O
40		5	88.42 O	96.19O	93.40 O	99.46 O	14.59O	7.18 O

Table 1: Mean values for convergence angle and axial taper angle on all crown preparations.

Angle	N	Mean	SD
Buccolingual convergence angle	40	29.92	15.3°
Mesiodistal convergence angle	40	40.29	11.8°
Mesial axial taper	40	98.83	8.5°
Distal axial taper	40	78.90	10.0°
Buccal axial taper	40	98.70	12.4°
Lingual axial taper	40	93.34	16.3°

Results

A total of 40 crown preparations were performed by many dentists. The overall mean total occlusal convergence angle was 29.92º± 9.50 where axial wall taper values was 92.44° ± 2.50.

In the maxilla, the total number of prepared crowns was 30 and the anterior teeth were the highest number 15 (15/40 = 37.5 %), out of which 14 (93.33%) of the total anterior were in maxilla. The upper central incisors prepared in 7 (7/14 = 50%), upper lateral incisors were 6 (6/14= 42.8%) and 2 upper canines were prepared (2/14= 14.2%). A total of 11 (11/40=27.5%) of upper premolar were prepared by dentists in a private clinic, and 5 (5/40=12.5 %) were in upper molar region.

In the mandible, a total of 10 mandibular (lower) single crowns were prepared and included in this study. The highest number were in lower molar region, were 7 (7/10=70%), 2 in lower premolar and 1 in lower anterior.

In general, anterior teeth had significantly higher mean convergence angles bucco-lingually (42.32º) compared to molar teeth (24.52º), whilst premolar teeth had higher mean convergence angles mesio-distally (18.65º) compared to anterior teeth (17.63º) (Table 2).

The mean mesio-distal and bucco-lingual angles of all preparations were 40.29° and 29.92° respectively and are presented in (Table 1).

Mesial, distal, buccal and lingual axial wall tapers are also shown in Table 2. There was no statistical difference in the mean mesial axial taper between anterior (99.69º) and posterior preparations (98.02º).

The distal and buccal axial tapers were significantly higher in posterior teeth (99.90º), (101.55º) respectively compared to the anterior preparations were (93.04º), (90.46º). Conversely, mean buccal or labial wall anterior taper (90.46º) was significantly lower than the equivalent posterior taper value (101.55°) as shown in Table 2.

Table 2: Mean convergence angle and taper values of anterior and posterior teeth.

Angle	Anterior (15)	Posterior (25)	*P*-value
	Mean (SD)	Mean (SD)	
Buccolingual convergence angle	42.32° (12.2°)	24.52° (15.5°)	<0.001*
Mesiodistal convergence angle	20.39° (10.2°)	20.00º (12.2°)	<0.001*
Mesial axial taper	99.69° (8.3°)	98.02° (8.6°)	0.962
Distal axial taper	93.04° (9.4°)	99.90° (9.8°)	<0.001*
Buccal axial taper	90.46° (11.8°)	101.55° (11.5°)	<0.001*
Lingual axial taper	125.07° (14.0°)	102.82° (13.3°)	<0.001*

Mean convergence angle and axial wall taper values differed significantly between maxillary and mandibular teeth as shown in Table 3 ($p<0.05$). Maxillary teeth had significantly higher bucco-lingual convergence and lingual axial taper values, compared to mandibular teeth. On the other hand, mandibular teeth had significantly higher mesio-distal convergence and distal axial taper values. There was no statistical difference between the two groups in relation to mesial and buccal axial tapers. In the maxillary arch, the lingual taper was the highest compared to the other axial wall inclinations. In the mandibular jaw the distal taper was the highest while mesial taper was the lowest.

Table 3: Mean convergence angle according to jaw.

Angle	Maxillary (30)	Mandibular (10)	p-value
	Mean(SD)	Mean (SD)	
Buccolingual convergence angle	32.46º (15.2°)	27.38° (15.1°)	0.045*
Mesiodistal convergence angle	58.81º (9.8°)	21.77° (15.9°)	0.002*
Mesial axial taper	98.36° (7.4°)	99.31° (11.3°)	0.695
Distal axial taper	57.22° (9.3°)	100.58° (11.3°)	0.002*
Buccal axial taper	96.06° (12.4°)	101.35° (12.4°)	0.389
Lingual axial taper	84.47° (16.7°)	102.21" (14.5°)	0.015*

Discussion

Theoretical guidelines for axial wall taper and convergence angle during tooth preparation are arbitrary and are not consistent with the reality. In clinical practice, they are vary from tooth to tooth in different dimensions and depends upon operator experience, vitality, and restorative status of tooth.

The clinical success of the retention of a crown is a multi-factorial such as; taper, height, surface area, and location of the remaining tooth structure. Researchers differ about ideal taper and occlusal convergence of the crown preparation, although rarely ideal taper angle can be achieved but, they achieved clinically acceptable results.

In this study, the mean of total occlusal convergence angle in 40 preparations was 35.10° against the recommended maximum for porcelain bonded crowns of 20°, which although significantly higher, is similar to the results found in previous studies (Fahd Abudulla *et al.*, 2018).

In the current study, convergence angles were ranged (32.46º- 27.38º) in upper jaw and lower jaw respectively, tooth type and whether anterior (42.32º) or posterior (24.52º). These results corroborate previous findings (Saunders *et al.*, 1998) but clinically, since all the preparations were for porcelain bonded crowns, retention may not have been compromised but tooth vitality may have been.

The position of the tooth in either the upper or lower jaw also influenced the convergence angle. In the lower jaw the presence of the tongue may be an obstacle during preparation, compared to the upper teeth. Furthermore, tooth anatomy may have had an impact on convergence angles. Incisors are usually easier to access and thus to prepare, in this study, the low convergence mesio-distally angles (20.39º), but because

of palatal cingula, higher convergence angles labio-palatally (42.32º) are likely in upper anterior teeth.

Difficulty angling the hand piece during molar preparation can lead to increased taper, especially distally, was (98.02º) in our study. Premolars are easier to access than molars, which may account for the more acceptable total occlusal convergence angle.

Several studies have found that the clinically established mean convergence angle among dental students and general practitioners ranged between 12° and 26° and that there is wide variation in convergence angles among general practitioners (Guth *et al*., 2013).

A mean convergence angle of 24.2° (± 11.95°) on 125 porcelain fused to metal crowns performed by undergraduate dental students on patients, as opposed to typodonts, was regarded as similar to that produced by experienced dentists (Virdee *et al*., 2018). Thus experience itself may not be a factor in over-preparation.

The mean convergence angle in this study were 42.32º and 24.52º for bucco-lingual and mesio-distal convergence angle respectively. This is nearly in agreement with the literature, mean convergence values were 32.6° and 24.6° for the bucco-lingual and mesio-distal convergences., in which nearly all operators tend to produce greater convergence bucco-lingually. The suggested reasons are, removal of more buccal tooth structure in order to eliminate molar undercut and poor palatal teeth albeit cingulum management in anterior maxillary, for metal ceramic preparations (Ghafoor *et al*., 2012).

The mesio-distal values were comparable with other studies reporting mean convergence angles practiced by clinicians. In the current study, the mesial angles was 99.69º and 93.04º distal value in anterior teeth, but these value exceeded most reported values in the literature (Leempoel *et al*., 1987). This could be explained by the fact that previous reports were mainly performed on posterior teeth were the inclusion of anterior tooth in this study has contributed to an increase in bucco-lingual convergence value, since palatal cingula in anterior teeth have influenced the results. These values exceeded the recommended values 4°-14° proposed in earlier studies (Goodacre *et al*., 2001; Shillingburg *et al*, 2012).

In this study, the bucco-lingual convergence angle in maxillary teeth of 32.46º in comparison to 27.38º for mandibular teeth with a very high palatal axial value of 84.47º. This is in agreement to previous study by Al-Omari *et al*., (2004), where they found that maxillary teeth had a mean bucco-lingual convergence angle of 33.8° compared to 28.9° for mandibular teeth with a very high palatal mean axial taper of 107.6'.

Maxillary bucco-lingual convergence was significantly higher than mandibular teeth possibly because direct vision is more likely for mandibular preparations. Direct line of sight from above and anterior to the long axis of the lower molar is likely to result in an increased distal taper and thus increased mesio-distal convergence. Premolars (bicuspids) had the lowest convergence values compared to all the other teeth all of which had similar angles. This was contrary to expectations as anterior teeth are the easiest to prepare and were previously reported to have the lowest convergence angles (Saunders *et al*., 1998; Al-Omari *et al*., 2004).

Conclusions

Within the limitations of this study, it can be concluded that there was a considerable disparity between the convergent angles and taper values recorded in this study. The mean convergence angles for porcelain bonded crowns produced by private dental general practitioners in Tripoli, Libya, were significantly greater in bucco-lingual dimension than mesio-distal. This results exceeded the recommended guidelines proposed in the literature and it was difficult for them to achieve ideal taper results. The findings of this study highlight the technically demanding nature of crown preparation and level of skilled dentists required to achieve ideal convergence value.

Further researches with large sample size, are needed to determine optimal degree of taper and therefore TOC specifically for porcelain bonded crowns.

Acknowledgments

This research was carried out and supported by members of dental technicians at Al-zendah private dental laboratory, Tripoli, Libya.

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