

Convergence Angles of Clinical Tooth Preparations Achieved by Dental Students at King Saud University, Saudi Arabia

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Abstract: The appropriate convergence angle (CA) for adequate retention and resistance of cast crowns has always been a matter of research and discussion. The purpose of this study was to measure the CA of tooth preparation for single crown (SC) or as abutments for fixed partial denture (FPD) carried out by final-year undergraduate dental students at the College of Dentistry, King Saud University and to compare them with the recommended CA. The convergence angles of 355 tooth preparations were evaluated and grouped into SC preparations and FPD abutment preparations. Dies were scanned using the computer-assisted design (CAD) system (Cercon, Degudent), and snapshots were then taken from buccal and mesial views. CA was calculated from a colored printout for each snapshot using a protractor. The overall mean CA was 18.56°. Only 32.7 percent of the preparations were within the recommended CA (<12°). The mean CA of SC (17.7°) was less than the mean CA for FPD abutment preparations (19.58°). The mean CA for anterior tooth preparations (15.8°) was significantly less than the mean CA for posterior tooth preparations (20.3°). The mean CA for mesio-distal axial wall preparations (16.66°) was less than the mean CA for the buccolingual axial wall preparations (20.45°). A wide range was found for the convergence of the axial walls among dental students. The recommended CA (<12°) was difficult to achieve clinically by these students.

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Parallel opposing walls of cast crown preparations can enhance retention and resistance; however, preparations in the oral cavity with no undercuts are not always clinically feasible. In addition, some degree of convergence is necessary in order to compensate for the possible inaccuracies of the fabrication processes and permit for assessment of preparation walls and prevention of undercuts, compensate for inaccuracies in fabrication, and permit more favorable seating during cementation. The convergence angle (CA) of a tooth preparation is the combined angle made by opposing axial walls when measured against the vertical long axis of the tooth.¹ Textbooks in fixed prosthodontics often recommend a CA of approximately 5° (4-6°) as the ideal and a range of 4-14° as acceptable.¹⁻³ However, these guidelines are difficult to follow clinically, and divergence from parallel might have to be as much as 12° to be observed clinically as diverging surfaces.^{4,5} Mack⁶

observed that a minimal taper of 12° was necessary to ensure the absence of undercuts. Goodacre et al.⁷ proposed that the total CA should range between 10° and 20°. Other investigators have recommended 10° and 16° CA based on laboratory studies.^{5,8,9}

Several techniques have so far been described for evaluating CA of tooth preparations. Devices such as photocopy machines,⁸ overhead projectors,¹⁰ goniometric microscopes,¹¹ 3-D laser scanners,¹² and diamond rotary cutting instruments¹³ have been used to measure the CA of working dies; however, none of these devices have widespread acceptance. In addition, previous studies have reported that the CA prepared by dental students was greater than that recommended in textbooks, with a mean CA of 19.2° mesio-distally (M-D) and 23° bucco-lingually (B-L) for vital teeth and 12.8° M-D and 22.5° B-L for non-vital teeth.⁴ Another investigation reported that final-year dental students prepared teeth for

full metal-ceramic crowns with a mean CA B-L and M-D of 25.3° and 22.4° respectively.¹⁴ Ayad et al.¹¹ showed the mean B-L CA ranged from 15.6° to 19.8°, whereas the mean M-D CA ranged from 14.1° to 19.4°. Furthermore, Noonan and Goldfogel⁸ reported a mean CA of 19° for normal clinic conditions and 15.7° for examination conditions. A CA that ranged from 21.4° to 27.8° was reported in another investigation.⁹ The results of a study in which final-year dental students were taught to prepare teeth for full crowns with a CA of 4-10° found that only 12.7 percent of the prepared teeth fell within the ideal range of 4-10° and the average CA value was 19°.¹⁵ Annerstedt et al.¹⁶ reported an average CA value of 21° by general dental practitioners and 19.4° by dental students.

Although the opinions of dentists vary considerably regarding the optimal CA, there is sparse data concerning the extent to which recommended values are used in dental practice.^{8,10,13} The aims of this study were to measure the CA of tooth preparations accomplished by final-year dental students at one dental school; to evaluate the effect of tooth location on the CA (anterior versus posterior); to assess the effect of single crown (SC) versus fixed partial denture (FPD) abutment preparations on the CA; and to measure the difference in CA between the M-D walls and the B-L walls in tooth preparation.

Materials and Methods

After receiving ethics committee approval, this study was conducted using final-year undergraduate students in the College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Three hundred and fifty-five dies from the students' master working casts were collected and were grouped into SC and FPD abutments.

The criteria for selection included tooth preparations for metal ceramic restorations either as SC or abutments for FPD. No special instructions were given to the instructor or the students that would indicate the preparations were to be evaluated for CA. The dies were scanned using the Cercon eye scanner (DeguDent GmbH, Hanau-Wolfgang, Germany). CAD software of Cercon art (DeguDent GmbH) was used to take snapshots for each die from two views (Figure 1). The buccal view was taken to measure the CA of the M-D axial walls, and the mesial view was taken to measure the CA of B-L axial walls.

The snapshots were saved in a PC computer and printed out on color paper. The CA was measured for

each view by drawing two lines over the right and left contour of the axial walls of the die, starting from the finish line and extending coronally (Figure 2). The angle formed by the intersection of the two lines was measured with a protractor. The abutments were divided into the two categories: anterior (incisors and canines) and posterior (premolars and molars). Data were collected and analyzed using descriptive and student's t-test with a statistical software package (SPSS v16.0, SPSS Corp., Chicago, IL, USA).

Results

The results for CA comparisons for all groups are shown in Table 1. The overall mean CA among all groups was 18.56°. The mean CA for the anterior tooth preparation (15.8°) was significantly less than the mean for the posterior tooth preparations (20.3°) ($p=0.000$). In addition, the mean CA of the SCs (17.7°) was significantly different from the mean CA of FPD abutment preparations (19.58°) ($p=0.021$). The preparations had a greater mean CA of the B-L 20.45° than the M-D 16.66° ($p=0.000$). Thirty-nine percent of B-L and 26.5 percent of M-D CA prepared by students were within the recommendations of <12° CA.

Only 32.7 percent of both M-D and B-L CA were within the recommendations (<12°). About 21 percent achieved CA of less than 10°, in comparison to around 40 percent who achieved CA of more than 20° (Table 2). When 16° CA was chosen as the criterion of the taper, 47.5 percent of preparations were within this category (Table 2). In posterior teeth, the mean CA of single crown abutments differed significantly from that of FPD abutments in comparison with anterior teeth ($p<0.05$) (Table 3).

Discussion

Convergence angles are one of many factors that directly affect the overall acceptability of a crown preparation.^{17,18} Recommendations have been made for optimal axial wall taper of tooth preparations for cast restorations, but these recommendations are theoretical and have proven difficult to achieve in clinical practice.^{4,5} The results of our study showed that the mean CA achieved by the final-year dental students was 18.56°. This finding is in agreement with previous studies investigating CA achieved in clinical sittings.¹⁵ According to Sato et al.,¹⁹ the mean CA achieved by dental students was 19°, whilst Annerstedt et al.¹⁶ reported a CA of 19.4°. However,

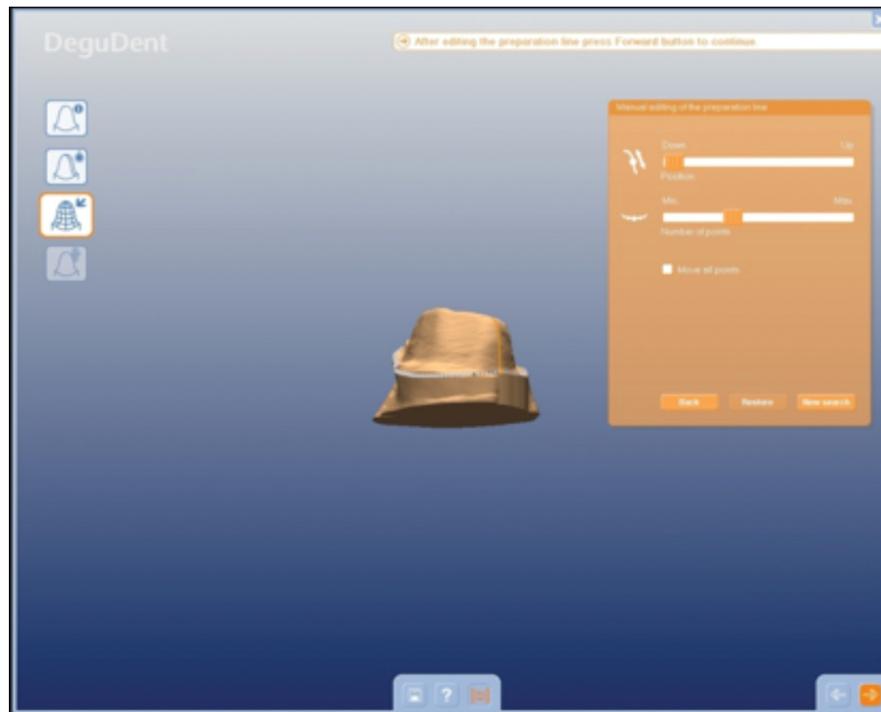


Figure 1. Snapshot from the Cercon art system



Figure 2. Angle calculation from a snapshot printout

Table 1. Mean, standard deviation (SD), and standard error for convergence angle (CA)

	Number	Mean CA	SD	Std. Error
Crown	193	17.70°	10.681	0.544
FPD	162	19.58°	10.718	0.596
Anterior	137	15.79°	9.494	0.575
Posterior	218	20.29°	11.101	0.532
B-L	355	20.45°	11.051	0.587
M-D	355	16.66°	10.065	0.535

minor differences could be attributed to different measuring methods and differences in sample size.

Although these final-year undergraduate dental students were under close supervision by the faculty instructors, only 32.7 percent of the preparations were in the recommended range for CA (<12°) as stated by fixed prosthodontics textbooks. These results were consistent with previous studies.^{14,15} Patel et al.¹⁵ found that only 12.7 percent of the prepared teeth fell within the ideal range of 4-10°. It may be influenced by gaining access to the oral cavity, position and inclination of the tooth itself, and the path of insertion on the FPD abutments preparation. Parker et al.¹³ proposed guidelines for preparation taper based on mathematical calculations. The taper required to provide resistance form for an individual preparation was calculated by using a preparation height to base ratio. The recommended values were 29-33° for incisors and canines and 8-10° for premolars and molars, which were outside the range for most values registered for posterior teeth in our study.

The results of this study showed that the FPD abutments had significantly greater CA than CA of SC. This may be partly a result of the fact that the FPD abutment preparation has to consider the common path of insertion and hence increasing the CA. However, Al Ali et al.²⁰ found the CA for SC was more than that of FPD abutments, and Nordlander et al.¹⁰ reported no significant difference between the CA of FPD and SC abutment preparations. In our study, the mean M-D CA was significantly less than the B-L CA. This may be due to better accessibility and visibility to the proximal axial walls compared to the B-L axial walls or due to some anatomical factors such as the lingual inclination of the mandibular posterior teeth. Short palatal surfaces of anterior teeth and reduction of the axial surfaces in two planes would produce a short wall surface and increase the B-L CA. However, several studies reported similar findings,^{5,8,10,14,16,21,22} with CA for crown preparations of 25.3° B-L and 22.4° M-D.¹⁴

Table 2. Distribution of examined teeth with regard to convergence angle (CA)

CA	Number	Percentage
<10°	75	21.1%
≥10° to ≤20°	132	38.6%
≤16°	169	47.5%
>16°	186	52.5%
>20°	143	40.3%
Total	355	100%

Table 3. Mean and standard deviation (SD) of convergence angle of single crown (SC) and fixed partial denture (FPD) for anterior and posterior teeth

		N	Mean	SD	p-value
Anterior	SC	85	15.89	10.338	0.82
	FPD	52	15.62	7.953	
Posterior	SC	108	19.13	10.753	0.031*
	FPD	110	21.43	11.342	

*p<0.05

Our study found that the CA of anterior tooth preparations was significantly less than the CA of posterior teeth. This finding is in agreement with previous studies^{10,14,16} that reported CA for anterior crown preparations of 19.1° and 27.05° for posterior teeth.¹⁴ This may be due to the relatively better accessibility to and visibility of the anterior teeth. Although the CA reported in this study is less than the CA in the case of posterior tooth preparations, it was greater than the recommended ideal range, which may suggest that the visual assessment for the taper has limitations clinically. The use of a mirror to occlusally visualize the prepared abutment might be the source of inaccuracy in assessing the CA and parallelism of opposing surfaces. For a more effective method to assess the CA, it has been recommended to use the mirror to visualize the preparation clinically from the lingual and the buccal views, rather than visualizing it from

the occlusal view.⁷ Moreover, the B-L inclination of molar teeth may force clinicians to overprepare teeth in order to overcome the undercuts.¹⁰

The Cercon eye scanner used in this study to scan the dies is a three camera system as well as a laser, which can precisely map up to sixteen units per model. With a scan time of less than twenty seconds per unit and a scanning precision of ten microns or less, even difficult model geometries, such as undercuts, are easily read. Therefore, this method might be a useful and accurate tool to assess the CA of prepared teeth.

In our study, it was not possible to assess any differences between vital teeth and those restored endodontically. Two studies have reported that the preparations of endodontically treated teeth have a larger CA than with vital teeth.^{4,5} However, in light of the findings in our study, there is perhaps a need for improvement in preparations carried out by the students. The long-term prognosis is not as certain as that in which preparations are carried out to more defined parameters.

Conclusion

Dental students in our study had difficulties in preparing teeth to achieve the generally recommended CA of less than 12°. The overall mean CA was 18.56°. The mean CA for the anterior tooth preparations was significantly less than the mean for the posterior tooth preparations. In addition, the mean CA of the crown abutment preparations significantly differed from the mean CA of FPD abutment preparations. Minimal clinical experience, limited access, visual errors, and anatomic variations are some of the obstacles to ideal preparation.

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