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CONVERGENCE ANGLES OF TOOTH PREPARATIONS ASSESSED ON DIES FOR FULL CROWNS AND BRIDGE RETAINERS
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ABSTRACT

Objective: **The aim of the study was to assess the convergence angles of tooth preparations on dies for full crowns and bridge retainers done by oral health providers in Nairobi, Kenya.** ***Study design:*** **This was a descriptive cross sectional study.**
Setting: **Selected dental laboratories in Nairobi, Kenya.**
Subject: **Dies of full crown and bridge retainers.**
Results: **A majority (59%) of the tooth preparations were for single crowns and 41% were for bridge retainers. The mean convergence angle for all the dies was 24.0○ with a mean buccal-lingual convergence angle of 26.7 ○ +11.93SD and a mean mesio-distal convergence angle of 22.1 ○ +10.89SD. Ideal tooth preparations were found in 18.1% of the dies. Majority of which were for single crowns (58.9%) followed by the abutment preparations for three unit bridges at 23.2%.**
Conclusion: **Most of the tooth preparations did not have both ideal mesio-distal and buccal-lingual convergence angle measurements. There is therefore a need to provide Continuing Professional Education courses for dentists on tooth preparation for crown and bridge to enhance clinical application of tooth preparation guidelines.**

INTRODUCTION

Full coverage crowns are indirect restorations which are indicated in patients who have weakened tooth structure and poor aesthetics with the aim of restoring function, tooth morphology and to improve or restore aesthetics1.Tooth loss and discolouration has been reported by Mignogna and Fedele (2) to cause physical

and psychological problems. Different types of crowns include full metal, all ceramic, metal ceramic and high strength porcelain crowns.

Crowns are subjected to masticatory forces in the oral cavity and for them to function optimally they have to resist displacement during function. This is achieved by incorporating retention and resistance features on the tooth preparations. Retention features prevent the dislodgement of the prosthesis along the path of insertion whereas resistance features prevent dislodgement when oblique, non-axial forces act on the tooth (3). Prostheses with poor retention predispose the patient to discomfort and marginal opening resulting in cement dissolution and micro-leakage of saliva and its bacterial components. This can result to sensitivity, dental caries and pulpal necrosis. Dental caries and loss of retention have been reported to account for 24% of metal ceramic crown re-treatments (4). Walton et al (5) reported that de-cemented crowns and bridges accounted for 15.1% of the mechanical complications. Loss of retention can arise due to several factors with poor geometry of the tooth preparation having the greatest effect. Other factors include the type of luting cement used, technique of luting and subjecting the prosthesis to large magnitude of dislodging forces due to trauma or para-functional habits (6, 7).

The retention and resistance form of the tooth preparation increase with an increase in parallelism of the axial walls (6, 7), which is assessed by measuring the convergence angle formed between opposing axial walls. Maximum retention is achieved at convergence angles of 6° to 12° (3, 8). This has been reported to be difficult to achieve clinically without creating unfavourable undercuts in the tooth preparation. The clinically achievable convergence angles range from 6° to 24°, although the ideal is between 10-20° (3).

Studies on clinically achievable convergence angles have been done by measuring the convergence angles of dies of the prepared teeth by using different methods including overhead projectors (9), Goniometer Microscope (10), AutoCAD software program (11), and diamond rotary cutting instruments (12). Measurements using the overhead projectors are inexpensive and easily available but are more susceptible to error due to a 3-dimensional object being measured as a 2-dimensional image. However, the measurements obtained using the overhead projector is reported to be more reproducible when compared to the use of photocopiers (13). AutoCAD software is relatively cheaper when compared to purchasing the microscopes. It analyses the shape and dimensions of a 3-dimensional object and the angular dimensions of photographs or scanned dies can be obtained. The measurements obtained using the Tool Maker Microscope, Goniometer Microscope and AutoCAD have been reported to be more accurate and more reproducible compared to measurements obtained using overhead projectors.

Studies carried out by various authors to evaluate convergence angles of tooth preparations for full crowns have reported varying measurements with mean tapers of between 11° to 27° for dental students and 14° to 20° for prosthodontists and dental practitioners (12, 14). In a Swedish study by Annerstedt et al (14), adherence to recommended guidelines were found to be low (28%). This is similar to the findings of a Jordainian study by Al-Dwairi et al (15), which reported 29% adherence. However, the findings of a study in Tokyo by Sato el al 16 reported a much lower adherence of 12.7%. The difference in the findings of the various studies could be attributed to the difference in the study population. In the study by Sato et al (16), preparations done by undergraduate students were evaluated

whereas Al-Dwairi et al (15) evaluated dies prepared by general dentists. Annerstedt et al 14 evaluated dies prepared by both undergraduate students and general dentists. The general dentists may have more clinical experience in tooth preparation for crown and bridge when compared to the undergraduate students which may lead to lower adherence by undergraduate students as reported by Sato et al (16).

The factors likely to influence the degree of convergence during tooth preparation include the position of the teeth in the dental arch and the level of qualification of the clinician. Tooth preparations for posterior teeth have been shown to have greater convergence angles than anterior tooth preparations (14). In a study by Kent et al (17), the tooth preparations for mandibular molars were found to have the greatest convergence angles. This could be attributed to easy accessibility of the anterior tooth and the difference in the anatomic shapes between the anterior and posterior teeth. Lower convergence angles have been reported in preparations done by dental students working under supervision and during examinations than by students working independently (14). This has been attributed to more attention to the preparation geometry if assessment is going to be done by another dentist.

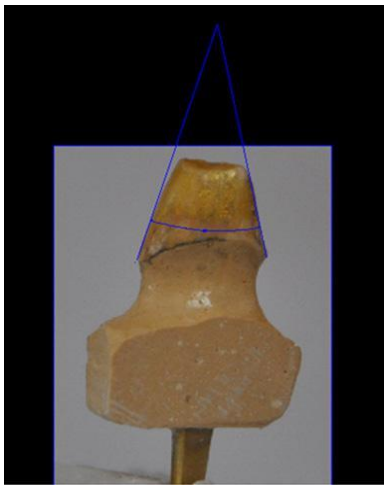
Buccal-lingual surfaces of the teeth have been reported to be prepared with greater convergence angles than mesio-distal surfaces (10). The convexity of the buccal and lingual walls especially of the molars may necessitate more preparation to avoid undercuts. Bridge abutments have been reported to be prepared with greater convergence than individual crown preparations. This could be as a result of the tendency to over taper the preparations as the dentist tries to achieve an ideal preparation especially in cases with multiple abutments.

The aim of this study was to determine the convergence angles of tooth preparations on dies for full crowns and bridge retainers done by dentists in Nairobi, Kenya.

MATERIALS AND METHODS

This was a descriptive cross sectional study conducted at selected dental laboratories from August 2013 to August 2014 in Nairobi, Kenya. A convenient sampling method was used to select the dental laboratories. 310 dies that met the inclusion criteria were evaluated. The inclusion criteria stipulated that the dies should be fabricated from die stone material, there should be no porosities or fractures on the tooth preparation and the dies should be fabricated from impressions done using elastomeric impression materials. The selected dies of the prepared teeth were removed from the stone model base and mounted on a square shaped hard plaster block to stabilise the dies in a fixed vertical position. The type of complete coverage crown for which the tooth had been prepared, the number and location of prepared teeth were noted and recorded in the data collection form. Photographs of the facial and proximal aspects of each die were taken by the principal investigator using a 12.3 Megapixels digital single-lens reflex camera (Nikon D90, Nikon, Thailand). The photographs were transferred to a computer and an AutoCAD 2007 software program (Autodesk, Inc, USA) was used to measure buccal-lingual and mesial-distal convergence angles of each preparation. Lines were drawn on the gingival third of the buccal-lingual and mesio-distal surfaces and extended until they met to form an angle above the image (Figure 1).

Figure 1
Convergence angle measurement between buccal and lingual walls using AutoCAD, 2007 (Autodesk, Inc, USA)



The principal investigator carried out all the measurements on the dies to eliminate inter-examiner variation. Every 10th die was re-examined to evaluate intra-examiner reliability. A different investigator evaluated 5 percent of the dies to ensure inter-examiner reliability. Cohen's kappa score was used to calculate inter-examiner reliability. The kappa value obtained was 0.87.The data was analysed using the SPSS version 20 and MS EXCEL. The data has been presented by use of tables and texts.

RESULTS

The study evaluated 310 dies. All the dies had been prepared for metal ceramic crowns. Three quarter of the dies [242 (78.1%)], were for teeth in the maxillary arch and 68 (21.9%) were for teeth in the mandibular arch. The majority of the preparations were for single crowns [183 (59%)] and 127 (41%) were for abutments. Table 1 shows the position of the prepared tooth type in the dental arch.

Table 1
The position of the prepared tooth type within the dental arch

Tooth type	Maxillary		Mandibular		Test statistic
n	(%)		n (%)		
Central incisor	63	(20.3%)	9 (2.9%)		Fishers exact test.
Lateral incisor	6	(1.9%)	2 (0.6%)		P=0.189
Canine	15	(4.8%)	4 (1.3%)		
Premolar	102	(32.9%)	31	(10.0%)	
Molar	56	(18.1%)	22	(7.1%)	
Total	242	(78.1%)	68	(21.9%)	

A third of the tooth preparations were maxillary premolars 102 (32.9%) followed by the maxillary central incisor 63 (20.3%). However, the variation in the frequency of the prepared tooth type in the maxillary and mandibular arch was not statistically significant (X2=0.175, d.f.=4, p=0.189). The mean convergence angle of all the dies was 24.4°. The ideal convergence angle measurements (10-20○) in both the buccal-lingual and mesio-distal aspects were found in 56 (18.1%) dies. The majority of these ideal convergence angles 25 (44.6%) were found in maxillary premolars, followed by maxillary anteriors 9 (16.1%), mandibular molars 7 (12.5%), mandibular anteriors 6 (10.7%), mandibular premolars 5 (8.9%) and maxillary molars 4 (7.1%). The majority of the ideal convergence angle, in both buccal-lingual and mesial-distal aspects, were

found in tooth preparations for single crowns 33 (58.9%) followed by abutment preparations for three unit bridges which were 13 (23.2%).

The overall mean buccal-lingual convergence angle for all the dies was 26.7° (+11.93 SD) with a range of 1° to 61°. Table 2 shows the buccal-lingual convergence angle measurements in different tooth types and number of teeth prepared in each cast.

Table 2
Buccal-lingual convergence angle measurements in different tooth types and number of teeth prepared in each cast

	Ideal 10-20○ n (%)	Non Ideal n (%)	Test statistic
Tooth type			
Maxillary anterior	25 (29.8%)	59 (70.2%)	X 2 = 16.1, d.f. = 5
Maxillary premolar	40 (39.2%)	62 (60.8%)	p = 0.006
Maxillary molar	8 (14.3%)	48 (85.7%)	
Mandibular anterior	7 (46.7%)	8 (53.3%)	
Mandibular premolar	13 (41.9%)	18 (58.1%)	
Mandibular molar	11 (50%)	11 (50.0%)	
Number of dies prepared in each cast			
1	45 (35.4%)	82 (64.6%)	X 2 = 9.25, d.f. = 3
2	43 (31.6%)	93 (68.4%)	p = 0.025
3	10 (62.5%)	6 (37.5%)	
More than 3	6 (19.4%)	25 (80.6%)	

The tooth preparations for the mandibular molars had the highest percentage of the ideal buccal-lingual convergence angle measurements while those of the maxillary molars had the least. This difference in degree of conformity with regard to the tooth type prepared was statistically significant (X 2= 16.1, d.f. = 5, p = 0.006).

The dental casts with tooth preparations on 3 teeth had a significantly higher percentage of ideal buccal-lingual convergence angle measurements on the dies at 62.5% as compared to 35.4% in casts that had a single tooth preparation and 31.6% in casts with tooth preparations on 2 teeth (X 2 = 9.25, d.f. = 3, p = 0.025).

The mean mesio-distal convergence angle for all the dies was 22.1° (+10.89 SD) with a range of 1° to 58°. Table 3 shows the mesio-distal convergence angle measurements in different tooth types and number of teeth prepared. The tooth preparations of the mandibular molar had the highest percentage of ideal preparations 68.2% whereas the mandibular premolar had the least percentage of ideal cases at 25.8%. This difference in ideal preparations of the mesio-distal convergence angle with regard to the tooth type was not statistically significant (X 2 = 10.48, d.f. = 5, p = 0.062). The dental casts with tooth preparations on 3 teeth had a significantly higher percentage of ideal mesio-distal convergence angle measurements on the dies at 62.5 % as compared to 45.7% in casts that had a single tooth preparation and 36.8% in casts with tooth preparations on 2 teeth (X2 = 9.55, d.f. = 3, p = 0.022).

Table 3
Mesio-distal convergence angle measurements in different tooth types and number of teeth prepared

	Ideal 10-20° n (%)	Non Ideal n (%)	Test statistic
Tooth type			
Maxillary anterior	31 (36.9%)	53 (63.1%)	X 2= 10.48, d.f. =5
Maxillary premolar	41 (40.2%)	61 (59.8%)	p = 0.062
Maxillary molar	23 (41.1%)	33 (58.9%)	
Mandibular anterior	7 (46.7%)	8 (53.3%)	
Mandibular premolar	8 (25.8%)	23 (74.2%)	
Mandibular molar	15 (68.2%)	7 (31.8%)	
Number of dies prepared in each cast			
1	58 (45.7%)	69 (54.3%)	X 2 = 9.55, d.f. =3
2	50 (36.8%)	86 (63.2%)	p = 0.022
3	10 (62.5%)	6 (37.5%)	
More than 3	7 (22.6%)	24 (77.4%)	

DISCUSSION

This study evaluated three hundred and ten dies prepared by oral health providers in Nairobi with the aim of establishing whether the structural preparations for single crowns and bridge abutments adhered to ideal guidelines. The ratio of maxillary to mandibular dies evaluated was approximately 3.6:1. This may be attributed to the fact that maxillary anterior and premolar teeth, which comprised the majority of the maxillary preparations, are in the aesthetic zone and are visible when an individual smiles (3). A patient would therefore be more likely to have these teeth restored or replaced for aesthetic reasons.

Majority of the tooth preparations did not have ideal convergence angle measurements with only 18.1% having ideal convergence angle measurements in both the buccal-lingual and mesio-distal aspects. These results are similar to those of studies that have reported that tooth preparations are routinely not prepared with ideal convergence angles (9, 14, 15, 19). Studies carried out in Sweden (14) and Jordan (15), found that ideal tooth preparations constituted 28% and 29% of the total tooth preparations evaluated respectively. Tooth preparations with large convergence angle measurements result in reduced retention and stability of the prostheses. The lack of conformity to recommended tooth preparation guidelines can be attributed to inadequate clinical experience in fixed prosthodontic treatment or inability to accurately estimate the parallelism of axial walls of tooth preparations intra-orally. The recommended guidelines for tooth preparation include provision of adequate retention and resistance, adequate tooth reduction to ensure structural durability of the restorative material and good marginal integrity (3). Various methods have been suggested to improve on the quality of tooth preparations for crowns and bridge retainers. This includes the use of magnification loupes during tooth preparation, the use of digital assistance software such as the PREP assistant, (KaVo, Leutkirch) during pre-clinical training to enable students accurately assess their tooth preparation, the use of designated burs to

enable calibration of tooth reduction as well as meticulous attention to detail during tooth preparation (20).

The mean buccal-lingual convergence angle was higher than the mean mesio-distal convergence angle at 26.7 ° (+11.93 SD) and 22.1° (+ 10.89 SD) respectively, similar to those of a previous study that evaluated the same tooth types (19). This has been attributed to the morphology of the teeth which are more convergent in the buccal-lingual aspect when compared to the mesio-distal aspect. However, this is in contrast to the findings by Kent 17that reported higher mean mesio-distal convergence angle measurements of 24.2° (+9.90) mm and mean buccal-lingual convergence angle measurements of 20.3° (+7.60) mm. This difference can be attributed to the variation in the oral health providers within the different studies. In the study by Kent (17), all the tooth preparations were done by one experienced clinician whereas in the current study and in that by Noonan and Golfogel (19), the tooth preparations were done by several oral health providers with different levels of qualification. The tooth preparations for the mandibular molar had the majority of the ideal buccal-lingual and mesio-distal convergence angle measurements when compared to the preparations of the other tooth types with a mean of 22.8°. These findings contrast with those of Annerstedt et al (14) and Kent et al (17) who both reported that tooth preparations of mandibular molars had the highest mean convergence angles when compared to other tooth types. In the study by Kent, the tooth preparations evaluated consisted of maxillary and mandibular posterior teeth whereas in the current study and in that by Annerstedt et al, all tooth types were evaluated. Annerstedt el al (14) scanned the dies using the Procera CAD/CAM system (Nobel Biocare, Yorba Linda California) and took angular measurements of cross-sections of the tooth preparations. The difference in preparation among different tooth types may also be attributed to differences in accessibility and morphology of the teeth.

CONCLUSION

From the findings, it can be concluded that most of the tooth preparations by dentists in Nairobi, Kenya did not have both ideal mesio-distal and buccal-lingual convergence angle measurements. There is therefore a need to provide Continuing Professional Education courses for dentists on tooth preparation for crown and bridge to enhance clinical application of tooth preparation guidelines.

REFERENCES

1. Blair, F.M., Wassell, R.W. and Steele, J.G. Crowns and other extra coronal restorations: preparations for full veneer crowns. British Dental Journal. 2002; 192: 561-571.
2. Mignogna, M.D. and Fedele, S. The neglected global burden of chronic oral diseases. Journal of Dental Research 2006; 85: 390-391.
3. Shillinburg Jr, H.T., Hobo, S., Whitsett, L.D., Jacobi, R. and Brackett, S.E. Fundamentals of Fixed Prosthodontics. Third Edition. Quitessence Publishing Company; 1997 pp 119-142,
4. 151-152, 419.
5. Walton, T.R. A 10 year longitudinal study of fixed prosthodontics: clinical characteristics and outcome of single unit metal-ceramic crowns. The International Journal of Prosthodontics. 1999; 12: 519-526.
6. Walton, J.N., Gardner, F.M. and Agar, J.R. A survey of crown and fixed partial denture failures: Length of service and reasons for replacement. Journal of Prosthetic Dentistry 1986; 56:416-421.
7. Narula, S., Punla, V., Khandelwal, M., Sharma, V. and Pamecha, S. Retention in conventional fixed partial dentures; A review. Journal of Clinical and Diagnostic Research 2011; 5: 1128-1133.

8. Goodacre, C.J., Campagni, W.V. and Aquilino, S.A. Tooth preparations for complete crowns: An art form based on scientific principles. Journal of Prosthetic Dentistry. 2001; 85: 363-376.
9. Wilson Jr, A.H., Chan, D.C.N. The relationship between preparation convergence and retention of extra coronal retainers. Journal of Prosthodontics 1994; 3: 74-78.
10. Nordlander, J., Weir, D., Stoffer, W. and Ochi, S. The taper of clinical preparations for fixed prosthodontics. Journal of Prosthetic Dentistry. 1988; 60: 148-151.
11. Ayad, M.F., Maghrabi, A.A. and Rosenstiel, S.F. Assessment of convergence angles of tooth preparations for complete crowns among dental students. Journal of Dentistry. 2006; 33: 633-638.
12. Ali, K., Wazzan, K.A., Amri, M.D., Al-Shahrani, A., Al-Shahrani, M. and Qahtani, H. Assessment of convergence angle of full veneer preparations carried out by practitioners with different levels of experience. Saudi Dental Journal 2009; 21: 37-41.
13. Parker, M.H., Ivanhoe, J.R., Blalock, J.S., Frazler, K.B. and Plummer, K.D. A technique to determine a desired prepared axial inclination. Journal of Prosthetic Dentistry. 2003; 90: 401-405.
14. Rafeek, R., Seymour, K. and Zou, L. Modern metrology concerns-Dimensional measurement for dentistry. First Edition 2012; pp 447-458.
15. Annerstedt, A., Engstrom, U., Hansso, A. and Jansson, T. Axial wall convergence of full veneer preparations. ActoOdontologica Scandinavia 1996; 54: 109-112.
16. Al-Dwairi, Z.N., Al-Hiyasat, A.S. and Aboud, H. Standards of teeth preparations for anterior resin bonded all ceramic crowns in private dental practice in Jordan. Journal of Applied Oral Science. 2010; 370-377.
17. Sato, T., Al Mutawa, N., Okada, D. and Hosegawa, S. A clinical study on abutment taper and height of full cast preparations. Journal of Medical Dental Science 1998; 45:205-210.
18. Kent, W.A., Shillinburg, H.T. Jr and Duncansson, M.G. Jr. Taper of clinical preparations for cast restorations. Quintessence International 1988; 19: 339-345.
19. Mark, P.J. A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. Journal of Oral Rehabilitation 1980; 7: 255-265.
20. Noonan, J.E. and Goldfogel, M.H. Convergence of the axial walls of full veneer crown preparations in a dental school environment. Journal of Prosthetic Dentistry 1991; 66: 706-708.
21. Esser, C., Kerschbaum, T., Winkelmann, V., Krage, T. and Faber, F.J. A comparison of the visual and technical assessment of preparations made by dental students. European Journal of Dental Education 2006; 10: 157-16