Effect of preparation convergence on retention of multiple unit restorations - An *in vitro* study

Dileep Nag Vinnakota

Abstract

Background and Aim: Convergence angle (CA) is one of the major determinant factors in the retention of single as well as multiple units. Hence, the aim of the present study was to determine the effect of preparation convergence on the retention of multiple unit restorations. **Materials and Methods:** Nickel-chromium alloy single crowns as well as three, six and nine multiple unit fixed partial dentures (FPDs) were casted for standardized milled dies that simulate canine, premolar and molar teeth machined with two different degrees of convergence, 12 ($n = 55$) and 20 ($n = 55$). The dies were threaded on rectangular metal platforms with the help of retainer shaft in the proper position to model either single or multiple preparations. The casted crowns and FPDs were cemented and retention tested by securing the units in an Instron universal testing machine. The tabulated values were analyzed statistically using Mann–Whitney test. **Results:** Single and multiple units with 12° CA needed greater force to dislodge compared to 20°, but this difference was not statistically significant for single units of premolar ($P > 0.05$). Irrespective of the angle, there was a simultaneous statistically significant increase in retention as the number of units increased in FPDs, except for the difference between 3 and 6 units in 20° group ($P > 0.05$). **Conclusion:** This study highlights the importance of emphasizing on CA, during canine and molar preparation for single units as well as preparation of canines for 6 units FPDs.

Keywords: Convergence, multiple, preparation, taper, tooth

Introduction

Crowns and fixed partial dentures (FPDs) are the major prosthodontic treatment modalities for past several decades with factors like esthetics, contact points and pontics playing an important role in varying their design. However, one property of cement retained fixed restorations, retention, has been of prime importance in all designs.[1-3] It is proposed to be influenced by factors such as height and diameter of the preparation, luting cement and predominantly by one of the operator controlled factors, convergence angle (CA). The length and diameter of the preparations are often limited by the existing dental anatomy; and improved retention due to cement depends upon mechanical interlocking of cement, surface area of cement coverage, durability of cement, resistance to mechanical breakdown and dissolution. Thus, CA, the angle between two opposing axial walls that equals the sum of the taper (angle between one axial wall and the long axis of the preparation) of two opposing axial walls of a preparation, is considered as a prime variable. It gives marginal and internal adaptation for the crowns and can be controlled by the operator. CA is inversely proportional to the retention, with greater angles reducing the retention of crowns.[4-7]

Various angles have been proposed as ideal in textbooks; Shillinburg *et al*.[1] recommended a 6 degree (°) taper, which gives a convergence of 12° as ideal; Tylman *et al*.[8] state that the ideal taper is 2° on anterior teeth and 2–5° on the posterior teeth. Johnston suggested 5–7° (10–14° CA) and Kronfeld accepted a range that includes all these figures.[9] To know the ideal and/or the recommended CA, a tooth preparation should possess for attaining maximum retention, led to the proposal of guidelines on preparation taper and convergence, both for individual and group of teeth, depending on height to base diameter ratio.[10] However, obtaining an ideal axial wall convergence is not routinely possible clinically. Studies conducted on dental students, general dentists and specialists to determine the clinically achievable angles, depicted values outside the recommended range with the mean value between 14.3° and 20.1°. Interestingly, there was no apparent correlation to the operator level of education or experience; some practitioners were even preparing teeth with a CA between 30° and 50°.[11-15]

Assessment of CA achieved in preparations of FPDs was not significant, compared to those of individual preparations.

Department of Prosthodontic Dentistry, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India

Correspondence: Dr. Dileep Nag Vinnakota,
Department of Prosthodontic Dentistry, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India.
E-mail: dileepnagmds@yahoo.co.in

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Nonetheless, increasing the CA of FPDs to achieve a common path has been found to be a common practice.[5] Among several reasons for failure of FPDs, lack of retention was proved to be a common one, which depends on the CA.[16] However, all the existing literature is on the retention of single crowns,[17-23] leaving behind the effect of these angles on retention when planning for multiple unit castings; thus creating a major lacuna in the field of CAs. Hence, the present study was carried out to verify the retention of nickel-chromium alloy single crowns as well as FPDs casted for dies machined with two different degrees of convergence, 12 and 20.

Materials and Methods

A total of 110 aluminum dies were machined (at HEBIC Industrial Training Institute, Mangalore, India) to stimulate complete veneer crown preparations with either a CA of 12° (n = 55) or 20° (n = 55), each group containing canines (n = 25), premolars (n = 15) and molars (n = 15). The dimensions of simulating dies were as follows: Canines 5 mm of gingival diameter (D) and 6 mm of occlusogingival height (H); premolars 5 mm of D and 5 mm of H; molars 6 mm of D and 4 mm of H. Each die had a 1 mm 90° shoulder finish line and all the above dimensions were recorded using an optical measuring microscope (Nikon Model MM-11U).

Five dies each, simulating canine, premolar and molar from both CA groups were used for testing retention of single unit and remaining dies used for the preparation of 3, 6 or 9 units FPDs. Each 3 units FPD was made using a premolar and a molar die of same convergence threaded on rectangular metal platform with the help of a retainer shaft in the position of first molar and first premolar, thus making a total of 5 units in each CA group. For each 6 units FPD, two canine dies of the same convergence were threaded in position of canines on both sides of the arch, making a total of 5 units in each group. Each 9 units was prepared with canine, premolar and molar dies on one side of the arch and a canine in cross arch, making a total of 5 units in each group.

A die spacer (Pico-Fit, Renfert, USA) was applied for all the dies using a unidirectional application technique to obtain a uniform film thickness of 1 mm over which aluminum molds were fabricated. Using these molds, wax patterns were fabricated using standard protocol.[24] Wax patterns of multiple units were made by attaching the single patterns with the help of a 2.5 mm diameter wax connector. Each wax pattern was immediately invested with hygroscopic technique after marginal refinement to minimize distortion. The conventional lost wax technique was carried out for complete elimination of wax from the molds and all castings were carried out in induction casting machine (Fornax T, Bego, USA) to make cobalt-chromium copings and FPDs. The intaglio surface and margins were checked for blebs, air abraded with 50 μm aluminum oxide particles under a pressure of 60 psi and cemented using zinc phosphate luting cement (De Trey® Zinc cement, Dentsply, Germany) (mixed according to manufacturer's recommendations and consistency standardized to American Dental Association specification No. 8) to their respective dies or units on the metal platform. The vent on the occlusal surface of the casting enabled the easy escape of excess cement through it, thus ensuring a proper adaptation at the margins of the copings to the die. The excess cement was removed from the margins before it was fully set and all the cemented units were stored in 100% humidity for 24 h; then secured in an Instron universal testing machine and adjusted such that the casting was in line with the central axis of the machine arm. An aluminum rod with hooks at either end was attached to the loop on the occlusal surface of the casting at one end and to the Instron machine on the other end. In case of the multiple units FPD castings, double sided hooked rods of equal length were attached to the loops on all the abutments and the platform adjusted under the Instron machine arm such that equal force was directed to all the abutments. The machine was adjusted to apply an initial load of 50 Newtons (N) for 20 s, followed by a sustaining pressure until the casting was pulled free from the die. The peak load values in N were recorded, tabulated and analyzed statistically using unpaired t-test.

Sample size determination

With the level of significance set at 0.05, power of 80% to detect a force difference of 2 N; and force required to dislodge the crown/FPD as primary outcome measure, a minimal sample size of five was required. With the level of significance set at 0.05, power of 80% to detect a force difference of 2 N; and force required to dislodge the crown/FPD as primary outcome measure, a minimal sample size of five was required.

Results

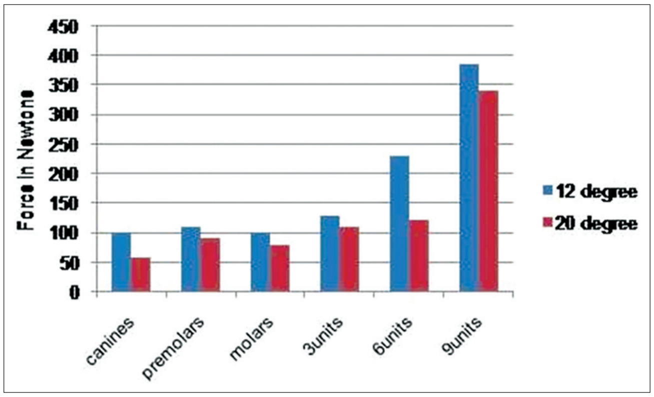
The mean, standard deviation, and range of tensile forces necessary to dislodge the castings for all the test groups are listed in Table 1 and Graph 1.

Table 1: Mean tensile force in Newton for single and multiple unit removal

Unit	Mean±SD (range)		P
	12° convergence angle	20° convergence angle	
Canine	101.7±7.5 (94.5-112.8)	59.7±4.8 (54.3-66.7)	<0.01**
Premolar	111.3±9.9 (103.5-128.3)	93.01±13.6 (81.4-111.1)	0.12^{NS}
Molar	100.8±2.6 (97.3-104.4)	81.2±2.6 (77.1-84.0)	<0.01**
3 unit	129.6±4.1 (123.5-133.2)	110.5±9.1 (96.5-121.3)	<0.01**
6 unit	230.2±12.1 (218.0-242.6)	121.9±11.6 (110.3-137.6)	<0.01**
9 unit	385.3±13.0 (363.5-398.6)	341.2±12.4 (324.2-351.9)	<0.01**

Intragroup comparisons	12° convergence angle	20° convergence angle
3 unit versus 6 unit	<0.01**	0.25^{NS}
3 unit versus 9 unit	<0.01**	<0.01**
6 unit versus 9 unit	<0.01**	<0.01**

**Highly significant; ^{NS}Nonsignificant. SD: Standard deviation



Graph 1: Mean force in Newtons for single and multiple unit removal

Single units

It can be appreciated from the results that 12° units needed greater force to dislodge irrespective of the type of the tooth compared to 20° convergence. However, the difference between the two CAs is statistically significant for canines and molars ($P < 0.01$) while nonsignificant for premolar preparations ($P > 0.5$).

Multiple units

For all the multiple units, 12° units needed statistically significant ($P < 0.01$) greater force, compared to 20° CA and irrespective of angle, there was a simultaneous increase in the amount of force required to dislodge the FPD as the number of units increased. However, this increase from 3 to 6 units was less and statistically insignificant in units with 20° angle ($P > 0.5$).

Discussion

The CA established during tooth preparation predominantly influences the retention, resistance and marginal fit of the prosthesis. The first study comparing the relationship between retention and CA was done on cemented complete veneer crowns with angles ranging between 5° and 45°, in increments of five, which concluded that the retention at 5° will be far superior to its counterpart at 45°.[25] To find the ideal CA led to further observations, based on which heading educators have recommended a range of ideal values that tooth preparations should possess.[1,8,9] In the present study, 12° was selected for various reasons; the first and foremost being, the maximum angle in the range of ideal values, to accommodate optimal thickness of cement, which results in lesser variation in marginal discrepancy as well as higher retention values.[17] Second being a proven fact that, preparations up to 12° angle produce no effect on retention, irrespective of the type of luting agent used,[19] and the marginal and internal adaptation was also found to be good.[26] Additionally, clinical advantages comprise the ability to see the preparations to be free of undercuts with the naked eye, and ease to prepare a tooth to house a CA of 12° by the human hand.[27] However, the average achieved in practice by the dental students, general dentists and specialists, with no apparent correlation to their level of education or experience, was 20–21°.[11-15] Hence, in the present study, 20° was chosen as another angle for comparison. Thus, the degrees of convergence were selected for specific reasons; 12° being the maximum ideal limit taught in dental schools and 20° the mean of achievable angles.

For CAs in the range of 10–20°, the minimal occlusocervical (OC) dimension for premolars and anterior teeth was proposed to be 3 mm. As molars have a greater diameter and bear greater occlusal forces, they are prepared with greater convergence than anterior teeth, with 4 mm projected as the minimal OC dimension. These dimensions were maintained in the present study along with the recommended OC/FL ratio of 0.4 or higher for both single and multiple unit preparations.[6]

It can be appreciated from the results of the present study that, among single units, premolars have no significant difference in retention even on increasing the CA, whereas canines and molars had significant decrease; that cautions us about the care to be taken while preparing canines and molar. However, it is reported that, in practice, premolar preparations will have smaller angles than anteriors, which in turn will have smaller angles than molar preparations. The limitation in visual assessment of CA and anatomy of the tooth were reported as reason for this. Additionally, mandibular tooth will be prepared with greater angles than maxillary, which was ascribed to difficulty in preparing ideal angle due to poor access.[5,12,22] Hence, we highlight the importance of minimizing the CA during molar tooth preparations using small headed handpieces and while preparing anterior teeth suggest periodical assessment for better retention. Usage of high magnification loupes or surgical operating microscope was also suggested to facilitate minimal abutment CA.[28]

During multiple preparations, increasing the CA to achieve a common path of draw is a common practice, leading to greater angle for FPD abutments than individual crowns.[5] Thus, these overtapered abutments sacrifice the retentive form, which places the completed prosthesis in jeopardy.[24] Also, removal of too much tooth structure from the axial surfaces can damage the pulpal integrity of these abutments. Hence, the form of prepared teeth and the amount of tooth structure removed are important contributors to the mechanical, biologic and esthetic success of even FPDs. The results of the present study prove the hypothetical concept that, as the number of units increase or when there is cross arch stabilization the retention of FPDs will increase, irrespective of the CA angle. When the two CA groups were compared, irrespective of the number of units, 12° CA had significantly better retention than 20°; among which 6 units FPDs showing marked difference. Hence, we suggest concentrating more on achieving ideal CA when planning for a 6 units FPD. Besides CA, arch curvature has its effect on the stresses occurring in FPDs that have pontics outside the interabutment axis line, as for 6 units FPDs that replace the four incisors. For these, additional retention can be gained from the lever arm in opposite direction and at a distance from interabutment axis equal to the length of the lever arm.[29] For 9 units FPDs, eliminating the common inaccuracies caused by traditional techniques and visually assessing the finished preparations for unobstructed uniform path of insertion is also very important for the good prognosis of the prosthesis besides maintaining the CA.[9] The decrease noted in 3 units with 20° can be attributed mainly to increase in the CA of molars rather than premolars, which is clearly noticed in the retention of single units of the present study.

Casting should be well-fitted before cementation; however, the successful long-term performance of a restoration can also be ascribed to the role of luting agent. It is proposed that, the role of cement comes into play when the teeth are conical or having short crowns or when the convergence is >20°.[20,30] The type of cement does not affect the retention of crowns when the convergence is 12° or less;[19] thus the choice of cement for crowns in this range of angles has limited clinical significance with the luting ability of the cement considered to have only a secondary role.[21] Though in the present study zinc phosphate was used as luting agent, we suggest to concentrate on the selection of luting agent when the minimal CA of 12° cannot be maintained.

The limitation of the present study is continuous force was delivered until their dislodgement being this an *in vitro* study, whereas the forces in the mouth will be repetitive and mild. Crowns in a clinical situation might function despite CA much greater than recommended which is due to the fact that intraoral forces and loads interact in a manner that are more complex than can be reproduced in the laboratory.

Conclusion

All the single crowns and FPD prostheses showed more retention when the CA was 12°; and as the number of units increased in FPDs there was a better retention irrespective of CA. However, this study highlights the importance of emphasizing on CA when preparing canines and molars for single units and also while preparing canines for a 6 units FPD, as there is marked decrease in the retention when CA was increased from 12° to 20°. In summary, customizing the focus placed on CA during preparation can be emphasized, depending on the tooth and the design of FPD. Whenever ideal preparation cannot be achieved, we stress on considering the auxiliary retention methods.

References

1. Shillinburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE, editors. Principles of tooth preparation. In: Fundamentals of Fixed Prosthodontics. 3rd ed. Chicago: Quintessence; 1997. p. 119-37.
2. Blair FM, Wassell RW, Steele JG. Crowns and other extra-coronal restorations: Preparations for full veneer crowns. Br Dent J 2002;192:561-4, 567.
3. Willey RL. Retention in the preparation of teeth for cast restorations. J Prosthet Dent 1976;35:526-31.
4. Zuckerman GR. Factors that influence the mechanical retention of the complete crown. Int J Prosthodont 1988;1:196-200.
5. Nordlander J, Weir D, Stoffer W, Ochi S. The taper of clinical preparations for fixed prosthodontics. J Prosthet Dent 1988;60:148-51.
6. Goodacre CJ, Campagni WV, Aquilino SA. Tooth preparations for complete crowns: An art form based on scientific principles. J Prosthet Dent 2001;85:363-76.
7. Gilboe DB, Teteruck WR. Fundamentals of extracoronal tooth preparation. Part I. Retention and resistance form. J Prosthet Dent 1974;32:651-6.
8. Malone WF, Cavazos E Jr, Re GJ. Biomechanics of tooth preparation. In: Cavazos E Jr, Kaiser DA, Morgano SM, editors. Tylman's Theory and Practice of Fixed Prosthodontics. 8th ed. USA: Medico Dental Media International Inc., (All India Publishers and Distributors Regd. Medical Publishers, Chennai); 2002. p. 113-43.
9. Gold HO. Instrumentation for solving abutment parallelism problems in fixed prosthodontics. J Prosthet Dent 1985;53:172-9.
10. Parker MH, Calverley MJ, Gardner FM, Gunderson RB. New guidelines for preparation taper. J Prosthodont 1993;2:61-6.
11. Poon BK, Smales RJ. Assessment of clinical preparations for single gold and ceramometal crowns. Quintessence Int 2001;32:603-10.
12. Patel PB, Wildgoose DG, Winstanley RB. Comparison of convergence angles achieved in posterior teeth prepared for full veneer crowns. Eur J Prosthodont Restor Dent 2005;13:100-4.
13. Ayad MF, Maghrabi AA, Rosenstiel SF. Assessment of convergence angles of tooth preparations for complete crowns among dental students. J Dent 2005;33:633-8.
14. Noonan JE Jr, Goldfogel MH. Convergence of the axial walls of full veneer crown preparations in a dental school environment. J Prosthet Dent 1991;66:706-8.
15. Annerstedt A, Engström U, Hansson A, Jansson T, Karlsson S, Liljhagen H, *et al.* Axial wall convergence of full veneer crown preparations. Documented for dental students and general practitioners. Acta Odontol Scand 1996;54:109-12.
16. Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: Length of service and reasons for replacement. J Prosthet Dent 1986;56:416-21.
17. Chan DC, Wilson AH Jr, Barbe P, Cronin RJ Jr, Chung C, Chung K. Effect of preparation convergence on retention and seating discrepancy of complete veneer crowns. J Oral Rehabil 2005;32:58-64.
18. Dodge WW, Weed RM, Baez RJ, Buchanan RN. The effect of convergence angle on retention and resistance form. Quintessence Int 1985;16:191-4.
19. Chandra Shekar S, Giridhar K, Suhas Rao K. An *in vitro* study to evaluate the retention of complete crowns prepared with five different tapers and luted with two different cements. J Indian Prosthodont Soc 2010;10:89-95.
20. El-Mowafy OM, Fenton AH, Forrester N, Milenkovic M. Retention of metal ceramic crowns cemented with resin cements: Effects of preparation taper and height. J Prosthet Dent 1996;76:524-9.
21. Zidan O, Ferguson GC. The retention of complete crowns prepared with three different tapers and luted with four different cements. J Prosthet Dent 2003;89:565-71.
22. Leempoel PJ, Lemmens PL, Snoek PA, van 't Hof MA. The convergence angle of tooth preparations for complete crowns. J Prosthet Dent 1987;58:414-6.
23. Ayad MF, Johnston WM, Rosenstiel SF. Influence of tooth preparation taper and cement type on recementation strength of complete metal crowns. J Prosthet Dent 2009;102:354-61.
24. Shillinburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE, editors. Principles of tooth preparation. In: Fundamentals of Fixed Prosthodontics. 3rd ed. Chicago: Quintessence; 1997. p. 335-53.
25. Jørgensen KD. The relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 1955;13:35-40.

26. Corazza PH, Feitosa SA, Borges AL, Della Bona A. Influence of convergence angle of tooth preparation on the fracture resistance of Y-TZP-based all-ceramic restorations. Dent Mater 2013;29:339-47.
27. Mack PJ. A theoretical and clinical investigation into the taper achieved on crown and inlay preparations. J Oral Rehabil 1980;7:255-65.
28. Mamoun JS. The total occlusal convergence of the abutment of a partial fixed dental prosthesis: A definition and a clinical technique for its assessment. Eur J Dent 2013;7:509-13.
29. Shillinburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Treatment planning for the replacement of missing teeth. In: Fundamentals of Fixed Prosthodontics. 3rd ed. Chicago: Quintessence Publishing, New Delhi (Indian edition); 1997. p. 85-103.
30. Browning WD, Nelson SK, Cibirka R, Myers ML. Comparison of luting cements for minimally retentive crown preparations. Quintessence Int 2002;33:95-100.

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