Effect of ferrule design on fracture resistance of anterior teeth restored with bonded cast post and core

Loubna Shamseddine, *DChD, MSc, DScO.*
Department of Prosthodontics,
Faculty of Dental Medicine, Lebanese University, Hadath, Lebanon

ABSTRACT

Aims: The concept of a ferrule appears established in fracture resistance, the superiority of any specific ferrule design has not been confirmed by research.The aims of the study is to compare fracture resistance of anterior teeth prepared according to three different ferrule design: standard internal tapering coronal walls, a contra bevels added to the cast post and flaring the entrance of the post.

Materials and Methods: Ninety plastic analogues of an upper incisor were endodontically treated and prepared with 6⁰ taper of internal coronal residual walls on the 2mm of ferrule. Divided into three groups (n=30), one used as control group, the second with 30⁰ bevel on the buccal and lingual internal walls and the third one with 30⁰ taper on the buccal and lingual external walls. All analogues were restored with Ni-Cr alloy posts and crowns and exposed to a compressive load with a 1-kN cell at a crosshead speed of 0.05mm/min at 130° to the long axis until fracture occurred. Failure modes were observed, and the data of fracture resistance, in Newton, were collected. The tests of normality (Lilliefors) followed by Mann–Whitney test was used to test the strength between groups. Significant differences accepted at P<.05.

Results: Mean failure loads for the groups were respectively 1038.69 (±243.52) for the control group,1231.86 (±368.76) for the flaring group and 1078.89 (±352.21) for the contra beveled one.

Conclusion: Flaring the entrance of the root canal is a better approach for obtaining the maximal fracture resistance, while a contra bevel used as an anti-rotary device is not significant.

Keywords: Cast post and core, fracture resistance, ferrule design, contra bevel

Corresponding author:
Loubna Shamseddine / drloubna1@hotmail.com

INTRODUCTION

The restoration of endodontically treated teeth (ETT) fail for several reasons. They are brittle and subjected to fracture,[1] they have little coronal structure remaining, and a decreased structural integrity due to endodontic access and cavity preparation.[2] Obviously, post and core restoration is needed to improve the retention of the core build up material and to distribute occlusal stress along the remaining tooth structure.[2] Posts can be metallic (either custom cast posts or prefabricated) or fiber (custom or prefabricated). Fracture strength in anterior teeth have been reported higher with cast posts than with fiber posts,[3-6] as well as that with prefabricated titanium post and composite core.[7] Although cast post and cores showed a prevalence of irreparable failures,[8] they exhibit a high survival rate up to 19.5 years.[9]

Successful prosthetic restoration of ETT depends on the pre-prosthetic treatment of the remaining teeth structure.[10] Multiple studies have shown the ferrule as the most important factor for success.[11-15] Therefore, it should have at least 1.5 to 2 mm of height.[16-18] Although the concept of a ferrule appears established, the superiority of any specific ferrule design has not been confirmed by research. In cast post and core restoration a balance exists between maximizing retention and maintaining resistance to root fracture.[19] Acting as an anti-rotary device and improving the biomechanical stability of the tooth,[2,21-23] ferrule design have been studied and found to produce greater strength when it is circumferential and uniform.[24-26] Other modifications in the ferrule design, incorporated to the cast post and core have been suggested. An antirational mechanism as grooves, contra bevels as secondary ferrule,[26-28] and root flaring entrance of the post.[29] Despite these suggestions, few studies demonstrate that grooves incorporated to the cast post do not enhance fracture resistance of the teeth.[28] Recently, a previous study by Shamseddine et al in 2014 concluded that for anterior teeth, increasing taper of the internal residual coronal walls enhances fracture resistance.[30]

MATERIALS AND METHODS

Test groups

Ninety clear acrylic standardized analogues B22X-500 (Kilgore International 49036) simulating endodontically treated maxillary central incisors, and a special metallic device was fabricated to mount the analogues subsequently for this experiment (Fig. 1).

This device was made of a base and a mounting block with a hinge access having the ability to move in mesio-distal direction. In addition a protractor instrument related to the base was used for the inclination of the block.

Preparation of the crown

Into the block, all specimens were prepared on an electronic surveyor. The crowns were reduced perpendicular to the root axis with an abrasive disc (Abrasive Technology Inc, X928-7 TP), leaving 5mm above the cervical area. The axial surface of the tooth was reduced with specific burs (1.5 mm facial ISO n 806 104 173 544 031, 0.8 mm palatal and proximal ISO n 806 104 173 544 016) following the cement enamel junction at the proximal sides, to receive a full coverage metal crown.

Ferrule design preparation

Analogues were prepared with an access cavity of 6° taper. A 2 mm ferrule was left at the proximal sides. The specimens were divided into 3 groups of thirty each.

Group 1: Control group with no modifications.

Group 2: Facial and palatal residual coronal walls were prepared to create an internal bevel 30° to the long axis of the tooth.

Group 3: Facial and palatal residual coronal walls were prepared to create an external bevel 30° to the long axis of the tooth (Fig. 1)

Then root canal preparation was executed and filled with a conventional step back technique through 18mm length. Gutta-percha was laterally condensed with a manual spreader (Kerr, W 0697840 and W 0693510).

Post and cores fabrication

N°3 Gates Glidden drill (DENTSPLY Maillefer A0008 240 005 00) and 1.1mm Largo (DENTSPLY Mailllefer A0008 230 002 00- A0008 230 003 00) were used to prepare the post spaces, leaving 7mm of apical seal.

Post and core was constructed using 1.25mm plastic burn out pattern. For the coronal fabrication, a silicone index of the intact tooth and wax were used to standardize the coronal dimension for all specimens. For group III the bevel at the coronal part was filled by wax patterns and was a part of the post and core. The post and cores were cast in a Nickel Chrome alloy, and cemented using spiral paste filler (Dentsply Maillefer Instruments, SA, Ballaigues, Switzerland), under a static load 1.5Kg for 15 minutes with zinc phosphate cement (Spofa Dental Adhesor). (Fig. 2)

Cast crowns fabrication

After removing excess cement, an over-casting crown was waxed and adapted directly to the analogue using the previously made silicone index. After investing the wax pattern and casting it with Nickel Chrome metal, the crown was cemented with zinc phosphate under a static load of 1.5kg for 15 minutes.

Fracture testing

For the two groups, fracture strength test was done at the laboratory of the mechanical engineering department at the American University of Beirut in Lebanon. The testing device is a tension and compression system Y.L.U.T.M. (Y.L. Universal Testing Machines). The device is fully controlled by computer. Certified and calibrated by the National Institute of Sciences and Techniques (N.I.S.T.) known as National Bureau of Standards, the testing machine allows an error of 0.04% for maximal load of 10 000 kilograms, 0.01% for repetitive maximal load of 10 000 kilograms, resolution of displacement 0.01 millimetre (10 μ) and accurate speed of 0.01% of full scale. The crowned analogues were subjected to a compressive load with a 1-KN cell at a crosshead speed of 0.05 mm/min at 130° to the long axis until fracture occurred. In order to analyse the results, statistical software (SPSS 17; SPSS Inc, USA) was used. Average and standard deviation (SDs) were established. Statistical tests of normality (Lilliefors) were used to check whether the data obtained matches a normal distribution or an exponential distribution. Non-parametric Mann-Whitney test was used to test the null hypothesis for resistance to fracture between groups. Probability value of P<0.05 was set.

RESULTS

The incomplete seating of posts for all specimens of group III was the first result noticed before fracture testing. (Fig. 3)

Statistical results are summarized in Table 1 and Table 2. The Group with 30⁰ internal taper demonstrated a higher

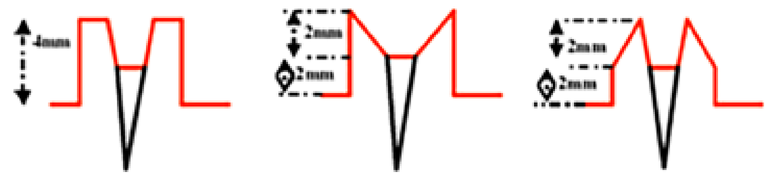

Fig 1. Schematic representation of the ferrule design in each group.

Fig 2. Specimen of bonded post and core in each group.

Fig 3. Fracture line after testing visualized in all specimens.

Table 2. Summary of the statistical results for load fracture.

Group	Load Means (SD)	Test of normality (Lilliefors) for Strength		Mann-Whitney Strength test between peer group	
		P Value	Judgment 5%	P Value	Judgment 5%
1	1038.69 (243.52)	0.028	Absence of normal distribution	G: 1/2 0.0010	Significant difference
2	1231.86 (368.76)	0.000		G: 2/3 0.0085	Significant difference
3	1078.89 (335.21)	0.008		G: 1/3 0.7675	No significant difference

Table 2. Summary of the statistical results for displacement.

Group	Displacement Means (SD)	Test of normality (Lilliefors) for Displacement		Kruskal-Wallis test for Displacement between peer group	
		P Value	Judgment 5%	P Value	Judgment 5%
1	1.36(0.31)	0.053	Absence of normal distribution	0.7470	No significant difference
2	1.28(0.50)	0.200			
3	1.44(0.58)	0.003			

fracture resistance (1231.86 ± 368.76) than the control group (1038.69 ± 243.52) and the 30^0 external group (1078.89 ± 335.21). The Group with 30^0 external taper demonstrated the same resistance than the standard group (P=0.7675).

DISCUSSION

Standardization of the specimens was essential for obtaining comparable results because deformation and fracture load depends on geometry. Human incisors have a greater variability in size and morphology, and are therefore more difficult to standardize.[31] The major objective of this study is comparative rather than to determine the precise fracture load for each group, consequently mechanical properties of plastic analogues used in this study did not affect results and what matters were relativity numbers. These teeth analogues were used to have comparable conditions between the test specimens and ensure a standard size and quality of root structures.

The present study shows that there is reasonable evidence ($p<0.05$) that an increasing of internal walls have a significant effect on resistance to tooth fracture. Whereas, a contra bevel added to the cast post does not enhance strength. These results would be due to a combination of effective contact surface and stress distribution differences among groups.

The main advantage of using a cast post and core technique is the ability to conform to any canal space and to provide a good fit in order to distribute forces uniformly within the root.[32-35] A cast post should fit properly and passively into the canal. Moreover, it should resist to rotation or to rocking.[19] When a post is supported with core and coronal coverage, stress distribution becomes a larger function of the post geometry and "fit".[36] Mathematically, normal stress is most commonly designated with Greek letter sigma (σ). Stress is inversely proportional to the surface contact $\sigma = \frac{F}{S}$. Since the surface in group II increases, stress in group 2 decreases. In group 2, increasing taper allows a better wax pattern filling. As for complete crown, taper of walls affects Zinc Phosphate filtration phenomenon and escapement at cementation procedure[37] and alleviate hydraulic pressure during cementation.[38] The results in this study for group 2 could be explained by a uniform stress distribution between post and the canal as the cement layer provides a buffer zone.[39]

The results between group 1 and group 2 could be explained by the mass volume of post was increased in the group 2. As it was stated by Giovani et al in 2009 that when this masse decreases, the absorption of forces by post system decreases to a considerable degree and they more efficiently transfer the forces to less rigid tooth dentin, endangering the tooth structure to more root catastrophic fracture.[40]

Whereas, this masse volume was also increased in the same value in external part of the post in group 3. The results found in this study that the third group have similar strength then the group 1 and the higher strength for the group 2 could be explained by the defect in the seating of the post as visualized in all specimens of group 3 (Fig.). This defect could be attributed to that additional part is extra coronal the canal and its casting simultaneous to the post inconvenient.

The adaptation of the cast contra bevel to the wall might make difficult for air and excess cement to escape from the canal and increases the occurring of the filtration phenomenon. This phenomenon could prevents the post from being well placed and affect the physicochemical properties of the cements and biomechanical behavior of the fixed restauration.[34] Moreover, custom cast post core was made undersized to fit passively the shape of the post space, in order to lead a better transmission of the stress. In group 3, as the post and core approaches its final position, this space becomes smaller. The flow of non-compressible liquid is inhibited and seating of restoration is resisted.

Given these findings and considering the limitations of this study, the final analysis verified that fracture resistance is not associated to the cast post and core designed with a ferrule while increasing tapering opening canal increases strength of anterior teeth restored with cast post and core.

Aknowledgments:
The authors reported no conflicts of interest related to this study.

REFERENCES

1. Al Hamad KQ, Al-Omari FA, Al Hyiasat AS. The taper of cast post preparation measured using innovative image processing technique. BMC Oral Health 2010;10:19-26.

2. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of ferrule and post placement on fracture resistance endodontically treated teeth after fatigue loading. J Dent 2013;41(3):207-215.

3. Maccari PC, Conceição EN, Nunes MF. Fracture resistance of endodontically treated teeth restored with three different prefabricated esthetic posts. J Esthet Restor Dent 2003;15(1):25-30.

4. Hegde J, Ramakrishna, Bashetty K, Srirekha, Lekha, Champa. An in vitro evaluation of fracture strength of endodontically treated teeth with simulated flared root canals restored with different post and core systems. J Conserv Dent 2012;15(3):223-227.

5. Bacchi A, dos Santos MBF, Pimen-tel MJ, Caetano CR, Sinhoreti MAC, Consani RLX. Influence of post-thickness and material on the fracture strength of teeth with reduced coronal structure. J Conserv Dent 2013;16(2):139-143.

6. Pereira JR, do Valle AL, Shiratori FK, Ghizoni JS, Bonfante EA. The effect of post material on the characteristic strength of fatigued endodontically treated teeth. J Prosthet Dent 2014;112(5):1225-30.

7. Sendhilnathan D, Nayar S. The effect of post-core and ferrule on the fracture resistance of endodontically treated maxillary central incisors. Indian J Dent Res 2008;19(1):17-21.

8. Barcellos RR, Correia DP, Farina AP, Mesquita MF, Ferraz CC, Cecchin D. Fracture resistance of endodontically treated teeth restored with intra-radicular post: The effects of post system and dentine thickness. J Biomech 2013;46(15):2572-7.

9. Raedel M, Fiedler C, Jacoby, St, Boewing KW. Survival of teeth treated with cast post and cores: A retrospective analysis over an observation period of up to 19.5 years. J Prosthet Dent 2015;114(1):40-45.

10. Peroz I, Blankenstein F, Lange KP, Naumann M. Restoring endodontically treated teeth with posts and cores – A review. Quintessence Int 2005;36(9):737-46.

11. Fokkinga WA, Kreulen CM, Bronkhorst EM, Creugers NH. Up to 17-year controlled clinical study on post-and-cores and covering crowns. J Dent 2007;35(10):778-786.

12. Ferrari M, Cagidiaco MC, Goracci C, Vichi A, Mason PN, Radovic I, Tay F. Long-term retrospective study of the clinical performance of fiber posts. Am J Dent 2007;20(5):287-291.

13. Creugers NH, Mentink AG, Fokkinga WA, Kreulen CM. 5-year follow-up of a prospective clinical study on various types of core restorations. Int J Prosthodont 2005;18(1):34-39.

14. Monticelli F, Grandini S, Goracci C, Ferrari M. Clinical behavior of translucent-fiber posts: a 2-year prospective study. Int J Prosthodont 2003;16(6):593-596.

15. Cagidiaco MC, Radovic I, Simonetti M, Tay F, Ferrari M. Clinical performance of fibre post restorations in endodontically treated teeth: 2-year results. Int J Prosthodont 2007;20(3):293-298.

16. Zhi-Yue L, Yu-Zing Z. Effects of post-core design and ferrule on fracture resistance of endodontically treated maxillary incisors. J Prosthet Dent 2003;89(4):368-373.

17. Carlini-Júnior B, Cecchin D, Farina AP, Pereira GDS, Prieto LT, Paulillo LA. Influence of remaining coronal structure and of the marginal design on the fracture strength of roots restored with cast post and core. Acta Odontol Scand 2013;71(1):278-282.

18. Glazer B. Restoration of endodontically treated teeth with carbon fibre posts - a prospective study. J Can Dent Assoc 2000;66(11):613-618.

19. Stockton LW. Factors affecting retention of post systems: A literature review. J Prosthet Dent 1999;81(4):380-385.

20. Mamoun JS. On the ferrule effect and the biomechanical stability of teeth restored with cores, posts, and crowns. Eur J Dent 2014;8(2):281-286.

21. Singh S, Thareja P. Fracture resistance of endodontically treated maxillary central incisors with varying ferrule heights and configurations: In vitro study. J Conserv Dent 2014;17(2):115-118.

22. Aggarwal V, Singla M, Yadav S, Yadav H, Sharma V, Bhasin SS. The effect of ferrule presence and type of dowel on fracture resistance of endodontically treated teeth restored with metal-ceramic crowns. J Conserv Dent 2014;17(2):183-187.

23. Baba NZ, Goodacre CJ. Restoration of endodontically treated teeth: contemporary concepts and future perspectives. Endod Topics: 2014;31(1): 68-83.

24. Ng CCH, Dumbrigue HB, Al-Bayat MI, Griggs JA, Wakefeld CW. Infuence of remaining coronal tooth structure location on the fracture resistance of restored endodontically treated anterior teeth. J Prosthet Dent 2006;95(4):290-296.

25. Naumann M, Preuss A, Rosentritt M. Effect of incomplete crown ferrules on load capacity of endodontically treated maxillary incisors restored with fiber posts, composite build-ups, and all-ceramic crowns: an in vitro evaluation after chewing simulation. Acta Odontol Scand 2006;64(1):31-36.

26. Tan PL, Aquilino SA, Gratton DG, Stanford CM, Tan SC, Johnson WT, Dawson D. In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 2005;93(4):331-336.

27. Gopi MA, Dhiman Col R.K, Kumar Lt Col Dinesh. A simple antirotational mechanism in a posterior two piece post and core. Armed Forces Med J India 2015 in press.

28. Cho H, Michalakis KX, Kim Y, Hirayama H. Impact of interproximal groove placement and remaining coronal tooth structure on the fracture resistance of endodontically treated maxillary anterior teeth. J Prosthodont 2009;18(1):43-8.

29. Wiskott HWA. Elément de biomécanique. Cahiers de prothèse 1996;96:14-23.

30. Shamseddine L, Eid R, Homsy F, Elhusseini H. Effect of tapering internal coronal walls on fracture resistance of anterior teeth treated with cast post and core: In vitro study. J Dent Biomech 2014;5: DOI: 10.1177/1758736014547550.

31. da Silva NR, Raposo LH, Versluis A, Fernandes-Neto AJ, Soares CJ. The effect of post, core, crown type, and ferrule presence on the biomechanical behavior of endodontically treated bovine anterior teeth. J Prosthet Dent 2010;104(5):306-17.

32. Krammer R. A time-saving method for indirect fabrication of cast posts and cores. J Prosthet Dent 1996;76(2):209-11.

33. Ravanshad S, Ghoreeshi N. An in vitro study of coronal microleakage in endodontically-treated teeth restored with posts. Aust Endod J 2003;29(3):128-33.

34. Dakshinamurthy S, Nayar, S. The effect of post-core ferrule on the fracture resistance on endodontically treated maxillary central incisors. Indian J Dent Res 2008;19(1):17-21.

35. Camarinha SM, Pardini L, Garcia L, Consani S, Pires-de-Souza F. Cast metal core adaptation using two impression materials and intracanal techniques. Braz J Oral Sci 2009;8(3):128-131.

36. Mireku AS, Romberg E, Fouad AF, Arola D. Vertical fracture of root filled teeth restored with posts: the effects of patient age and dentine thickness. Int Endod J 2010;43(3):218-225.

37. Jorgensen K. Relationship between retention and convergence angle in cemented veneer crowns. Acta Odontol Scand 1955;13(1):35-40.

38. Dimashkieh M, Davies E and von Fraunhofer J. Measurement of the cement film thickness beneath full crown restorations. Br Dent J 1974;137(7):281-284.

39. Tjan A and Whang S. Resistance to root fracture of dowel channels with various thicknesses of buccal dentin walls. J Prosthet Dent 1985;53(4):496-500.

40. Giovani AR, Vansan LP, de Sousa Neto MD, Paulino SM. In vitro fracture resistance of glass fiber and cast metal posts with different length. J Prosthet Dent 2009;101(3):183-188.