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Fracture Resistance of Roots with Thin Walls Restored Using an Intermediate Resin Composite Layer Placed Between the Dentine and a Cast Metal Post

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Abstract - *Thin-walled roots restored using conventional cast metal post-cores are at risk of fracture. Placing a thick intermediate layer of resin-based composite (RBC), sandwiched between the root dentine and a small-diameter metal post or dowel, may improve the fracture resistance of such roots. In this initial laboratory study, two similar groups each of six decoronated maxillary central incisor teeth were prepared with approximately 1.0 mm thick tapered root canal walls. Cast metal alloy post-cores and metal-ceramic crowns were fabricated and cemented for one group with, and for the other control group without, a thick intermediate layer of RBC. The mean force (N) to fracture the roots was 639.3 (SD 51.6) for the intermediate layer of RBC group and 360.8 (42.9) for the control group, P <0.0001. These significantly different findings require clinical confirmation.*

KEY WORDS: Root canal, Resin composite, Tooth fracture

INTRODUCTION

The long-term successful restoration of decoronated root-canal-filled teeth requires the minimisation of potential causes of biological and mechanical failures. The selection of post-core systems for the retention of the coronal restorations should be based largely on biomechanical principles[1].

The sole function of a post or dowel is to assist in the retention and resistance to displacement of either a coronal buildup or an artificial crown. The post system chosen to retain the restoration must provide adequate retention and stiffness to prevent any micro-movement between the artificial crown and the root face. The luting cement system should prevent coronal microleakage, augment retention of the post and reduce mechanical stresses transmitted by the post to the remaining root structure. Despite contrary evidence, many dental practitioners still believe that a post reinforces a root-filled tooth, which also is thought to be more brittle than a similar vital tooth[2,3]. However, the volume of dentine remaining is of most relevance to tooth strength[4].

During preparation of the root canal for placement of a post, it is generally accepted that as much of the remaining dentine should be preserved as is possible, and that at least 4-5.0 mm of the apical root canal filling should remain undisturbed[2]. For metal posts, it is desirable that a passive, small-diameter, parallel-sided post be placed, and that the length of the post equals that of the clinical crown for maximum retention[5,6]. However, these recommendations cannot always be implemented, and a tooth with insufficient coronal tooth substance, a widely-flared root canal and a short root length poses a restorative dilemma.

Following the removal of extensive dental caries, the coronal part of the root canal may be left widely flared and encircled only by a narrow rim of intact radicular dentine. In such situations it is impossible to make a 1.5-2.0 mm wide retentively-designed ferrule preparation, which also requires a minimum 1.0 mm thickness of encircling dentine remaining after the preparation[1,2], even if either crown lengthening or orthodontic extrusion procedures are undertaken. These latter two procedures are not without their own subsequent restorative challenges, and there is not much point in destroying what little sound dentine remains by attempting an inadequate ferrule preparation[7]. However, it may be possible to strengthen the remaining thin root canal walls by placing a bonded resin-based composite (RBC) as a dentine substitute before cementing a small-diameter metal post in mature[8,9,10] and immature teeth[11].

Therefore, in the present initial study, the null hypothesis proposed is that when standardised large tapered post holes are prepared in extracted maxillary central incisor tooth roots, there will be no significant difference in fracture resistance between those teeth restored using a cemented conventional cast metal alloy post-core, and those restored using a cemented small-diameter tapered cast metal alloy post-core following the placement of a thick intermediate layer of RBC.

MATERIALS AND METHODS

Twelve recently-extracted, similar-sized intact maxillary central incisor teeth were obtained from healthy Chinese males aged 20-30 years who lived in the same locality.

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The cleaned teeth were examined carefully for root cracks before being stored in 0.9% saline solution at 4°C for less than 2 weeks. After the natural crowns were removed at the cemento-enamel junction, standardized root canal therapy was performed, using laterally-condensed gutta percha with an endodontic sealant (Zinc Oxide Cataplasm) to obturate the canals. Similar-sized large tapered post holes were then prepared by routing out the internal dentine to a depth of 8.0 mm, and to leave approximately 1.0 mm thick dentine walls (Figure 1). The prepared roots were randomly assigned to two equal groups, each having very similar dimensions as shown in Table 1.

Group 1 (Control): After taking an addition-cured silicone impression of the prepared post hole, a large tapered nickel chromium (Ni-Cr) alloy (Optimus) post-core was cast and sandblasted. The root face margins of the core followed the inner margins of the dentine walls. The canal was etched with 32% phosphoric acid (UNI-ETCH EZ-DOSE) for 15 seconds, rinsed thoroughly and dried lightly with paper points before applying two coats of a resin adhesive (ALL-BOND 2) to the dentine walls. The Ni-Cr post-core was placed using a self-cured resin luting cement (POST CEMENT HI-X) according to the manufacturer's instructions.

Group 2 (Experimental): After etching the prepared post hole and applying the resin adhesive as before, the post hole was completely filled by injecting and packing a dual-cured RBC (BIS-CORE). Before the resin material set, excess material was squeezed out and a narrow tapered post hole space was prepared with a diamond point within the RBC to leave an approximately 1.0 mm thick encircling layer or rim of RBC. The exposed RBC was light cured for 40 seconds. A small-diameter tapered Ni-Cr alloy post-core was constructed and cemented, as before (Figure 2). Metal-ceramic crowns were then fabricated and cemented for both groups. The specimens were stored in the saline solution at all times.

Table 1. *Root widths (at the root face) and root lengths (mm)*

Dimension	*Group 1 (N=6) Mean (SD)*	*Group 2 (N=6) Mean (SD)*	*t (df=10)*	*P-Value*
Mesial-distal width	5.67 (0.30)	5.56 (0.25)	0.690	0.51
Labial-palatal width	7.00 (0.34)	7.03 (0.29)	0.164	0.87
Length	12.24 (0.36)	12.29 (0.33)	0.251	0.81

Group 1 = cast post-core (control); Group 2 = BIS-CORE + cast post-core.
SD = Standard Deviation of the Mean. df = degrees of freedom.

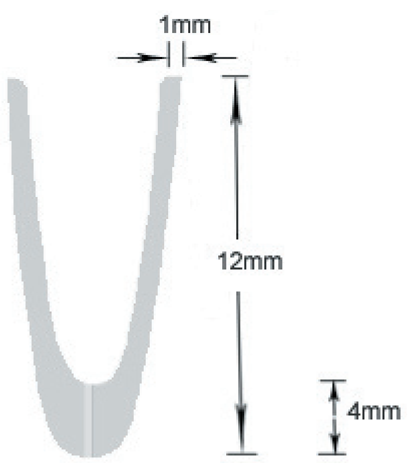

Figure 1. *Dimensions of the prepared roots of the maxillary central incisor teeth.*

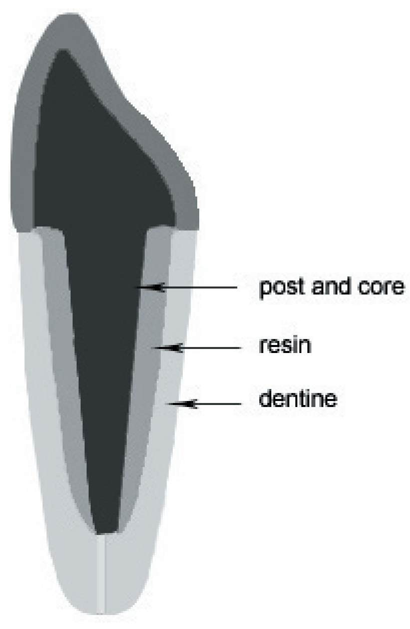

Figure 2. *Diagrammatic representation of the intermediate layer of resin-based composite present between the cast metal post-core and the thin root canal walls.*

Each root was coated with a thin layer (approximately 0.1-0.2 mm) of an addition-cured silicone rubber to simulate the periodontal membrane before being embedded, from 2.0 mm apical to the root face margin, in a 20 mm cube of self-cured acrylic resin (Figure 3). After 24 hours, a unidirectional static load was then applied (using a universal load-testing machine (Model CSS-2202) at a crosshead speed of 2.0 mm/minute), to a locating groove cut in the metal palatal concavity of the crown 2.0 mm from the incisal edge, at an angle of 135 degrees from the long axis of the root. This angle approximated that present palatally between the long axes of the maxillary and mandibular central incisors. The force (N) for initial root fracture was recorded. The results between the two groups were compared using Student's *t*-test and the Mann-Whitney U-test, with statistical significance set at α=0.01.

RESULTS

Table 2 shows that a significantly higher mean force (N) was required to fracture the tooth roots in Group 2 (Experimental), which had a thick layer of RBC surrounding the small-diameter tapered cast metal posts, than in Group 1 (Control), P <0.0001. Therefore, the null hypothesis was not accepted. There were no fractures of the metal posts.

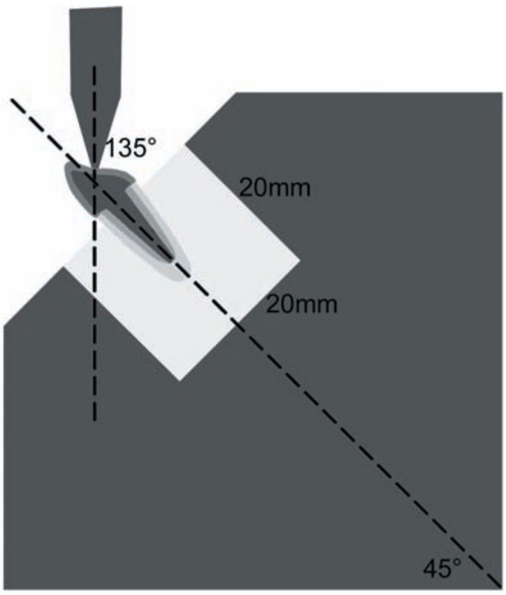

Figure 3. *Diagrammatic representation of the method used for fracture strength testing.*

Table 2. *Force (Newtons) required to fracture the tooth roots in each group*

Group 1 (N=6) *Mean (SD)*	*Group 2 (N=6)* *Mean (SD)*
360.8 (42.9)	639.3 (51.6)
t-test = 10.17, df = 10, P =<0.0001	

Group 1 = cast post-core (control); Group 2 = BIS-CORE + cast post-core.
SD = Standard Deviation of the mean.

DISCUSSION

Thin-walled roots restored with cast metal post-cores are at an increased risk of failure from fracture[10,12]. Increasing the thickness of the walls with a suitable dentine substitute may reduce this risk. The elastic moduli of many universal and posterior RBCs approximate that of dentine[13,14], which may allow a bonded RBC to strengthen the remaining root and, together with a lower modulus resin-based luting cement[15], to reduce the transfer of mechanical stresses from a rigid metal post to the remaining root dentine. The resin-based materials may act as 'mechanical buffers', by dissipating cervical stresses caused by the mismatch of properties between metal and dentine. These assumptions appeared to be supported by the findings of the present initial laboratory study, where the placement of a thick intermediate layer of RBC, sandwiched between the root dentine and the cemented small-diameter metal post, increased significantly the fracture resistance of the thin-walled roots.

The present findings confirmed those from another study using extracted structurally-weakened maxillary central incisor teeth; where the fracture resistance to a simulated masticatory load for a bonded resin-reinforced cast post-core system was significantly greater than the fracture resistance of a custom (morphologic) cast post-core procedure[9]. Interestingly, for the resin-reinforced post-cores, there was no significant difference in fracture strengths for those roots prepared with or without a tapered 2.0 mm wide ferrule[9].

Although the unidirectional static loading test method used for fracture strength did not replicate the complex dynamic forces present in the oral environment, the findings between the two groups were very different, demonstrating a much higher fracture resistance for Group 2 (Experimental). In practice, root fracture failures in post-core restored maxillary central incisor teeth are more likely to occur from either cyclic fatigue or a single severe impact. Obviously, controlled clinical trials under more realistic conditions are required to confirm the increased fracture resistance of the thin-walled roots observed in Group 2.

With the intermediate layer or 'sandwich' method, instead of fabricating a cast metal post as in the present study, direct-placement parallel-sided wrought metal posts[8] and fibre posts[16] could be cemented following the placement and polymerization of the intermediate layer of RBC. A two-stage procedure involving the creation of a post hole space is recommended to reduce high stresses arising during the polymerization of the thick intermediate layer. Improvements in root fracture resistance resulting from using the alternative post systems in this manner require further investigation, as previous laboratory studies of various materials and post designs have shown widely different results for the protection from biomechanical failures of non-weakened tooth roots[17].

CONCLUSION

Extracted maxillary central incisor teeth with simulated thin root canal walls had tapered cast Ni-Cr alloy post-cores fabricated to retain artificial metal-ceramic crowns. Bonding a thick intermediate layer of RBC, as a dentine substitute, to the remaining dentine and to the sandblasted cemented posts, resulted in a very significant increase in the fracture resistance of the roots. Further laboratory studies and controlled clinical trials are required to confirm the findings of this initial report.

MANUFACTURER DETAILS

- ALL-BOND 2, Bisco Inc., Schaumburg, IL, USA
- BIS-CORE, Bisco Inc., Schaumburg, IL, USA
- POST CEMENT HI-X, Bisco Inc., Schaumburg, IL, USA
- UNI-ETCH EZ-DOSE, Bisco Inc., Schaumburg, IL, USA
- Model CSS-2202, Changchun Tester Institute, Changchun, Jilin, PR China
- Optimus, Matech Inc., Sylmar, CA, USA
- Zinc Oxide Cataplasm, Shanghai Tooth Material Manufacturer, Shanghai, PR China

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