

Effect of length post and remaining root tissue on fracture resistance of fibre posts relined with resin composite

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SUMMARY To investigate the influence of post length and amount of remaining root tissue on the fracture resistance of roots restored with fibre posts relined with resin composite. Ninety upper canine teeth were divided into nine groups ($n = 10$). The post spaces were prepared resulting in different lengths, as follows: group 2/3, preparations with lengths of 10 mm; group 1/2, preparations with lengths of 7.5 mm; and group 1/3, preparations with lengths of 5 mm. Each group was divided into 3 subgroups according to amount of remaining root tooth tissue (2, 1 mm or 0.5 mm of thick root). Fibre posts relined with resin composite were cemented, and all teeth were restored with metal crowns. The samples were submitted to the fracture resistance test in a universal testing machine, at an angle of 135° and speed of 0.5 mm min^{-1} . Failure modes were

observed and the data of fracture resistance were submitted to the ANOVA and Tukey's ($\alpha = 0.05$). No statistically significant difference in fracture resistance was found among different post lengths ($P > 0.05$). Remaining dentin thickness of 2 and 1 mm did not differ statistically in fracture resistance ($P > 0.05$), which was higher than of 0.5 mm dentin thickness ($P < 0.05$). A prevalence of repairable failure was observed in all groups. It can be concluded that the length of fibre post relined with resin composite did not influence fracture resistance, but thickness was an important factor for the restoration of endodontically treated teeth. **KEYWORDS:** endodontically treated teeth, fracture resistance, glass fibre post, root fracture

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Introduction

In endodontically treated teeth with minimal coronal structure, a post is indicated to provide retention of the crown and improve the distribution of the functional loads to the root (1). The fracture susceptibility of teeth restored with posts may be related to factors such as the amount of remaining tooth structure, which provides resistance to the fracture of the tooth (2), and the characteristics of the post, such as modulus of elasticity, composition of the material, diameter and length (1, 3–6). A root fracture is the most serious type of failure in post-restored teeth (7). To avoid root fractures, a post having a modulus of elas-

ticity similar to that of dentin helps in distributing the stress of occlusal load in a uniform pattern (3, 4).

For a long time, cast metal post and core systems have been used for intra-radicular retention (1,5), but they have disadvantages such as a high modulus of elasticity, increasing the possibility of irrecoverable fractures of the remaining tooth structure (1,3–5). Pre-fabricated fibre glass posts have led to great advancement, especially in mechanical properties, such as high flexural strength and a modulus of elasticity similar to that of dentin, minimising the transmission of stresses on the root walls and decreasing the possibility of fractures (3, 4, 8–10). However, as

most clinical failures in teeth restored with fibre posts occur because of post debonding (7) in large root canals with thin tapered walls, the use of a fibre post relined with resin composite has been proposed, creating individualised intra-radicular posts with a better adaptation to root canals (4, 11, 12).

Furthermore, once the fibre posts are adhesively luted into the canal, a high in-depth insertion into the root canal may not be necessary to improve retention (6). Over-preparing the canal space for a large post or inserting it too deeply can diminish the tooth's resistance to fracture (1), or affect the apical seal. Therefore, the aim of this study was to investigate the influence of post length and amount of remaining root tissue on the fracture resistance of roots restored with fibre posts relined with resin composite. The hypotheses were that: (1) Post length would influence fracture resistance; and 2. Thickness of remaining dentin would affect fracture resistance.

Materials and methods

This study was approved by the Ethics Committee of the University of Passo Fundo (protocol 472-423). Extracted upper canines were kept frozen for no longer than 6 months after extraction. The inclusion criteria were absence of caries or root cracks and absence of previous endodontic treatments, posts and crowns. Furthermore, teeth of a similar size and shape were selected by root dimensions after measuring the height and bucco-lingual and mesio-distal widths in millimetres, allowing a maximum deviation of 10% from the determined mean. Ninety teeth were obtained after this analysis.

Endodontic treatment

All root canals were prepared by one trained operator. Each tooth was decoronated below the cemento-enamel junction perpendicular to the longitudinal axis using a slow-speed, water-cooled diamond disc (Isomet 2000*). The roots were cut to a uniform length of 15 mm from the apical end. The apexes of the teeth were sealed with a temporary filling material. Endodontic treatment was performed following a standardised crown-down technique using rotary

Ni-Ti instruments of the K3 System†. The apical foramen was prepared to size 50. The following irrigation regimen was used. Before a new instrument, the canal was filled with 2% chlorhexidine gel (Natufarma‡). After the use of each instrument, 5.0 mL of distilled water was used as an irrigating solution with a 5-mL syringe and a 30-G needle 3 mm short of the working length. Final irrigation with 2 mL 17% EDTA for 3 min followed by irrigation with 5 mL distilled water was performed to remove the smear layer. After that, all canals were dried with sterile paper points to conclude the protocol (13). The root canals were filled with gutta-percha points and Endofill§ using the lateral condensation technique and accessory gutta-percha points. After root canal filling, any excess gutta-percha or sealer was removed, and the coronal portion was sealed. The specimens were immersed and kept in distilled water at 37 °C for a period of 1 week, corresponding to the root canal sealer setting time.

Specimen preparation

The teeth were randomly divided into nine groups ($n = 10$), defined by the two factors investigated: post length [group 2/3, removal of two-thirds of the sealing material (10 mm); group 1/2, removal of one-half of the sealing material (7.5 mm); and group 1/3, removal of one-third of the sealing material (5 mm)]; and amount of remaining root tooth tissue (2, 1 mm or 0.5 mm of thick root) (Fig. 1).

Intra-radicular preparation

The root canal sealer and cone materials were removed from the root canals with heated instruments and using size 3 Largo burs (Dentsply Maillefer§) with a low-speed handpiece at 10, 7.5 mm or 5 mm of depth. Additionally, the roots in all groups were prepared with a spherical diamond bur (no. 1014;¶) that was initially used at a slow speed to flare the root canal to a depth of 10, 7.5 mm or 5 mm, and another spherical diamond bur (3017 HL; KG Sorensen¶) was used for middle third flaring. Final

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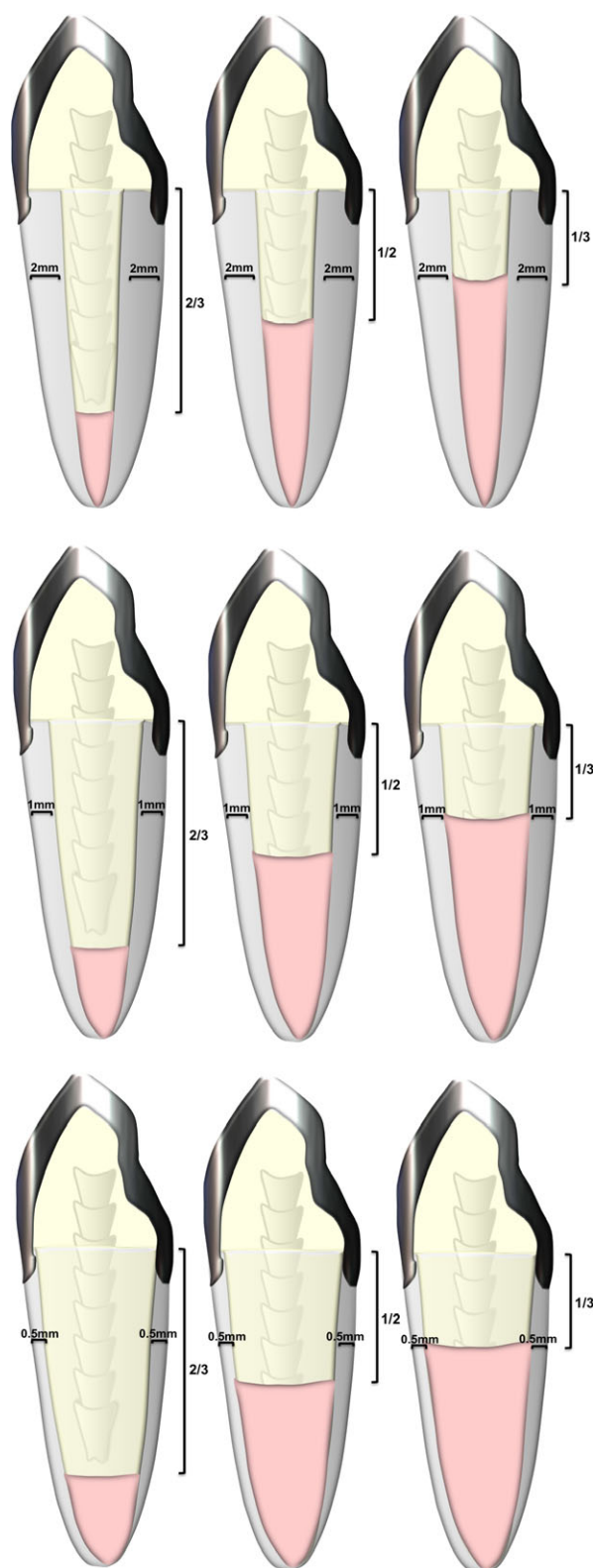


Fig. 1. Specimen preparation for all groups defined by the two study factors: post length and amount of remaining root tooth tissue.

preparation was performed using size 4 Largo burs to a depth of 10, 7.5 mm or 5 mm. With the aid of a thickness metre, constant measurements were made until dentinal walls with a thickness of 2 mm were obtained in 30 roots. The thickness of the other 60 roots was 1 and 0.5 mm, respectively. Chlorhexidine 2% in gel base was the chemical auxiliary used with the Largo burs for root canal preparation. Distilled water was the irrigating solution used to remove CHX and the material originating from preparation of the root canal. The diamond bur was used with a slow-speed diamond and under copious distilled water spray (4).

Restorative procedures

The dentin was etched with 37% phosphoric acid, and Adper Scotchbond Multi-Purpose^{||} was applied according to the manufacturer's recommendations and light polymerised for 40 s. The glass fibre posts^{**} were cleaned with alcohol and the adhesive system was immediately applied, which was polymerised for 20 s on each side.

Afterwards, the canal walls were lubricated with a hydrosoluble gel. The fibre post was covered with the resin composite Z250 (B0.5, Z250, 3M ESPE^{||}) and inserted into the canal. After removal of the excess resin, the tip of the light-curing unit was placed over the post, and the device was activated for 20 s. After composite resin polymerisation, the post was clamped with needle-nose pliers and removed from the canal. Completion of the polymerisation of the fibre post relining with resin composite was performed outside the root canal for 40 s.

After copious rinsing removal of the lubricant gel, the root canal was dried with absorbent paper points. One drop of the *bond* of the Adper Scotchbond Multi-Purpose system was applied onto the root canal surface, and the excess was removed with absorbent paper points and light polymerised for 40 s. The dual-polymerising resin-luting material Rely X ARC (3M ESPE^{||}) was mixed and injected into the prepared root canal with an appropriate Centrix syringe (20 G) (DFL^{††}) in all groups. Subsequently, the intra-radicular

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retainers were covered with cement, seated inside the root canal and kept under finger pressure for 20 s; the excess cement was then removed. The posts were cemented in a centred position within the root canal. The cement was light polymerised for 30 s on each surface (i.e. buccal, palatal, mesial and distal), resulting in a 2-min light polymerisation cycle.

To restore the coronal portion of fibre posts relined with resin composite, the incremental technique was used to place the composite resin Z250 (3M ESPE||) around the posts to make filling cores. To standardise the size of the cores, an acetate matrix was used to position the last layers. The matrix was made in a vacuum plasticiser from a core model 7 mm high and 4 mm in diameter.

All specimens were finished with a diamond bur (no. 3216) at high speed with water spray. Specimens were prepared to receive complete crowns with a reduction of 1.5 mm and ferrule of 2.0 mm. Standardised crowns were obtained for all teeth and cemented with Rely X ARC. Rectangular-shaped stops with a central concavity were made on the palatine face of the patterns to locate and stabilise the metal tip during the fracture resistance test.

The teeth were embedded in epoxy resin and condensation silicone to simulate the periodontal ligament, up to 2 mm short of the cervical portion, using a circular metal matrix (25 mm in diameter \times 20 mm high). The set (tooth, matrix and resin) remained immobile for 72 h to ensure resin setting. Next, the specimens were subjected to a compressive test in a universal testing machine (Emic DL 2000^{§§}). The position of the specimens was standardised using a device on the base of the apparatus, and load was applied at an angle of 135° in relation to the long axis of the roots (4, 6). An increasing oblique compressive load was applied on the cingulum of the tooth's palatal aspect (3 mm from the incisor edge), using a cylindrical-shaped device with a round tip (2.7 mm in diameter). A cross-head speed of 0.5 mm min⁻¹ was applied until fracture. The maximum failure load was recorded in Newtons (N).

The root-post fragment set was removed from the acrylic resin after fracture and observed under a stereoscopic magnifying glass at $\times 20$ magnification for fracture analysis. The fractures were classified accord-

ing to location as follows: (1) coronal fracture (displacement of the prosthetic set with fracture at the cementation line); (2) transverse fracture in the cervical third of the root canal; and (3) transverse fracture in the middle third of the root canal. There were no transverse fractures in the apical third of the root canal and vertical fracture. Furthermore, failures were classified as follows: (i) repairable when the fracture line was above the simulated bone level (types 1 and 2); and (ii) irreparable when the fracture line was below the simulated bone level (type 3) (Fig. 2).

Fracture resistance data were analysed using two-way ANOVA, with three post lengths and three levels of remaining tooth, followed by the Tukey's honestly significant difference (HSD) test ($\alpha = 0.05$).

Results

Table 1 shows the mean values and standard deviations for fracture resistance. No statistically significant difference was observed among different post lengths ($P > 0.05$). With respect to remaining dentin thickness, fracture resistance of 2 and 1 mm thickness did not differ statistically ($P > 0.05$) and were statistically higher than that of 0.5 mm thickness ($P < 0.05$).

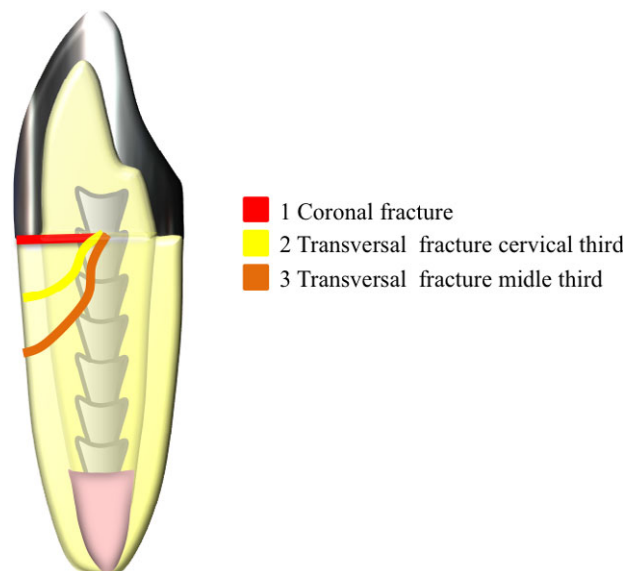


Fig. 2. The fracture locations observed for the experimental groups were as follows: coronal fracture (displacement of the prosthetic set with fracture at the cementation line); transverse fracture in the cervical third of the root canal; and transverse fracture in the middle third of the root canal.

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Table 1. The mean fracture resistance (N) and standard deviation (SD) for each experimental condition

Post length	Root condition		
	2 mm	1 mm	0.5 mm
10 mm	1051.23 (290.65) ^a	1010.98 (152.18) ^a	672.82 (134.77) ^b
7.5 mm	1151.44 (261.51) ^a	1009.50 (222.39) ^a	690.25 (166.10) ^b
5 mm	1165.18 (195.08) ^a	1073.48 (200.07) ^a	698.66 (175.42) ^b

Means followed by the same letters are not statistically different (ANOVA/Tukey's test, $\alpha = 5\%$).

Table 2 shows the failure modes observed in each group. A prevalence of transverse fracture in the cervical third of the root canal was observed in all groups. No transverse fractures in the apical third of the root canal and vertical fracture were observed in this study. A prevalence of repairable failure was observed in all groups.

Discussion

In this study, the increase in the intra-radicular length of the glass fibre posts relined with resin composite did not significantly influence the fracture resistance of endodontically treated teeth. Therefore, the first hypothesis was rejected by the results. Excessively long posts cannot increase the resistance of the roots because of excessive wear of tooth structure to receive the post (14). Leary (15) showed that preparation for an intra-radicular post considerably weakened the remaining root structure. In other words, when using a post, a large amount of dentinal structure needs to be removed during root preparation to receive the post, which may weaken the tooth rather than reinforce it. This may explain why increasing the post length did not consistently increase the fracture

resistance of roots in the present study. While the length of the root canal preparation is important for retention, it is also necessary to respect the principle of biomechanical resistance, directly related to the quantity of remaining dental structure, by preserving it to the maximum extent. Thus, canal preparation must be both sufficient to retain the core and as minimal as possible to avoid weakening the tooth (16). These results allow glass fibre posts relined with resin composite of an intermediate length to be indicated for use to provide prosthetically restored roots with adequate fracture resistance. This is an important factor in clinical situations when root length is small and the tooth has a short clinical crown.

The minimum thickness of root dentin required around a post is uncertain, and values from 1.0 to 1.75 mm are often suggested (17). Root canal treatment might result in larger root canals and thinner surrounding dentin walls. In the present study, standardised canal preparations were performed to 0.5, 1 and 2 mm remaining root dentin thickness. The results of our study showed no significant difference in fracture resistance between 1 and 2 mm remaining root dentin thickness. These results are in accordance with Barcellos *et al.* (4). However, the thickness of

Table 2. Failure mode distribution in experimental groups ($n = 10$)

Groups		Failure mode distribution				
Post length	Root condition	Type 1	Type 2	Type 3	Repairable	Irreparable
10 mm	2 mm	–	9	1	9	1
7.5 mm		–	7	3	7	3
5 mm		3	7	–	10	–
10 mm	1 mm	–	7	3	7	3
7.5 mm		–	7	3	7	3
5 mm		–	7	3	7	3
10 mm	0.5 mm	–	10	–	10	–
7.5 mm		–	7	3	7	3
5 mm		–	9	1	9	1

0.5 mm resulted in lower values of fracture resistance. Therefore the second hypothesis was accepted. These results may be explained by the fact that greater remaining tooth structure results in a stronger tooth (14–16). Therefore, the amount of residual dentin following endodontic treatment appears to be a relevant factor for the prognosis of the tooth.

The distribution of the fracture mode is an extremely important parameter for comparative analysis between post systems. In our study, a prevalence of repairable failure was observed in all groups. It is known that the stress distribution in a root-filled tooth restored with posts is influenced by the characteristics of the constituent material of the posts. Coelho *et al.* (18) showed the similarity between the elastic modulus of dentin (15–25 GPa), glass fibre posts (30–40 GPa) and composite resin (20 GPa). A material with an elastic modulus similar to dentin, such as fibre posts and composite resin, accompanies the natural flexural movements of the tooth (8, 9, 18). This property reduces stress concentrations at the interfaces, enabling the complex restoration to mimic the biomechanical behaviour of sound teeth (18) and minimising irreparable fractures (7, 19, 20). Other studies reported that the cast post and core showed a higher number of irreparable failure (1, 3–5, 19–21), particularly where the root thickness was lowest. When a post system with a high modulus of elasticity in cast posts and core (NiCr: 200 GPa) is loaded (18), a slowly growing crack causes a successive adhesive failure of the post–cement–root dentin interface. After loss of post adhesion, the post is more or less mobile within the root and is consequently allowed to act like a wedge. The energy accumulated in the inner post is transferred by the dentin, causing root fracture (18, 21).

In this study, relining the fibre post with resin composite was carried out. Customising the post increases its adaptation to the root walls and reduces the thickness of the resin cement (11). Closer contact between cement type and dentin is also important to improve the frictional retention of the post (22). Frictional retention is directly proportional to the contact area (the larger the contact surfaces, the better the retention) (12). In addition, a higher post-to-root canal adaptation increases the sustained pressure during cementation. The application of sustained pressure results in better contact between the cement/post assembly and the dentin and reduces blister formation

in the cement (23). According to Macedo *et al.* (12), it seems that the relining procedure increases fibre post retention by improving the contact between the cement and the adhesive rather than by reducing the defects observed in thin cement layers.

Our study showed that different lengths of glass fibre posts relined with resin composite exhibited similar fracture resistance. Moreover, according to Barcellos *et al.* (4), the use of glass fibre posts relined with composite resin showed the best results of fracture resistance when compared with cast post core and glass fibre post. So it seemed to be an effective method to improve fracture resistance and reduce irreparable failures on endodontically treated teeth. Despite good results with these posts, additional clinical studies are necessary to determine the best techniques and materials to closely mimic tooth structures and to recover the mechanical properties and resistance to fracture of structurally compromised teeth.

Conclusion

Within the limitations of this investigation, the findings indicated that the intra-radicular length of glass fibre posts was not a relevant factor in the fracture resistance of endodontically treated teeth. Remaining root tissue with 2 or 1 mm thickness showed similar fracture resistance, which was higher than that of remaining root tissue with 0.5 mm thickness.

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