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Techniques for restoring enlarged canals: an evaluation of fracture resistance and bond strength

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Abstract

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Aim To verify the influence of fibreglass post diameter, as well as use of accessory posts on fracture resistance and bond strength, when used for restoring enlarged root canals.

Methodology One hundred maxillary single-rooted canine human teeth were decoronated and root canals were prepared using a No.4 drill (White Post, FGM, Joinville, SC, Brazil). The roots were assigned to five groups: (EC1) post No.1 (Exacto Cônico, Angelus, Londrina, PR, Brazil); (EC2) post No.2 (Exacto Cônico, Angelus); (EC3) post No.3 (Exacto Cônico, Angelus); (ECA) post No.1 (Exacto Cônico, Angelus) plus two accessory posts (Reforpin, Angelus); (WP) post No.4 (White Post, FGM). Posts 1–4 have a crescent diameter. Posts were luted (Rely X-Arc, 3M ESPE, USA) and composite resin filling cores were prepared for the fracture resistance test ($n = 10$). For the push-out test ($n = 10$), roots were sectioned into 1 mm thick slices. Both tests were performed in a universal testing machine. Data were analysed using ANOVA and Tukey's test.

Results Groups WP and EC3 had higher fracture resistance than the other groups ($P < 0.05$), which were statistically similar. Root fractures occurred in 14% of the specimens. Groups EC1 and EC2 had lower bond strength values than Groups EC3 and ECA which were lower than the WP Group ($P < 0.05$). Bond strength was lower in the apical and middle third than in the cervical third of root canals ($P < 0.05$).

Conclusions Thicker posts were associated with higher resistance to fracture and bond strength to root canals. Using a post plus two accessory posts improved the bond strength but not the fracture resistance.

Keywords: accessory posts, bond strength, enlarged canals, fracture resistance, posts, restorative techniques.

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Introduction

Root filled teeth with significant loss of tissue are usually restored with posts (Assif & Gorfil 1994, Morgano 1996). Cast metal or ceramic posts and prefabricated metal posts were widely used. However, a higher incidence of root fracture and catastrophic failures are associated with the use of these systems (Mannocci *et al.* 1999, Fokkinga *et al.* 2004). In addition, the compromised aesthetics associated with these posts (Michalakis *et al.* 2004) has encouraged the use of fibre posts. Fibre-posts have been associated with adequate mechanical strength, fewer root fractures, non-catastrophic failures and excellent aesthetic results (Boschian Pest *et al.*

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2002, Bonfante *et al.* 2007, Martelli *et al.* 2008, Giovani *et al.* 2009, Torabi & Fattahi 2009, Santos *et al.* 2010).

Fibre posts are usually cemented into root canals with resin cements and composite resins are used as cores, composing a 'monoblock' (Freedman 1996), that is, a mechanically homogeneous unit, with an elastic modulus similar to that of dentine (Braem *et al.* 1986, Asmussen *et al.* 1999, Ferrari *et al.* 2000a). Moreover, adhesive cementation of the posts contributes to establishing this unit, allowing the retention of the core, which is the primary purpose of these posts (Robbins 1990, Goodacre & Spolnik 1994).

It has been demonstrated that adaptation of posts to root canal walls can influence fracture resistance and bond strength to dentine (Lloyd & Palik 1993). If posts are not well adapted to the root canal wall, a thicker layer of resin cement is necessary to fill any voids, increasing the shrinkage stresses induced by the polymerization of the composite cement (Giachetti *et al.* 2004). The C-factor of the root canal is much higher than in intracoronal restorations, exceeding 200, and the shrinkage stress could exceed the bond strength, causing debonding (Bouillaguet *et al.* 2003) or gaps and voids (Giachetti *et al.* 2004, Grandini *et al.* 2005).

Canals enlarged due to caries, anomalies, internal resorption or iatrogenic overpreparation (Lui 1994) can impair post adaptation to root canal walls. Accessory posts together with a main post or thicker posts could be used, ensuring a thinner layer of resin cement. Enlarged canals restored with well-adapted posts have higher bond strength values (Schmage *et al.* 2009). On the contrary, better bond strength results have been found when thinner posts were used (D'Arcangelo *et al.* 2007). It has also been demonstrated that the thickness of resin cement does not influence the bond strength values of root canals restored with posts (Perdigao *et al.* 2007).

It has been reported that the use of accessory posts does not improve fracture resistance values, although they do diminish catastrophic fractures, that is, fractures involving the middle or apical third of the root (Martelli *et al.* 2008).

In view of the controversies in the literature, the aim of the present study was to investigate whether the use of fibreglass posts with different diameters or accessory posts in enlarged canals could influence the bond strength to the root canal wall, the fracture resistance and the failure mode. The null hypotheses were that different techniques for restoring enlarged root canals with fibreglass posts did not influence the bond strength to the root canal, nor the fracture resistance and failure mode.

Material and methods

One hundred maxillary single-rooted canine human teeth, recently extracted for periodontal or orthodontic reasons, were selected. The inclusion criteria were: absence of caries or endodontic treatment, straight root canals and a root length of at least 15 mm. After cleaning and storing in an aqueous solution of 1% chloramine, the teeth were washed and sectioned below the buccal cementoenamel junction, using a low speed diamond disc (KG Sorensen, São Paulo, Brazil), 14 mm from the apex. The root and canal coronal diameters were measured with a digital caliper (Mitutoyo, São Paulo, Brazil) and a mean value calculated for each one. Roots and/or canals with differences larger than 1.5 mm were discarded and replaced by other specimens.

The root canals were enlarged under irrigation with 2.5% sodium hypochlorite, at a working length of 1 mm from the apex, using Largo drills sizes 1, 2 and 3 (Dentsply Maillefer, Ballaigues, Switzerland). Finally, the size 4 drill supplied by the manufacturer of the White Post System (FGM Produtos Odontológicos, Joinville, SC, Brazil) was used to create an overflared canal. One drill was used for four roots and then discarded. The root apices were sealed externally with a composite resin (Z100; 3M ESPE, St. Paul, MN, USA), and the entire root was coated with black cosmetic nail varnish to avoid light propagation through external root surfaces.

For the fracture resistance test, the external surfaces of fifty roots were coated with a 3 mm-thick layer of polyethylene using a vacuum plasticiser (Bio Art, Equipamentos Odontológicos Ltda., São Carlos, SP, Brazil) to simulate the periodontal ligament. Each root was embedded in a PVC tube with epoxy resin up to 3 mm below the cervical limit to simulate the conditions of teeth within alveolar bone (Soares *et al.* 2005). A dental surveyor (EDG, São Carlos, SP, Brazil) was used for this procedure, to ensure that the roots were mounted perpendicular to the horizontal surface.

The canals were restored according to the experimental groups outlined in Table 1 (n = 10 for each test). The characteristics of each post are described in Table 2. Before cementation, all posts were silanated with two coats of Ceramic Primer (3M ESPE). The roots canal walls were etched for 15 s with 37% phosphoric

Table 1 Experimental groups

Experimental Groups	Technique
EC1	Root canals restored with the post Exacto Cônico No. 1
EC2	Root canals restored with the post Exacto Cônico No. 2
EC3	Root canals restored with the post Exacto Cônico No. 3
ECA	Root canals restored with the post Exacto Cônico No. 1 plus two accessory posts (Reforpin)
WP	Root canals restored with the post White Post No. 4

acid (Uni-Etch; Bisco, Schaumburg, IL, USA), rinsed with distilled water for 30 s and blot dried with three paper points (Dentsply Maillefer). The Activator, Primer and Catalyst of the adhesive system (Scotchbond Multipurpose, 3M ESPE) were applied according to the manufacturer's instructions using a microbrush.

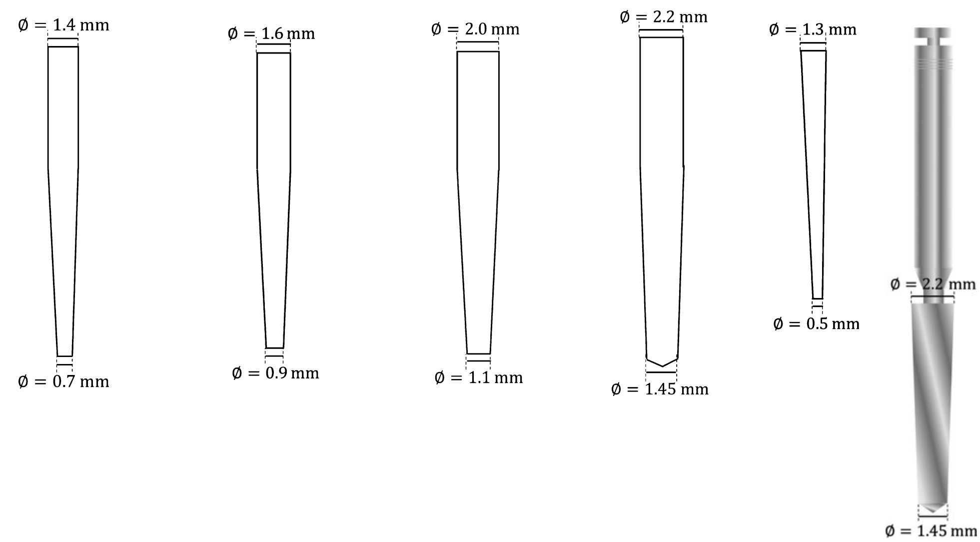
The cement Rely-X ARC (3M ESPE) was manipulated, and a syringe (Centrix Incorp, Shelton, CT, USA) was used to fill the post space. Finally, the posts were inserted into the canals, and the cement excesses were removed and light-cured (800 mW cm^{-2}) for 60 s using a halogen unit (Optilux 501; SDS Kerr Corp., Orange, CA, USA). The tip of the light-curing unit was located on the top of the post, 6 mm from the cervical surface of the root. Two more irradiations of 60 s were performed as close as possible to the cervical surface, to ensure maximum conversion of the resin cement. Irradiance was monitored using a radiometer (model 100; Demetron Inc, Danbury, CT, USA).

Fracture resistance test

A composite core was constructed using an acetate matrix. The composite Filtek Z250 (3M-ESPE) was inserted into the matrix, and a small hole on the incisal edge allowed the excess to extrude. After the core was positioned in the root and excess composite was

Table 2 Characteristics of the posts and the No. 4 drill* used in the present study

	Exacto Cônico No. 1	Exacto Cônico No. 2	Exacto Cônico No. 3	White Post No. 4	Reforpin	No. 4 Drill
Cervical and apical diameters	Ø = 1.4 mm Ø = 0.7 mm	Ø = 1.6 mm Ø = 0.9 mm	Ø = 2.0 mm Ø = 1.1 mm	Ø = 2.2 mm Ø = 1.45 mm	Ø = 1.3 mm Ø = 0.5 mm	Ø = 2.2 mm Ø = 1.45 mm
Glass fibre (%)	80	80	80	80	80	–
Epoxy Resin (%)	20	20	20	20	20	–
Manufacturer	Angelus, Londrina, PR, Brazil	Angelus, Londrina, PR, Brazil	Angelus, Londrina, PR, Brazil	FGM, Joinville, SC, Brazil	Angelus, Londrina, PR, Brazil	FGM, Joinville, SC, Brazil
Batch number	**	**	**	131208	6429	131208



*Information provided by manufacturers.
**Not provided by the manufacturer.

removed, each side of the matrix was light-cured for 40 s (800 mW cm^{-2}), and the matrix was removed.

A coping was waxed over the composite core and casted in NiCr alloy. This precise fitting metal cover was placed on the composite core to avoid elastic deformation of this material under compressive loads during the mechanical test (Adanir & Belli 2008, McLaren *et al.* 2009). The cover also allowed load application on the palatal side at an angle of 135° to the long axis of the roots. After storing for 24 h in saline solution at 37 °C, the specimens were placed in a retention device and mounted on the Universal Testing Machine (DL 2000; EMIC, São José dos Pinhais, SP, Brazil). A continuously increasing controlled load was applied at a crosshead speed of 0.5 mm min^{-1} until failure. The load required to fracture the specimen was recorded (N).

Specimens were analysed under a stereomicroscope (Olympus SZ40, Olympus, Tokyo, Japan) to verify the failure mode: cohesive in core/post and cohesive in root (cervical, middle or apical third).

Push-out test

After root canals preparation and post cementation as described previously, roots were stored in saline solution at 37 °C for 24 h, and sectioned into six 1-mm thick slices by means of a cutting device (Isomet 1000; Buehler, Lake Bluff, IL, USA), using water as a cooling agent. Before the test, the apical and coronal diameters of the cement/post, as well its thickness, were recorded using a digital caliper (Mitutoyo, Kakogawa, Japan) and a stereomicroscope (Olympus SZ40).

Each slice was positioned on the Universal Testing Machine (DL 2000, EMIC), and a continuously increasing controlled load was applied on the apical portion of the specimen at a crosshead speed of 0.5 mm min^{-1} until failure. A cylindrical punch tip, attached to this machine, was aligned to come into contact, not only with the post but also with the cement. As the prepared root canal was conical, it was necessary to use three different tip diameters to concentrate the stresses on the adhesive interface between the dentine and cement. The failure load for each specimen was recorded (N) and the bond strength (BS) calculated by the formula: BS = $F(N)/A$, where A was the area of the adhesive interface and F was the failure load.

$$A = \Pi(R + r)[h^2 + (R - r)^2]^{0.5},$$

where π = 3 1416, R = coronal diameter of the cement/post, r = apical diameter of the cement/post and h = slice thickness.

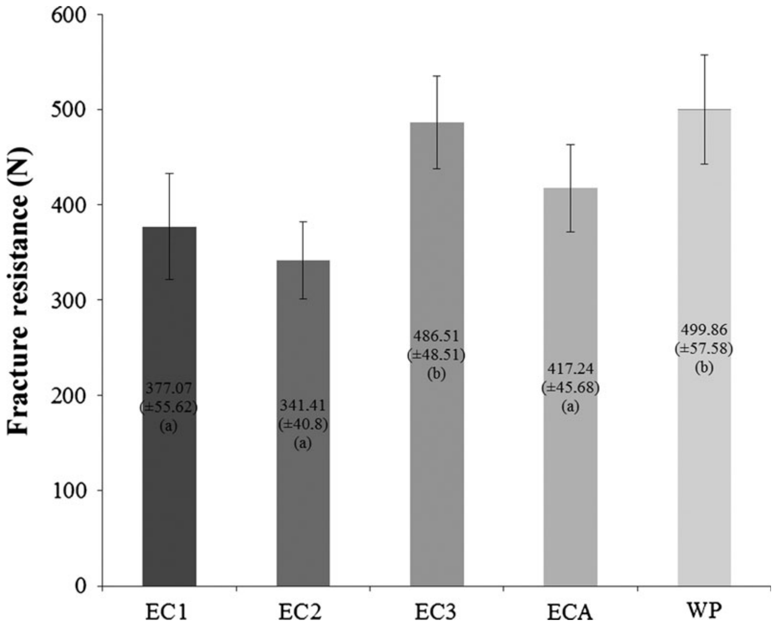


Figure 1 Fracture resistance means (N) and standard deviation (±SD) for all groups. (different letters means statistically significant differences).

The mean of the two sections per third of the roots, that is, coronal, middle and apical third, was calculated for the statistical analysis.

Statistical analysis

The statistical analysis was performed using the software Statgraphics (PLUS 5.1, Manugistic Inc., Rockville, MD, USA). Data were examined for normality of distribution (Shapiro-Wilk test) and homogeneity of variances (Hartley's test). Subsequently, fracture resistance values were submitted to one-way ANOVA, whilst bond strength values were submitted to two-way ANOVA. Tukey's test was applied for *post hoc* comparisons ($\alpha = 0.05$).

Results

Fracture resistance

Significant differences were found between groups ($P < 0.05$), where Groups WP and EC3 had the highest values of fracture resistance. Groups EC1, EC2 and ECA were similar (Fig. 1). Only 14% of the failures were root fractures. Group WP had no root fractures. All root fractures were considered noncatastrophic, as they were limited to the cervical third of the root. The fracture modes are presented in Table 3.

Bond strength

The highest bond strength value was recorded for Group WP, followed by Groups ECA and EC3, and then Groups EC1 and EC2 (Fig. 2). Differences between groups were significant ($P < 0.05$). The apical third was associated with the lowest bond strength values ($P < 0.05$) for all groups (Fig. 3). Between the cervical and middle thirds, no significant difference was found. There were also differences between bond strength values in the apical third for Group WP, compared with Groups EC1, EC2 and ECA ($P < 0.05$).

Table 3 Failure mode distribution for the fracture resistance

	Failure mode	
Groups	Cohesive of core/post	Cohesive of root (all compromising the cervical third)
EC1	7	3
EC2	8	2
EC3	9	1
ECA	9	1
WP	10	0

Discussion

With respect to fracture resistance, the null hypothesis of the present study was rejected, that is, the technique used to restore the flared canal influenced this property. When enlarged canals were restored using posts better adapted to the dentine wall (Groups EC3 and WP), the fracture resistance was significantly higher. However, the use of accessory posts together with the main post did not improve the fracture resistance, which is in agreement with other studies (Bonfante *et al.* 2007, Martelli *et al.* 2008).

A direct relationship has been reported between the proportion of fibres/resin and the fracture resistance of root filled teeth (Newman *et al.* 2003). This is in agreement with the present study as Groups EC1 and EC2, with a thicker layer of resin cement, and therefore lower proportion of fibres/resin in the canals, had lower fracture resistance values than Groups EC3 and WP, with posts better adapted to the root canal. Although Groups EC1, EC2 and ECA were similar, a propensity could be observed for the Group ECA, which had more fibres as the accessory posts were associated with the principal post, to show higher fracture resistance values compared with Group EC1 and EC2 (Fig. 1). Indeed, an association of fibres and resin cement was recommended for restoring enlarged canals (Erkut *et al.* 2004).

Even with structurally compromised roots, only 14% of the failures were root fractures (Table 3), however, all were noncatastrophic, limited to the cervical third, allowing reconstruction (Mannocci *et al.* 1999), which is in agreement with several studies (Newman *et al.* 2003, Bonfante *et al.* 2007, Martelli *et al.* 2008, Torabi & Fattahi 2009). Indeed, in a clinical study, only 11.4% of the roots restored with fibre posts failed, and only one of 120 roots analysed suffered an unfavourable fracture (Naumann *et al.* 2005).

Groups EC1 and EC2 had higher numbers of root fractures (Table 3). These groups had a thicker layer of a conventional resin cement, which had a lower elastic modulus (approximately 5.5 GPa) (Saskalauskaite *et al.* 2008) than the fibreglass post (approximately 49 GPa) (Stewardson *et al.* 2010) and the dentine (approximately 20 GPa) (Poolthong *et al.* 2001). Thus, it could be speculated that, due to the

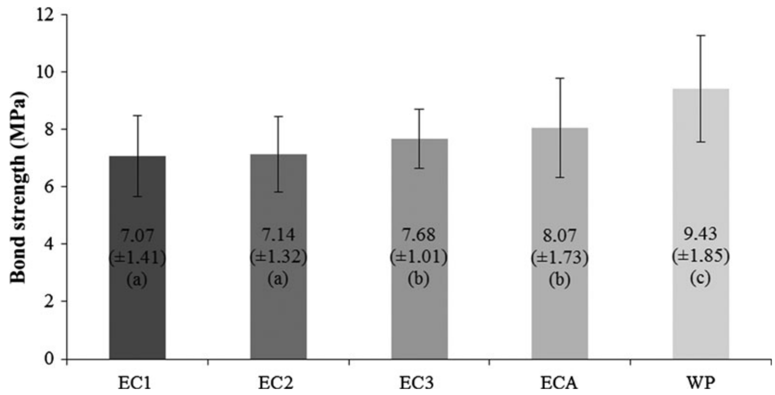


Figure 2 Bond strength means (MPa) and standard deviation (±SD) for all groups. (different letters means statistically significant differences).

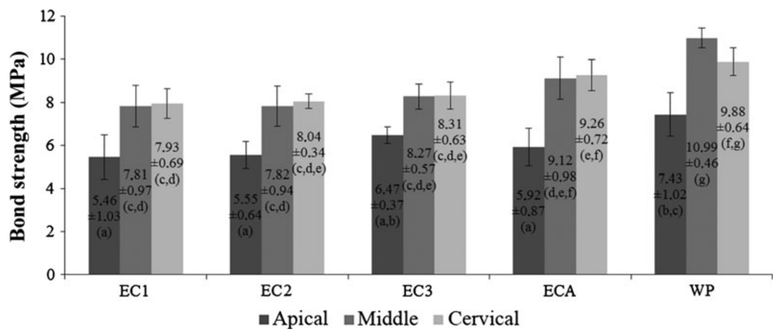


Figure 3 Bond strength means (MPa) and standard deviation (±SD) for all groups, taking into account each level of the root. (different letters means statistically significant differences).

different elastic behaviour, the cement would deform more than the post and dentine when the compressive force was applied, increasing the probability of root fractures. More noncatastrophic fractures were also found for the roots restored with a principal post plus accessory posts than the group restored only with the principal post (Martelli *et al.* 2008).

With regard to bond strength, the null hypothesis was also rejected. In previous studies, post silanization has shown to improve bond strength to resin cements (Albaladejo *et al.* 2007, Bitter *et al.* 2007) and to cores (Rathke *et al.* 2009), or had no effect on this property (Wrbas *et al.* 2007, Oliveira *et al.* 2011). So, for the present study, it was also decided to silanate the post surface, ensuring better bond strength values.

Figure 2 shows higher bond strength for Group WP, which had a well-adapted post to the root canal and a thinner cement layer, followed by Groups EC3 and ECA, and then Groups EC1 and EC2. The resin cement thickness could be responsible for this result, as the thinner the cement layer, the less the strain and stress shrinkage developed in the adhesive interface (Feilzer *et al.* 1987, Bouillaguet *et al.* 2003). In agreement with this finding, the bond strength decreased substantially when the cement layer was thicker for a greater post space (D'Arcangelo *et al.* 2007). The presence of accessory posts for Group ECA was able to minimize the cement layer, making the bond strength values similar to those of the Group EC3 and higher than those of Groups EC1 and EC2.

The greater friction of the posts on the root canal walls (Goracci *et al.* 2005) of Groups EC3, ECA and Group WP could have also contributed to the higher bond strength values reached by these groups. Indeed, when well-adapted posts were used to fill overflared canals, better push out bond strength was reported (Schmage *et al.* 2009). Corroborating these *in vitro* results, clinical studies (Ferrari *et al.* 2000a,b) have also found a higher frequency of post displacements when the resin cement layer in the root canal was thicker.

Other authors did not find any difference (Perez *et al.* 2006, Huber *et al.* 2007, Perdigao *et al.* 2007) in the bond strength when the cement layer was thicker. Two of these studies (Huber *et al.* 2007, Perdigao *et al.* 2007) used a self-curing resin cement, which may make polimerization slower, allowing accommodation of the molecular chains during the pre-gel phase, leading to fewer stresses at the bond interface (Feilzer *et al.* 1993). In the other study (Perez *et al.* 2006), the load was applied only to the post, and not to the post and cement simultaneously. Thus, their results could reflect the bond between the post and cement, whilst in the present study the results reflect the bond between the cement and root canal dentine, which is more susceptible to the effects of the shrinkage stresses (Bouillaguet *et al.* 2003, Tay *et al.* 2005).

The bond strength values of the cervical third of the root canal were higher than those of the apical third and similar to those of the middle third (Fig. 3), which is in agreement with other studies (Perdigao *et al.* 2006, 2007, D'Arcangelo *et al.* 2008). This could be explained by the difficulty with inserting the cement and light-curing it in deeper layers of the root canal (Vichi *et al.* 2002, Bergmans *et al.* 2005). Similar bond strength values for cervical and middle third were not found in another study (D'Arcangelo *et al.* 2008). However, these authors found lower values of bond strength for middle and apical third, compared with the cervical third, which was also attributed to the above-mentioned reasons.

In the apical third of Groups EC1, EC2, EC3 and ECA, the bond strength values were lower than those found for the apical third of Group WP (Fig. 3), probably due to the negative effects of the shrinkage stresses at the bond interface associated with a thicker cement layer. During the tests, an absence of accessory posts in this portion was observed for Group ECA. The bond strength reached in the cervical and middle third for Group ECA was similar to cervical third of Group WP. Thus, the responsibility for the lower bond strength values found for Group ECA can be attributed to the apical third.

Within the limitations of the current study, it can be concluded that the use of fibre posts for restoring enlarged canals is safe, as only noncatastrophic root fractures were found, that is, none of them compromised the middle or apical third. It can be inferred that, for posts with a greater diameter, the cement layer necessary to fill the post space is thinner, improving fracture resistance and bond strength to the canal walls.

Conclusions

The following conclusions can be drawn:

- Fibreglass posts better adapted to the root canal increased fracture resistance values.
- The use of posts better adapted to the root canal or an association of a main post and accessory posts improved bond strength values to the dentine.
- Root fractures were more frequent when single posts not well adapted to the root canals were used.
- The cervical third of the root had higher values of bond strength than the middle and apical ones.

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