In vitro fracture resistance of glass-fiber and cast metal posts with different lengths

Alessandro Rogério Giovani, MS,[a] Luiz Pascoal Vansan, PhD,[b] Manoel Damião de Sousa Neto, PhD,[c] and Silvana Maria Paulino, PhD[d]

University of Ribeirão Preto (UNAERP), Ribeirão Preto, São Paulo, Brazil; Faculty of Dentistry of Ribeirão Preto, University of São Paulo (FORP-USP), Ribeirão Preto, São Paulo, Brazil

Statement of problem. Dental fractures can occur in endodontically treated teeth restored with posts.

Purpose. The purpose of this study was to evaluate the in vitro fracture resistance of roots with glass-fiber and metal posts of different lengths.

Material and methods. Sixty endodontically treated maxillary canines were embedded in acrylic resin, except for 4 mm of the cervical area, after removing the clinical crowns. The post spaces were opened with a cylindrical bur at low speed attached to a surveyor, resulting in preparations with lengths of 6 mm (group 6 mm), 8 mm (group 8 mm), or 10 mm (group 10 mm). Each group was divided into 2 subgroups according to the post material: cast post and core or glass-fiber post (n=30). The posts were luted with dual-polymerizing resin cement (Panavia F). Cast posts and cores of Co-Cr (Resilient Plus) crowns were made and cemented with zinc phosphate. Specimens were subjected to increasing compressive load (N) until fracture. Data were analyzed with 2-way ANOVA and the Tukey-Kramer test (α=.05).

Results. The ANOVA analysis indicated significant differences (*P*<.05) among the groups, and the Tukey test revealed no significant difference among the metal posts of 6-mm length (26.5 N ±13.4), 8-mm length (25.2 N ±13.9), and 10-mm length (17.1 N ±5.2). Also, in the glass-fiber post group, there was no significant difference when posts of 8-mm length (13.4 N ±11.0) were compared with the 6-mm (6.9 N ±4.6) and 10-mm (31.7 N ±13.1) groups. The 10-mm-long post displayed superior fracture resistance, and the 6-mm-long post showed significantly lower mean values (*P*<.001).

Conclusions. Within the limitations of this study, it was concluded that the glass-fiber post represents a viable alternative to the cast metal post, increasing the resistance to fracture of endodontically treated canines. (J Prosthet Dent 2009;101:183-188)

Clinical Implications

In situations involving small and/or curved roots, the glass-fiber post with a smaller length represents a viable alternative to restore endodontically treated canines requiring prosthetic restoration, without decreasing the resistance to fracture.

This study was financially supported by the Brazilian agency CAPES (Coordination for Improvement of Higher Education Personnel), grant number PROSUP 0012/02–5.

[a]PhD candidate, Department of Endodontics, University of Ribeirão Preto (UNAERP).
[b]Associate Clinical Professor, University of Ribeirão Preto (UNAERP).
[c]Associate Clinical Professor, Department of Restorative Dentistry, University of São Paulo (FORP-USP).
[d]Associate Clinical Professor, University of Ribeirão Preto (UNAERP).

Endodontically treated teeth with extensive loss of coronal tooth structure are commonly restored with a post and core and a crown. Factors indicating this type of restoration include extensive dental caries, fracture, trauma, iatrogenic loss of tooth structure and pulpal pathology, as well as the endodontic treatment itself. In addition, the loss of water content in dentin after endodontic therapy can reduce tooth resilience and, consequently, increase the probability of fracture.[1,2]

After endodontic treatment, the restoration of pulpless teeth is important to ensure successful treatment outcomes. Restorations provide protection and reinforcement of the tooth, and also prevent the passage of microorganisms and organic liquids into root canals.[3-5] Failures involving the post and the crown can result in fracture of the post and root, and displacement or loss of retention of the post. Fracture of the remaining tooth structure is one of the most frequent causes of failure.[4-7]

Cast metal posts and cores have been used for many years[8]; however, there are now newer post systems available. Among the materials used for esthetic restorations, glass-fiber posts have gained popularity because of their purported favorable biomechanical properties.[1,9] They are reported to be more flexible than cast metal posts and allow a better distribution of forces, resulting in fewer root fractures.[9] In addition, these prefabricated posts are advantageous in situations in which adequate coronal tooth structure remains. Prefabricated posts are classified according to their structural composition as metal, ceramic, or resin reinforced with fibers.[10,11]

Some authors have reported that endodontically treated teeth restored with fiber posts show a decreased fracture resistance compared with teeth restored with metal posts.[12-14] Other authors,[15,16] however, have indicated that the fracture resistance of teeth restored with glass-fiber posts is equal to or greater than that of teeth restored with metal posts.

Studies suggest that the fracture susceptibility of teeth restored with posts may be related to factors such as the amount of remaining healthy tooth structure, which provides resistance to the fracture of the tooth,[4] as well as the characteristics of the post, such as the material composition,[11,17] modulus of elasticity,[7,9,18] diameter,[19] and length.[20] Some authors[20-22] have indicated that the length of the post is related to root fracture, and that the post should be two thirds of the length of the root, or, when this cannot be achieved, the post should have at least the same length as the clinical crown. According to Braga et al,[23] if neither goal can be reached, the post must extend at least half of the root length. The authors observed that posts that extended to half of the root length behaved similarly to those that were two thirds of the root length. Furthermore, such posts preserve a greater amount of root canal filling material; this is important because the apex is an area of greater anatomical complexity, with a high number of lateral and accessory canals.[24,25]

The purpose of this in vitro study was to evaluate the fracture resistance of roots with cast posts and cores and glass-fiber posts of different lengths by using a compressive test. The null hypothesis was that there would be no difference in the fracture resistance of endodontically treated canines restored with different types of post systems of different lengths.

MATERIAL AND METHODS

Sixty caries-free and restoration-free human maxillary canines with roots of similar form were selected. All selected teeth had a single canal and straight roots measuring approximately 16 mm. The clinical crowns were sectioned transversally, close to the cemento-enamel junction, leaving a root length of 15 mm.

The exploration of the radicular canal was accomplished with #25 K-files (Dentsply Maillefer, Ballaigues, Switzerland) to select the specimens that had a working length of 14 mm and an anatomical diameter of 250 μm. The preparation of the entrance of the radicular canal was accomplished with a flaring instrument (Endoflare .12, no. 25; Micro-Mega, Besançon, France), and the root preparation was accomplished with a rotary cutting instrument (HERO 642; Micro-Mega) at 300 rpm. The final instrument (#40 master apical file; Dentsply Maillefer) was standardized for all specimens. During preparation, the canals were irrigated with 2 ml of 1% sodium hypochlorite, alternating with 17% EDTA (ethylenediaminetetraacetic acid). Final irrigation was performed with 10 ml of distilled water, and the canals were dried with absorbent paper points (Dentsply, Petrópolis, Brazil). Root canals were obturated by the warm condensation technique[26] with gutta-percha points (Dentsply), accessory gutta-percha points (Dentsply), and sealer (AH Plus; Dentsply). The plasticizing of the gutta-percha points was accomplished with a condenser (McSpadden condenser; Dentsply Maillefer). The extracoronal excess of gutta-percha was removed by using heated condensers (Duflex; SS White, Rio de Janeiro, Brazil). Vertical condensation was performed with the same instruments, and the pulpal chambers were sealed with provisional cement (Citodur; DoriDent, Vienna, Austria). Specimens were immersed in distilled water and maintained at 37°C (±2°C) for a period of 36 hours. The roots were placed in aluminum molds (16 x 16 x 32 mm) and embedded in acrylic resin (Jet; Clássico, São Paulo, Brazil) to maintain 4 mm of root length extending beyond the top of the acrylic resin. For the cervical preparation of the roots, a reference line was marked with graphite pencil at a height of 2 mm. A diamond rotary cutting instrument (3069 diamond bur; KG Sorensen, São Paulo, Brazil) was used to prepare orientation notches with a depth of 1 mm. From these notches, the cervical portion of the tooth was prepared, resulting in a cervical terminus with a square shoulder.

The specimens were divided into 3 groups (n=20), according to their post lengths: group 6 mm, group 8 mm, or group 10 mm. Each group was divided into 2 subgroups, according to the post material (n=10): CPC (cast post and core) or GFP (glass-fiber post). Post spaces were prepared with parallel-sided burs from the post kit (FibreKor Post; Pentron Clinical Technologies, Wallingford, Conn) in a low-speed handpiece (Dabi Atlante SA, Ribeirão Preto, Brazil) attached to a dental surveyor (Bio-Art, São Carlos, Brazil).

For the standardization of the coronal portion of the core, a standard mold was made in the anatomical form of a core of the complete crown of the maxillary canine tooth, which was cast in copper-aluminum alloy (Goldent; AJE Goldent Comercial Ltda, São Paulo, Brazil). Beginning with this standard mold, 60 acetate molds were obtained in a plastifier (Bio-Art) under vacuum, and these aided in the fabrication of the wax patterns of the coronal portion of the core.

To obtain groups CPC 6 mm, CPC 8 mm, and CPC 10 mm, the posts were made by using the direct technique with acrylic resin (DuraLay; Reliance Dental Mfg Co, Worth, Ill) and prefabricated posts (Pin-Jet posts; Angelus Dental Solutions, Londrina, Brazil). The prepared posts were lubricated with petroleum jelly (União Química FTCA Nacional SA, São Paulo, Brazil) and, with the aid of a spiral drill (Lentulo bur #40; Dentsply Maillefer), the acrylic resin was placed into the prepared post space, followed by the insertion of the prefabricated plastic post. The previously made acetate mold was filled with acrylic resin (DuraLay; Reliance Dental Mfg Co) and placed on the post pattern, and the necessary finishing was performed with a diamond rotary cutting instrument (3069 diamond bur; KG Sorensen). The acrylic resin patterns were invested in a phosphate-bonded investment material (Termocast; Polidental, São Paulo, Brazil) and cast in copper-aluminum alloy (Goldent; AJE Goldent Comercial Ltda). The castings were airborne-particle abraded with 150-μm aluminum-oxide powder (Wilson; Polidental).

Cast posts were cemented with dual-polymerizing resin cement (Panavia F; Kuraray Co Ltd, Osaka, Japan), and its adhesive system (Kuraray Co Ltd). First, primer (Alloy Primer; Kuraray Co Ltd) was applied to the post. Then, each canal surface was acid etched (Ivoclar Vivadent; São Paulo, Brazil) for 30 seconds, rinsed with water, and dried with paper points (Dentsply). Next, 2 coats of adhesive were applied, followed by 20 seconds of drying and light polymerization with a halogen light (Ultralux Electronic; Dabi Atlante SA) for 30 seconds. The unit had a wavelength of 350 to 500 nm and light intensity of 350 to 500 mv/cm^2. The light was positioned perpendicular to the long axis of the root, and the distance of the light tip from the specimens was 2.0 mm. The cement (Panavia F; Kuraray Co Ltd) was applied in accordance with the manufacturer's instructions. A Lentulo spiral instrument (Dentsply Maillefer) was used for the application of the cement inside the prepared canals, and, to avoid any difficulty resulting from premature polymerization of the resin cement in the canal, the pin was inserted immediately after the placement of the cement. Any excess cement was removed, and the core was maintained under constant finger pressure for 60 seconds. A halogen light (Ultralux Eletronic; Dabi Atlante SA), with a wavelength of 350 to 500 nm and a light intensity of 350 to 500 mv/cm^2, was activated for 60 seconds. The light was positioned perpendicular to the long axis of the root, and the distance of the light tip from the specimens was 2.0 mm. A waiting period of 6 minutes was used to allow complete polymerization of the cement. An oxygen barrier (Oxyguard II gel; Kuraray Co Ltd) was applied to the superficial margins for 10 minutes and then removed with cotton rolls and water spray.

To obtain groups GFP 6 mm, GFP 8 mm, and GFP 10 mm, the glass-fiber posts were cemented with Panavia F cement (Kuraray Co Ltd), following the same protocol used for groups CPC 6 mm, CPC 8 mm, and CPC 10 mm, with the exception of the primer application procedure. To fabricate the core, the tooth structure was conditioned with 37% phosphoric acid gel (Ivoclar Vivadent) for 15 seconds, washed under a water stream for 20 seconds, and dried with compressed air. In sequence, with the dentin wet, 2 coats of the adhesive (Prime & Bond 2.1; Dentsply) were applied, with an interval of 30 seconds between coats to allow for the solvent evaporation. Compressed air was then applied for 5 seconds, and light polymerization was performed for 20 seconds with the halogen light (Ultralux Eletronic; Dabi Atlante SA). Layers of composite resin (Z100; 3M ESPE, St. Paul, Minn) were applied successively around the prefabricated post, and each layer (approximately 0.5 mm thick) was light polymerized for 20 seconds. To obtain the core form, the acetate molds were filled with the composite resin and positioned above the coronal portions. The excess composite resin was removed and the core was light polymerized for 40 seconds with the halogen light (Ultralux Eletronic; Dabi Atlante SA). After polymerization, the acetate molds were removed.

For the standardization of applied force during the compressive test, metal crowns were made for all of the specimens. The specimens were prepared by placing a chamfer at the cervical shoulder with a diamond rotary cutting instrument (no. 4219; KG Sorensen). A fine coat of petroleum jelly (União Química FTCA Nacional SA) was applied to the coronal portion of the core. Then, the crown patterns were made with casting wax (Odontofix, Ribeirão Preto, Brazil), invested in a phosphate-bonded investment material (Termocast; Polidental), and cast in Co-Cr alloy (Resilient Plus; Metalúrgica Riosulense SA, Santa Catarina, Brazil), according to the manufacturer's instructions. The crowns were airborne-particle abraded with 150-µm aluminum-oxide powder (Wilson; Polidental).

All crowns were cemented with zinc phosphate cement (Zinc Cement; SS White) in a ratio of 2.0 g of phosphate zinc powder to 0.5 ml of liquid. The crowns were filled with cement, placed on the preparations, and constant finger pressure was applied for 60 seconds. After 10 minutes, the excess cement was removed with a dental explorer. The specimens were then stored in 100% relative humidity, at a constant temperature of 37°C (±2°C), for a period of 72 hours.

The specimens were then subjected to a compressive test in a universal testing machine (Instron 4444; Instron Corp, Norwood, Mass). A device was used to standardize the position of the specimens at the base of the apparatus so that the load could be applied at an angle of 135 degrees in relation to the long axis of the roots. An increasing oblique compressive load was applied on the cingulum of the palatal surface (3.0 mm from the incisor region) by using a cylindrical-shaped device with a round terminus (2.7 mm in diameter). A crosshead speed of 1 mm/min was applied until the root fractured. The set of root-post fragments were removed from the acrylic resin, after the fracture, and observed under a stereoscopic magnifying glass (Leica Microsystems GmbH, Wetzlar, Germany), at ×3 magnification, for fracture analysis. With respect to the location, the fracture was classified according to the root third in which it occurred: cervical, middle, or apical. Regarding the type, the fracture plane was considered in relation to the long axis of the root and was classified as longitudinal, oblique, or transverse.

The values of the forces required for the roots to fracture, obtained in N, were submitted to preliminary statistical tests using software (InStat; GraphPad Software, Inc, La Jolla, Calif), to verify the normality of the distribution. The results were subjected to a preliminary statistical analysis. As the obtained values were not normally distributed, data were transformed to normalize them using the percentile-transformed data. A 2-way ANOVA was performed with the transformed data (α=.05). The Tukey-Kramer test was used to verify which groups differed among themselves (α=.05).

RESULTS

The mean values of the compressive loads required to fracture the roots in each of the 6 groups are displayed in Table I. The ANOVA indicated significant differences (P<.05) among the groups (Table II), and the Tukey-Kramer test (Table III) showed no statistical differences among the metal posts of different lengths: 6 mm (26.5 N ±13.4), 8 mm (25.2 N ±13.9), and 10 mm (17.1 N ±5.2). For the glass-fiber post group, the 8-mm posts (13.4 N ±11.0) were statistically similar to the 6-mm (6.9 N ±4.6) and 10-mm posts (31.7 N ±13.1). After the compression test, the post fragments were removed from the radicular canal for evaluation of the type and location of fractures. The fracture percentage values are shown in Table IV.

Table I. Mean values (SD) of strength (N) of compressive force required for root fracture

Post Type	Post Length 6 mm	8 mm	10 mm
Cast post and core	26.5 (13.4)^{b,c}	25.2 (13.9)^{b,c}	17.1 (5.2)^{a,b}
Glass fiber	6.9 (4.6)^{a}	13.4 (11.0)^{a,b}	31.7 (13.1)^{c}
Mean	16.75	19.3	27.4

Groups with same superscript letter were not significantly different according to Tukey-Kramer test (P>.05).

Table II. Two-way ANOVA with angle percentile-transformed data

Source of Variation	Sum of Squares	*df*	Mean Squares	F	*P*
Between lengths	0.0006	2	0.0003	2.54	8.669
Between types	0.0005	1	0.0005	3.87	5.132
Between groups	0.0032	2	0.0016	13.31	.009
Residual	0.0065	54	0.0001		
Total	0.0107	59			

Table III. Tukey-Kramer test, between groups

Post Type	Means	Critical Value (α=.05)
Cast post and core, 6 mm	26.5[ab]	13.22
Cast post and core, 8 mm	25.2[ab]	
Cast post and core, 10 mm	17.1[bc]	
Glass-fiber post, 6 mm	6.9[c]	
Glass-fiber post, 8 mm	13.4[bc]	
Glass-fiber post, 10 mm	31.7[a]	

Groups with same superscript letter were not significantly different according to Tukey-Kramer test (*P*>.05).

Table IV. Percentage of fractures in relation to location of root fracture according to post type and length

Place of Fracture	Post Type: Cast Metal, Length 6 mm	Cast Metal 8 mm	Cast Metal 10 mm	Glass Fiber 6 mm	Glass Fiber 8 mm	Glass Fiber 10 mm
Cervical	0	0	0	30	60	70
Middle	10	10	30	70	40	30
Apical	90	90	70	0	0	0

DISCUSSION

The current study evaluated the resistance to fracture of roots submitted to endodontic treatment and restored by using cast metal and glass-fiber posts with different lengths. The results of the current study support rejection of the null hypothesis that there would be no difference in the fracture of endodontically treated teeth restored with different types of post systems and different lengths.

Analysis of the results indicates that the length of cast posts did not affect the resistance of the roots to fracture. The authors hypothesize that, regardless of the length, when a rigid cast post with a high modulus of elasticity is submitted to stress or an oblique compressive load, it does not absorb the energy. Rather, it transmits energy to a less rigid structure, in this case, the dentin, which has a lower modulus of elasticity, thus increasing the fracture potential of the root.[7] Hayashi et al[7] noted that the fracturing of teeth restored with cast posts is related to the post's stiffness. In the current study, the fracture location was predominantly in the apical region, probably because of the oblique compressive load transferred from the post to dentin in the apical region.[7] With a fracture in this location, the tooth is nonrestorable.[7,9,18]

With respect to the glass-fiber posts, the results indicated that the roots restored with the longer posts (10 mm) had a greater resistance to fracture. Posts with a modulus of elasticity similar to dentin, such as the glass-fiber post, when submitted to a compressive load, can better absorb the forces concentrated along the root, which may decrease the probability of fracture.[9,18] This phenomenon may explain the results obtained in this study for the longer posts (10 mm), which, given their larger mass volume, possessed the capacity to absorb a greater amount of stress, rather than transferring stress to the dentin. However, the shorter posts (6 mm) appeared to concentrate the stresses in the smaller area of radicular dentin, with a greater susceptibility to fracture.

The fracture locations for the longer glass-fiber posts (8 and 10 mm) were predominantly in the cervical region, which may result from a greater concentration of forces in this region due to the angle of the joint between the glass-fiber post and the composite resin core. As for the 6-mm posts, there was a greater incidence of fracture in the middle region, probably because of the smaller mass volume of these posts, which resulted in a lower absorption of forces and their more efficient transfer to the dentin.

The 6-mm and 8-mm glass-fiber posts correspond, respectively, to 40% and 53.3% of the radicular length of 15 mm measured in this study. These lengths should be between one third and one half of the radicular length only in situations that do not allow the optimal length, two thirds of the root, to be obtained.[22,23] When the length of 10 mm was used for the glass-fiber posts (66.6%, or two thirds, of the root length), the force required for the fracture of these posts was significantly greater than that required for the 6-mm-long posts. The 8-mm post showed an intermediate value which was statistically similar to the values for the 6-mm and 10-mm posts. As in the present study, Braga et al,[23] working with glass-fiber and cast posts of different lengths, obtained satisfactory results for the 8-mm glass-fiber posts with respect to retention. Thus, considering that the 8-mm glass-fiber posts have demonstrated values similar to the 6- and 10-mm posts, with respect to both fracture strength and retention, their use can be recommended for situations in which the length of two thirds cannot be reached, for example, in situations involving curved roots. Based on these results, the recommendation of Shillingburg et al[20] that the intraradicular post be two thirds of the root length should be modified to suit the new prefabricated posts and adhesive material systems.

This current study has some limitations, such as the type of testing used, that is, a single cycle to failure, which does not represent the intraoral condition. Intraorally, teeth are subjected to cyclic loading through mastication and are immersed in a wet environment that is subject to chemical and thermal changes. The study also evaluated maxillary canines, and, therefore, the results can be applied only to that group of teeth. Furthermore, cement pressure was not standardized, as only finger pressure was used.

It is also important that clinicians consider the various types of materials available for post systems, as well as their mechanical properties. Future research is necessary to clarify the effects of different lengths of new post systems on the resistance to fracture. Finally, further investigations using a similar study design, but with a simulated periodontal ligament, should be used to compare the different esthetic post systems.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. In relation to the length, cast posts did not differ significantly in terms of the compressive load required to fracture the root (P=.17).

2. The 10-mm-long glass-fiber group demonstrated significantly higher values of fracture resistance, and the 6-mm-long glass-fiber group showed the lowest values for the force resulting in root fracture; these groups were significantly different from each other (P<.001).

REFERENCES

1. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod 2004;30:289-301.
2. Steele GD. Reinforced composite resin foundations for endodontically treated teeth. J Prosthet Dent 1973;30:816-9.
3. Iglesia-Puig MA, Arellano-Cabornero A. Fiber-reinforced post and core adapted to a previous metal ceramic crown. J Prosthet Dent 2004;91:191-4.
4. Ng CC, Dumbrigue HB, Al-Bayat MI, Griggs JA, Wakefield CW. Influence of remaining coronal tooth structure location on the fracture resistance of restored endodontically treated anterior teeth. J Prosthet Dent 2006;95:290-6.
5. Wu MK, Pehlivan Y, Kontakiotis EG, Wesselink PR. Microleakage along apical root fillings and cemented posts. J Prosthet Dent 1998;79:264-9.
6. Yang HS, Lang LA, Molina A, Felton DA. The effects of dowel design and load direction on dowel-and-core restorations. J Prosthet Dent 2001;85:558-67.
7. Hayashi M, Takahashi Y, Imazato S, Ebisu S. Fracture resistance of pulpless teeth restored with post-cores and crowns. Dent Mater 2006;22:477-85.
8. Plasmans PJ, Welle PR, Vrijhoef MM. In vitro resistance of composite resin dowel and cores. J Endod 1988;14:300-4.
9. Freedman GA. Esthetic post-and-core treatment. Dent Clin North Am 2001;45:103-16.
10. Qing H, Zhu Z, Chao Y, Zhang W. In vitro evaluation of the fracture resistance of anterior endodontically treated teeth restored with glass fiber and zircon posts. J Prosthet Dent 2007;97:93-8.
11. Martínez-Insua A, da Silva L, Rilo B, Santana U. Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent 1998;80:527-32.
12. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent 2003;89:360-7.
13. Saupe WA, Gluskin AH, Radke RA Jr. A comparative study of fracture resistance between morphologic dowel and cores and a resin-reinforced dowel system in the intraradicular restoration of structurally compromised roots. Quintessence Int 1996;27:483-91.
14. Möllersten L, Lockowandt P, Lindén LA. A comparison of strengths of five core and post-and-core systems. Quintessence Int 2002;33:140-9.
15. Teixeira ECN, Teixeira FB, Piasick JR. Thompson JY. An in vitro assessment of prefabricated fiber post systems. J Am Dent Assoc 2006;137:1006-12.
16. Seefeld F, Wenz HJ, Ludwig K, Kern M. Resistance to fracture and structural characteristics of different fiber reinforced post systems. Dent Mater 2007;23:265-71.
17. Fokkinga WA, Kreulen CM, Le Bell-Rönnlöf AM, Lassila LV, Vallittu PK, Creugers NH. In vitro fracture behavior of maxillary premolars with metal crowns and several post-and-core systems. Eur J Oral Sci 2006;114:250-6.
18. Standlee JP, Caputo AA, Collard EW, Pollack MH. Analysis of stress distribution by endodontic posts. Oral Surg Oral Med Oral Pathol 1972;33:952-60.
19. Grieznis L, Apse P, Soboleva U. The effect of 2 different diameter cast posts on tooth root fracture resistance in vitro. Stomatologija 2006;8:30-2.
20. Shillingburg HT Jr, Fisher DW, Dewhirst RB. Restoration of endodontically treated posterior teeth. J Prosthet Dent 1970;24:401-9.
21. Goerig AC, Mueninghoff LA. Management of the endodontically treated tooth. Part I: concept for restorative designs. J Prosthet Dent 1983;49:340-5.
22. Sokol DJ. Effective use of current core and post concepts. J Prosthet Dent 1984;52:231-4.
23. Braga NM, Paulino SM, Alfredo E, Sousa-Neto MD, Vansan LP. Removal resistance of glass-fiber and metallic cast posts with different lengths. J Oral Science 2006;48:15-20.
24. Stockton LW. Factors affecting retention of post systems: a literature review. J Prosthet Dent 1999;81:380-5.
25. De Deus QD. Frequency, location, and direction of the lateral, secondary, and accessory canals. J Endod 1975;1:361-6.
26. Tagger M, Tamse A, Katz A, Korzen BH. Evaluation of the apical seal produced by a hybrid root canal filling method, combining lateral condensation and thermatic compaction. J Endod 1984;10:299-303.

Corresponding author
Dr Silvana Maria Paulino
R: Florêncio de Abreu, 1201, apto. 92 - Centro
Ribeirão Preto
São Paulo
BRAZIL
141015-060
Fax: +55-16-39311072
E-mail: silvana.paulino@gmail.com