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ORIGINAL ARTICLE

Fracture resistance of endodontically treated teeth restored with or without post systems

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KEYWORDS
endodontically treated teeth;
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Abstract *Background/purpose:* The aim of this study was to determine and compare the fracture resistance of endodontically treated teeth restored with or without posts.
Materials and methods: Undamaged, extracted human premolar teeth (48 in total) were randomly divided into four groups of 12 each. Clinical crowns of the teeth were cut 3 mm coronal to the cementoenamel junction. Root canals were enlarged using rotary canal instruments (Dentsply) and filled with gutta-percha (Dentsply) as well as a sealer (AH 26, De Trey). In all groups, gutta-percha was removed, and the post space was prepared using tapered drills (FRC Postec post kit, Ivoclar Vivadent). The first group of fiber-reinforced composite posts (FRC Postec Plus, Ivoclar Vivadent) and the second group of Ever Stick posts (Stick Tech) were luted into the root canals using dual curing resin cement (Variolink II, Ivoclar Vivadent). In the third group, post spaces were filled using a hybrid resin composite (Tetric Evo Ceram, Ivoclar Vivadent). The fourth group served as a control with direct resin composite core reconstruction formed without a post. Composite cores were constructed with a hybrid resin composite (Tetric Evo Ceram, Ivoclar Vivadent) in all groups. Fracture loading was accomplished using an universal testing machine at a crosshead speed of 1 mm/min in compression mode.
Results: There were no statistically significant differences between the fracture resistance values for the four experimental groups ($P > 0.05$).
Conclusions: Fiber-reinforced posts can be used as a core material in endodontically treated teeth as well as composite core reconstructions.

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Introduction

Post and core systems have been used for decades as a foundational material to support the final restoration of endodontically treated teeth with extensive loss of tooth structure.[1] Therefore, custom-fabricated and prefabricated posts have been utilized for many years.[2,3]

Endodontically treated teeth were suggested to potentially exhibit a higher fracture risk against chewing forces and may fracture more easily than vital teeth.[4] Studies indicated that these teeth are more brittle because of loss of the tooth structure from caries, trauma, and the removal of dentin during treatment procedures.[5] Furthermore, endodontically treated teeth desiccate over time and experience changes in collagen cross-linking to dentin.[6,7] To improve the fracture resistance of endodontically treated teeth, researchers have tried to enhance new materials with greater physical properties.[1,8,9]

Fiber-reinforced composites (FRCs) have been described in the literature for 20 years.[10,11] In particular, glass-fiber-reinforced posts have been marketed and suggested as a superior alternative to cast or prefabricated metal posts due to the development of adhesive technologies in the last few decades.[12,13]

An ideal post and core material should have optimal physical properties similar to those of dentin to achieve the best results.[14] Fiber-reinforced posts are recently being used in restorative dentistry because of their superior properties, such as dentin-like rigidity. Furthermore, the elastic modulus of fiber posts is similar to that of dentin.[15] These posts also have higher aesthetic properties, require less dentin removal during treatment procedures, and can be bonded to dentin with adhesive luting resins.[16] Furthermore, fiber-reinforced posts do not result in metal corrosion or allergic reactions and can be easily removed from a root canal when failure occurs due to endodontic treatment.[17,18]

Due to the increased interest in fiber-reinforced posts in the dental literature, studies have focused on post materials,[19] luting agents,[20] post designs,[21] and ferrule effects to investigate the fracture resistance of these materials.[22] However, those studies produced conflicting results. Some studies indicated that endodontically treated teeth restored with fiber-reinforced posts exhibited lower fracture resistance compared to teeth restored with other posts, such as those composed of metal.[23,24] In contrast, some investigations found that the fracture resistance of endodontically treated teeth restored with fiber-reinforced posts is equal to or greater than those restored with metal posts.[25,26] A few authors concluded that posts are not necessary in endodontically treated teeth with minimal loss of tooth structure.[27,28] It is also uncertain whether fiber-reinforced posts strengthen endodontically treated tooth during clinical service.[28]

Some clinical investigations demonstrated the long-term clinical performance of fiber-reinforced posts, which were used in combination with composite buildup over an observation period of more than 5 years.[29,30] Post and core failures from root fractures were reported for 3–10% of all tooth buildup failures.[30,31] Dallari and Rovatti[32] proposed several attributes for an ideal intraradicular restorative system, suggesting that the biomechanical characteristics of this system should be similar to natural tooth tissues. The modulus of elasticity of dentin is approximately 14.2 GPa.[33] According to the material manufacturers in this study, fiber posts have moduli that are approximately 1–2 times greater, which may allow post flexion to mimic tooth flexion. Binding of a post to the dentin may reduce stresses in the remaining root and distribute forces more equally over the entire bonded interface.[34]

The use of FRC posts was suggested to allow for reductions in stress concentrations and in the incidence of root fractures.[35] Therefore, the aim of this *in vitro* study was to determine and compare the fracture resistance of endodontically treated premolar teeth restored with different FRC posts and with no post. The null hypothesis was that there would be no differences in the fracture resistance of the four experimental groups.

Materials and methods

For this study, 48 undamaged, extracted human mandibular premolar teeth that were free of caries and with approximately the same root length were selected. Each tooth was examined with a 2.5× binocular loupe (Orascoptic, Kerr Corporation, Middleton, WI, USA) to verify the absence of carious lesions, cracks, and microfractures. The coronal height and root length were limited to 8 ± 1 and 14 ± 1 mm, respectively. Anatomic crowns were similar in dimensions, measuring 8.75 ± 0.75 mm mesiodistally and 7.50 ± 0.75 mm buccolingually, at the cementoenamel junction. Selected teeth were stored in distilled water at 37°C during the experiment.

Clinical crowns of the teeth were cut 3 mm coronal to the cementoenamel junction. Root canals were prepared using rotary canal instruments (Pro Taper, Dentsply, Maillefer, Switzerland). After rinsing with a 2.5% sodium hypochlorite solution, the canals were dried with paper points (Spident, Incheon, Korea). All canals were filled with the single gutta-percha cone technique (Pro Taper, Dentsply) using eugenol-free root canal sealing material (AH Plus, Dentsply, De Trey, Germany).

Treated teeth were randomly assigned to four groups of 12 each. In the first three groups, post spaces were prepared using drill size 1 from the fiber-post system (FRC Postec, Ivoclar Vivadent, Schaan, Liechtenstein), according to the manufacturer's instructions. All roots of these three groups were uniformly prepared 10 mm deep from the sectioned surface with a silicone stopper to leave at least 4 mm gutta-percha apically.

The first group of FRC posts (FRC Postec Plus, Ivoclar Vivadent) and the second group of Ever Stick posts (Stick Tech, Turku, Finland) were luted into the root canals using a dual curing luting resin (Variolink II, Ivoclar Vivadent), according to the manufacturer's instructions. In the third group, post spaces were filled using a nanohybrid resin composite (Tetric Evo Ceram, Ivoclar Vivadent) with no post. The fourth group served as a control group, and direct resin composite core reconstructions were formed without a post. Composite cores were built with nanohybrid resin composite (Tetric Evo Ceram, Ivoclar Vivadent) and standardized to 4 mm in height from the sectioned tooth surface in all groups. Materials used in this study are presented in Tables 1 and 2.

Table 1 FRC posts used in this study.

Post	Manufacturer	Post type and design	Post composition
FRC Postec Plus	Ivoclar Vivadent (Schaan, Liechtenstein)	A radiopaque root canal post made of glass-fiber reinforced composite with a conicity of 5°18′	Unidirectional silane-coated glass fibers (61.5% weight) embedded in a polymer matrix of triethylene-glycoldimethacrylates and urethanedimethacrylates in combination with highly dispersed silicon dioxide
Everstick	StickTech Ltd. (Turku, Finland)	Individually formed and adaptable, polymer (PMMA) and resin-impregnated (bis-GMA) unpolymerized glass fiber post	Semi-interpenetrating polymer network of Polymethylmethacrylate, Mw 220,000 and 2,2-bis[4-(2-hydroxy-3- methacryloxypropoxy) phenyl] propane)

Roots of all specimens were covered with a thin layer of silicone impression material to simulate the periodontal ligament. Each tooth was then embedded in an autopolymerizing acrylic resin. Specimens were subjected to a compressive load in a universal testing machine (Lloyd LR 30 K; Lloyd Instruments, Fareham, UK) at a crosshead speed of 1 mm/min, with the use of a device that allowed loading at 135° to the long axis of the root (Fig. 1).

Failure loads were determined and recorded, and the Kruskal—Wallis test was then used to analyze the results between the four experimental groups. Furthermore, failure modes and fracture lines of specimens were determined by visual inspection with a 2.5× binocular loupe (Orascoptic, Kerr Corporation). Failure modes of the groups were determined as root fracture, cohesive failure, and adhesive failure, and statistically analyzed with Fisher's exact chi-square test.

Results

Mean fracture resistance values for the four experimental groups are presented in Table 3. Descriptive statistics of fracture resistance values (N) for the experimental groups with the Kruskal—Wallis test are presented in Fig. 2. These results demonstrated that there were no statistically significant differences in the fracture resistance of teeth restored using different post systems and the control group ($P > 0.05$).

Differences in the mode of failure among groups were observed and analyzed with a binocular loupe (Orascoptic, Kerr Corporation). Failure modes for the groups are presented in Table 4. Significant differences were found between the failure modes of the four experimental groups ($P = 0.001$). According to the visual inspection, 18 failures (37.5%) were in the form of root fractures (Table 4). The percentage of root fractures was highest in the control group (83.3% among groups and 55.6% among failure modes), which was composed of core reconstructions that were built without a post system (Table 4). The EverStick post group showed the lowest root fracture percentage (16.7% among groups and 11.1% among failure modes).

FRC and EverStick post groups showed equivalent cohesive failure percentages (50% among groups and 42.9% among failure modes), which were higher than those of the TetricEvo Ceram post and control groups (Table 4).

The TetricEvo Ceram post group exhibited the highest adhesive failure percentage (66.6% among groups and 50% among failure modes).

The fracture lines of 30 (62.5%) of the 48 specimens were in the form of adhesive or cohesive failure. Cohesive failure was observed in 14 teeth (29.2%). For cohesive failure, the fracture began at the composite core and continued apically into the composite structure with no root fracture. Sixteen of the fractures (33.3%) were evaluated as adhesive failure, since the failure occurred in the adhesive interface of the two adhesion components, which consisted of composite and tooth surfaces. Eighteen of the failures (37.5%) were in the form of root fracture.

Table 2 Resin cement and resin composite used in this study.

Luting agent	Manufacturer	Bonding agent	Composition of composite resins	Composition of primers	Polymerization mode
Variolink II	Ivoclar Vivadent, Schaan, Liechtenstein	ExciteDSC	Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacylate, ytterbium trifluoride, barium glass, silica	HEMA, Bis-GMA, glycerine dimethacrylate, phosphoric acid acrylate, highly dispersed silica, ethanol, catalysts, stabilizers Microbrush: coated with initiators	Dual-cured
Tetric Evo Ceram	Ivoclar Vivadent, Schaan, Liechtenstein	Excite DSC	Dimethacrylates, barium glass filler, copolymer, ytterbium trifluoride, initiators, stabilizers, and pigments		Light-cured

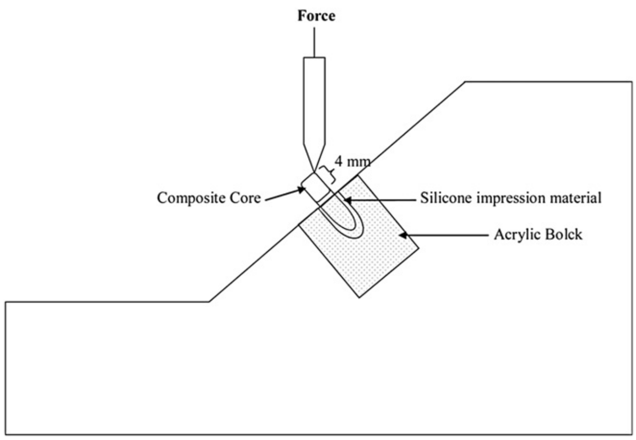

Figure 1 Use of the device that allowed fracture loading at 135° to the long axis of the specimen.

Discussion

The present study analyzed whether the fracture resistance of endodontically treated teeth restored using fiber posts was higher than that of endodontically treated teeth restored with no post. No difference was found among the fracture resistance values of the four experimental groups. Therefore, the present study determined that there was no significant difference in the fracture resistance of endodontically treated teeth restored using composite resin with or without fiber-reinforced posts.

Ferrario at al.[36] assessed the bite force of teeth from 52 healthy young adults and reported that single-tooth bite forces ranged from 178 to 291 N in premolar teeth. The mean fracture resistance values reported in this study were higher than the measured mean bite forces of premolar teeth from both women and men. Therefore, endodontically treated premolar teeth restored with fiber-reinforced posts were concluded to be able to resist normal occlusal forces. These higher fracture resistance values may be attributed to the similar modulus of elasticity of fiber-reinforced posts compared to dentin.[37]

Many studies investigated the fracture resistance of post and core systems in the literature; however, those results were contradictory. Maccari at al[38] evaluated the fracture strength of teeth with flared canals that were restored with two fiber-reinforced resin systems: a custom cast base metal (Ni—Cr) post and a core system. The fracture strength of teeth restored with cast posts was determined

Table 3 Comparison of mean fracture resistance values (N) with Kruskal—Wallis test.

Groups	N	Fracture resistance value (mean ± SD)
FRC (group 1)	12	763.5 ± 344.3*
Ever Stick (group 2)	12	705.5 ± 301.4*
Tetric Evo Ceram (group 3)	12	781 ± 521.5*
Control (group 4)	12	810 ± 414.3*

*Statistically equivalent values ($P > 0.05$).

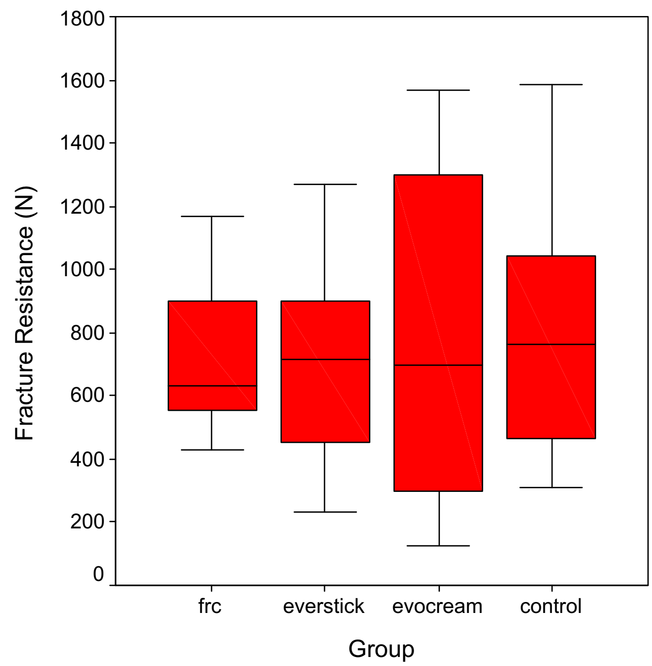

Figure 2 Box plots of fracture resistance values (N) for the groups

to be higher than teeth with glass or quartz fiber-reinforced resin posts, which exhibited similar behaviors. Rosentritt et al[39] evaluated the fracture strength of ceramic, metallic, and fiber-reinforced posts and cores compared to cast gold post and core restorations. The fracture strength of post systems with composite cores was determined to be higher than that of control gold alloy post and cores, and the fracture strength of the FRC group exhibited nearly equal values compared to gold alloy posts and cores. These conflicting results were due to variations in the methodology, chemical and physical properties of the materials used in the study, canal morphology, and the biochemical composition of extracted human teeth.[40]

The secondary aim of this study was to ascertain whether a post can retain a core in teeth with extensive loss of tooth structure. Although there was equal fracture resistance between the groups, these results indicated that fiber-reinforced posts may be suitable for clinical use. Other studies suggested that posts do not make teeth stronger, but retain the core in the tooth.[41] Thus, the influence of the ferrule effect was not evaluated, and the teeth were not restored with fabricated full crowns. When the ferrule effect is absent, forces are thought to be concentrated at the junction of the post and core.[42] Therefore, the post may easily fracture.[43] However, none of the posts fractured in this study. The influence of fatigue loading or thermal cycling on the fracture resistance was not investigated in this study, which should be considered in future *in vitro* studies.

This study showed that the mode of failure differed in premolar teeth restored with two different fiber posts, a composite post, and with no post. In terms of the mode of failure, most of the teeth restored with no post in the control group had vertical and horizontal root fractures in the middle third of the root. This type of fracture after

Table 4 Failure modes of the groups with cross-tabulation.

Failure modes ($n = 12$)		FRC Post (group 1)	EverStick Post (group 2)	TetricEvo CeramPost (group 3)	Control (group 4)	Total
Root fracture	Count	3	2	3	10	18
	% within FailureModes	16.7%	11.1%	16.7%	55.6%	100%
	% within Groups	25.0%	16.7%	25.0%	83.3%	37.5%
Cohesive failure	Count	6	6	1	1	14
	% within FailureModes	42.9%	42.9%	7.1%	7.1%	100%
	% within Groups	50.0%	50.0%	8.3%	8.3%	29.2%
Adhesive failure	Count	3	4	8	1	16
	% within FailureModes	18.8%	25%	50%	6.3%	100%
	% within Groups	25.0%	33.3%	66.7%	8.3%	33.3%

mechanical loading results in nonrepairable failures. However, root fractures occurred significantly lower in the other three post groups compared to the control group. This can be explained by the use of a fiber-reinforced post in the root canal dissipating forces along the root and reducing stresses on the root.[44] Therefore, a fiber-reinforced post has the ability to absorb stresses and to fracture at the coronal portion of a tooth without root fracture.[16]

The effect of intraradicular reinforcement with only a composite post on the fracture resistance of endodontically treated teeth was one of the concerns of this study. In this study, internal reinforcement with a composite with no post resulted in an equivalent fracture resistance of endodontically treated teeth compared to groups with fiber-reinforced posts. However, the mode of failure in the composite post group differed from those of the other two fiber-reinforced post groups. The adhesive-failure percentage in the composite post group was significantly higher than those of the other groups in this study. This type of failure is repairable, because the coronal part of the restoration was completely debonded from the tooth surface with no root fracture. This can be explained by the effect of the composite resin for root reinforcement, which results in transference of low levels of stresses to the cervical region of artificially simulated roots as in this study.[45]

This *in vitro* study has limitations as the tests were carried out with only two kinds of fiber-reinforced posts. Furthermore, this study tested teeth simulating loss of the coronal part of the crown by reducing the cervical third. Therefore, no ferrule preparation was possible with this study design. Additional *in vitro* studies along with long-term clinical investigations are needed to further evaluate the performance of fiber-reinforced posts.

Conclusions

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

1. Fracture resistance values of endodontically treated single-rooted premolar teeth restored with fiber posts, composite posts, and with no posts did not statistically differ.
2. The modes of failure in single-rooted premolar teeth varied according to the use of posts and the type of material.
3. The use of fiber-reinforced posts reduced the percentage of root fracture.
4. The use of composite resin as the post material did not influence the fracture resistance values. However, intraradicular reinforcement with composite resin resulted in reversible failures.
5. Endodontically treated single-rooted premolar teeth restored with no post or material resulted in irreversible failure due to root fracture.

References

1. Qing H, Zhu ZM, Chao YL, Zhang WQ. 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.
2. Sahafi A, Peutzfeldt A, Asmussen E, Gotfredsen K. Retention and failure morphology of prefabricated posts. *Int J Prosthodont* 2004;17:307—12.
3. Nergiz I, Schmage P, Ozcan M, Platzer U. Effect of length and diameter of tapered posts on the retention. *J Oral Rehabil* 2002;29:28—34.
4. Hansen EK, Asmussen E, Christiansen NC. In vivo fracture of endodontically treated posterior teeth restored with amalgam. *Endod Dent Traumatol* 1990;6:49—55.
5. Gutmann JL. The dentin—root complex: anatomic and biologic considerations in restoring endodontically treated teeth. *J Prosthet Dent* 1992;67:458—67.
6. Helfer AR, Melnick S, Schilder H. Determination of the moisture content of vital and pulpless teeth. *Oral Surg Oral Med Oral Pathol* 1972;34:661—70.
7. Rivera EM, Yamauchi M. Site comparisons of dentine collagen cross-links from extracted human teeth. *Arch Oral Biol* 1993;38:541—6.
8. King PA, Setchell DJ. An in vitro evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth. *J Oral Rehabil* 1990;17:599—609.
9. 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.
10. Duret B, Reynaud M, Duret F. Un nouveau concept de reconstitution corono-radiculaire: le composiposte (1) [New concept of coronoradicular reconstruction: the composipost (1)]. *Chir Dent Fr* 1990;60:131—41.

11. Duret B, Reynaud M, Duret F. Un nouveau concept de reconstitution corono-radiculaire: le composiposte (2) [A new concept of coronoradicular reconstruction: the composipost (2)]. *Chir Dent Fr* 1990;60:69—77.
12. Fredriksson M, Astback J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber-reinforced epoxy resin posts. *J Prosthet Dent* 1998;80: 151—7.
13. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. *Am J Dent* 2000;13: 9B—13B (Abstr).
14. Fernandes AS, Shetty S, Coutinho I. Factors determining post selection: a literature review. *J Prosthet Dent* 2003;90:556—62.
15. Lassilla LVJ, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts. *Dent Mater* 2004;20:29—36.
16. Strassler HE, Cloutier PC. A new fiber post for esthetic dentistry. *Compend Contin Educ Dent* 2003;24:742—4. 746, 748.
17. Fovet Y, Pourreyron L, Gal JY. Corrosion by galvanic coupling between carbon fiber posts and different alloys. *Dent Mater* 2000;16:364—73.
18. Lide'n C, Norberg K. Nickel on the Swedish market. Follow-up after implementation of the Nickel Directive. *Contact Dermatitis* 2005;52:29—35.
19. Vichi A, Vano M, Ferrari M. The effect of different storage conditions and duration on the fracture strength of three types of translucent fiber posts. *Dent Mater* 2008;24:832—8.
20. Monticelli F, Ferrari M, Toledano M. Cement system and surface treatment selection for fiber post luting. *Med Oral Patol Oral Cir Bucal* 2008;13:E214—21.
21. Varvara G, Perinetti G, Dilorio D, Murmura G, Caputi S. In vitro evaluation of fracture resistance and failure mode of internally restored endodontically treated maxillary incisors with differing heights of residual dentin. *J Prosthet Dent* 2007;98: 365—72.
22. Naumann M, Preuss A. RosentrittM. 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;64:31—6.
23. Martinez-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.
24. Sirimai S, Riis DN, Morgano SM. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. *J Prosthet Dent* 1999;81:262—9.
25. Zhang XH, Tong D, Wang XZ. The measurement and comparison of shear fracture strength and shear bond strength between carbon fiber post and some other posts. *Zhonghua Kou Qiang Yi Xue Za Zhi* 2003;38:339—41 (Abstract).
26. Möllersten L, Lockowandt P, Lindén LA. A comparison of strengths of five core and post-and-core systems. *Quintessence Int* 2002;33:140—9.
27. Trope M, Maltz DO, Tronstad L. Resistance to fracture of restored endodontically treated teeth. *Endod Dent Traumatol* 1985;1:108—11.
28. Heydecke G, Butz F, Strub JR. Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in-vitro study. *J Dent* 2001;29:427—33.
29. Ferrari M, Cagidiaco MC, Goracci C, et al. Long-term retrospective study of the clinical performance of fiber posts. *Am J Dent* 2007;20:287—91.
30. Jung RE, Kalkstein O, Sailer I, Roos M, Hammerle CHF. A comparison of composite post build ups and cast gold post and core build ups for the restoration of nonvital teeth after 5 to 10 years. *Int J Prosthodont* 2007;20:63—9.
31. Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: length of service and reasons for replacement. *J Prosthet Dent* 1986;56:416—21.
32. Dallari A, Rovatti L. Six years of *in vitro/in vivo* experience with Composipost. *Compend Contin Educ Dent* 1996;17: S57—63.
33. Standford JW, Weigel KV, Paffenberg GC, et al. Compressive properties of hard tooth tissues and some restorative materials. *J Am Dent Assoc* 1960;60:746—56.
34. Duret B, Duret F, Reynaud M. Long-life physical property preservation and postendodontic rehabilitation with the Composipost. *Compend Contin Educ Dent* 1996;20:S50—6.
35. Cormier CJ, Burns DR, DMD Moon P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. *J Prosthodont* 2001;10:26—36.
36. Ferrario VF, Sforza C, Serrao G, Dellavia C, Tartaglia GM. Single tooth bite forces in healthy young adults. *J Oral Rehabil* 2004; 31:18—22.
37. Plotino G, Grande NM, Bedini R, Pameijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. *Dent Mater* 2007;23:1129—35.
38. Maccari PC, Cosme DC, Oshima HM, Burnet LH, Shinkai RS. Fracture strength of endodontically treated teeth with flared root canals and restored with different post systems. *J Esthet Restor Dent* 2007;19:30—7.
39. Rosentritt M, Furer C, Behr M, Lang R, Handel G. Comparison of in vitro fracture strength of metallic and tooth-coloured posts and cores. *J Oral Rehabil* 2000;27:595—601.
40. Fernandes AS, Dessai GS. Factors affecting the fracture resistance of post-core reconstructed teeth: a review. *Int J Prosthodont* 2001;14:355—63.
41. Cheung W. A review of the management of endodontically treated teeth, core and the final restoration. *J Am Dent Assoc.* 2005;136:611—9.
42. Morgano SM, Brackett SE. Foundation restorations in fixed prosthodontics: current knowledge and future needs. *J Prosthet Dent* 1999;82:643—57.
43. Loney RW, Kotowicz WE, McDowell GC. Three-dimensional photoelastic stress analysis of the ferrule effect in cast post and cores. *J Prosthet Dent* 1990;63:506—12.
44. 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.
45. Yoldas O, Akova T, Uysal H. An experimental analysis of stresses in simulated flared root canals subjected to various post-core applications. *J Oral Rehabil* 2005;32:427—32.