In Vitro Fracture Resistance and Deflection of Pulpless Teeth Restored with Fiber Posts and Prepared for Veneers

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Abstract

The aim of this *in vitro* study was to evaluate the influence of endodontic therapy, veneer preparation, and their association on fracture resistance and deflection of pulpless anterior teeth and assess whether restoration with quartz fiber-reinforced post can influence these properties. Seventy-five freshly extracted human maxillary central incisors were selected. Teeth were randomly divided into 4 experimental groups (veneer preparation/endodontic therapy/endodontic therapy and veneer preparation/endodontic therapy, veneer preparation, and fiber post placement) and a control group (n = 15). Specimens were loaded to fracture recording crown deflection under load, and data were statistically analyzed. Veneer preparations and endodontic treatment did not significantly influence fracture resistance of maxillary incisors. On the contrary, preparation for veneer significantly increased the deflection values of the specimens. Fiber post restorations seemed to significantly increase mean maximum load values for specimens prepared for veneers. A fiber-reinforced post restoration can be suggested when endodontic treatment is associated with veneer preparation. *(J Endod 2008;34:838–841)*

Key Words

Deflection, fiber post, fracture resistance, incisors, veneer

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Endodontic treatment is generally reported as a cause of reduction in stiffness and fracture resistance of teeth (1). However, endodontic treatment does not increase teeth brittleness; dehydration after endodontic treatment does not weaken the dentinal structure with respect to compressive or tensile strengths (2, 3). A study reported that endodontically treated teeth and their contralateral vital pairs exhibited similar biomechanical properties, such as punch shear strength, toughness, and load required for fracture (4). Endodontically treated teeth often suffer extensive defects, and, therefore, post placement is often necessary to generate retention to core and restoration (5, 6). It is acknowledged that posts do not strengthen teeth and posts are needed only in case of substantial loss of tooth structure (7).

A recent study showed that fracture resistance of endodontically treated teeth restored with composite resins is not affected by fiber reinforced posts (8). However, the use of posts seems to optimize fracture patterns (8). *In vitro* studies on the mechanical strengths of pulpless incisors restored with fiber posts showed a reduction in root fractures during fracture tests (9, 10).

On the basis of these encouraging *in vitro* and *in vivo* findings (10, 11), fiber post composite (FRC) restorations have been recommended because they improve teeth flexibility under applied loads as well as stress distribution between post and dentin (12). They have also been recommended in light of their dentin-like Young's modulus (13).

Veneering tooth reduction might reduce tooth fracture resistance, particularly for endodontically treated teeth (7, 14, 15). Veneers seem indicated only when the remaining structure of endodontically treated teeth is relatively intact. This restoration technique represents an alternative to traditional restoration procedures such as metal-ceramic restorations and all ceramic crowns (16, 17). It preserves the remaining tooth structure, re-establishes function, and offers good esthetic results (18).

The purpose of this *in vitro* study was to investigate the influence of veneer preparation, endodontic therapy, and their association on the fracture resistance and on deflection of pulpless anterior teeth and to assess whether restoration with a quartz fiber-reinforced post can influence the results.

Materials and Methods

Seventy-five freshly extracted human maxillary central incisors were selected for this study. External debris was removed (Suprasson P-max; Satelec/Acteon Equipment, Merignac, France). Teeth with defects or cracks were excluded. Coronal height and root length were limited to 10 ± 1 mm and 13 ± 1 mm, respectively. Anatomic crowns were similar in dimension, measuring 8.25 ± 0.75 mm mesiodistally and 7.55 ± 0.8 mm buccolingually, at the level of the cementoenamel junction (CEJ). Selected teeth were stored in 0.5% chloramine T aqueous solution at 4°C until the beginning of experiment, but no longer than 1 week after extraction. Teeth were randomly divided, distributed into 1 control and four experimental groups (n = 15), and prepared as follows.

1. Group 0: control; 15 incisors were nonprepared and served as the control group.
2. Group 1: veneer preparation; in this experimental group, butt joint veneer preparations were executed (19). A silicone mold (Optosil; Heraeus Kulzer, Wehrheim, Germany) of each abutment tooth was made before preparation and was used to standardize the preparation procedure. Facial surfaces of the teeth were reduced by 0.5 mm. All preparations were within the enamel without sharp line angles. A cylindrical round-ended diamond rotary cutting instrument (No.

880.305S; Intensiv, Viganello-Lugano, Switzerland) was used under constant water irrigation to remove only the surface aprismatic enamel (20, 21). Diamond cutting instruments were discarded after preparing 5 specimens. The specimens were prepared freehand. The design of preparation was standardized as follows: 0.5 mm facial reduction, 2 mm incisal margin reduction, 0.5 to 1 mm interproximal reduction, and a cervical margin placed 1 mm incisal to the CEJ. Finishing procedures were performed with stones (Dura-White Arkansas Stones; Shofu Dental Corp, San Marcos, CA) and hand chisels (Hu-Friedy, Chicago, IL) (22).

3. Group 2: endodontic therapy; teeth from this group were submitted to conventional root canal therapy. After having achieved a palatal access, root canals were mechanically enlarged to International Organization for Standardization (ISO) size 25, 0.06 taper (MTwo; VDW GmbH, Munich, Germany). Irrigants used were 5% sodium hypochlorite (Ogna, Muggiò, Milan, Italy) and 17% EDTA (Pulpdent, Watertown, MA). Enlarged canals were rinsed with distilled water, dried with paper points (Roeko, Langenau, Germany), and sealed with gutta-percha (Lexicon Gutta Percha Points; Dentsply Tulsa Dental, Tulsa, OK) using the System-B HeatSource (Analytic Technology, Redwood City, CA) and endodontic sealer (Pulp Canal Sealer EWT; Kerr, Romulus, MI). Backfilling 1 mm below the buccal CEJ was performed with Obtura II (Spartan, Fenton, MO). The pulp chamber was restored with a light-cured hybrid composite and adhesive system according to the manufacturer's instructions (Enamel Plus HFO; Micerium, Avegno, Genova, Italy). No intermediate base was applied over the gutta-percha. After light curing the adhesive, the restorative resin was applied and light cured in 3 increments through the palatal access. Each increment of composite was cured for 40 seconds.
4. Group 3: endodontic therapy and veneer preparation; specimens from this group underwent both to the veneer preparation and to root canal therapy according to the techniques described in groups 1 and 2.
5. Group 4: endodontic therapy, veneer preparation, and fiber post placement; specimens from these group were prepared as those in group 3, but preformed fiber posts (Endo Light Posts size 2, Batch n. 049520702; RTD, St. Egrève, France) were placed in each root canal before the pulp chamber restoration. After the root canal therapy, teeth were temporized for 24 hours using a light-curing free-eugenol cement (Fermit N; Ivoclar Vivadent, Schaan, Liechtenstein). Then, gutta-percha was removed with warm endodontic pluggers (Sybron Dental Specialties, Romulus, MI). Post spaces were prepared to a depth of 15 mm measured from the incisal edge using Torpan drills ISO 100 Yellow (Batch n. 042190611, RTD). Post-space preparations were rinsed with 5% NaOCl. A final irrigation was accomplished with distilled water, and post spaces were dried with paper points. Every canal was etched for 60 seconds with 36% phosphoric acid (Conditioner 36, Batch n. 0704001714; DentsplyDeTrey, Konstanz, Germany), introduced into the spaces with a needle, rinsed using a water syringe, and then gently dried with paper points. XP Bond (Batch n. 065001399; Dentsply DeTrey, Konstanz, Germany) and Self-Cure Activator (Batch n. 0510061; Dentsply DeTrey) were mixed for 2 seconds and applied to the root canal for 30 seconds with a microbrush (Microbrush X; Microbrush Corp, Grafton, WI). The luting agent (FluoroCore 2, Batch n. 0610021, Dentsply DeTrey) was injected into the root canal by a tube with a needle and the appropriate plug (KerrHawe SA, Bioggio, Switzerland) using a specific Composite-Gun (KerrHawe SA). Posts were then seated to full depth in the prepared spaces using finger pressure. A luting agent in excess was immediately removed with a small brush. After initial chemical polymerization, the resin luting agents were light polymerized for 40 seconds. Exceeding posts were cut using a cylindrical diamond bur mounted on a high-speed handpiece (Bora L; Bien-Air, Bienne, Switzerland) under water-spray cooling. The coronal portion of the post was kept in the pulp chamber, 2 mm coronally to the lingual CEJ. Subsequently, pulp chamber was restored as described in group 2.

Fracture Strength Testing

All specimens underwent 10,000 thermal cycles between 5°C and 55°C, with a 30-second dwell time and a 5-second transfer between temperature baths. Specimens were then preserved in a saline solution at room temperature for 1 week.

Afterward, specimens were individually mounted in acrylic resin blocks, embedding the roots up to 1 mm from the buccal CEJ. Specimens were then submitted to the fracture strength test at a constant speed of 0.5 mm/min using a Universal Testing Machine with a displacement measurement system (Lloyd LR 30K; Lloyd Instruments Ltd, Fareham, UK) able to record crown deflection under load. The force was applied at a 45° angle to the long axis of the tooth (23, 24) by means of a 1.5-mm rounded loading tip located on enamel between the middle and the cervical third of the crown palatal aspect. Failure loads and the failure deflections were recorded. All specimens were examined for fractures, and the mode of failure was determined under an optical microscope (Stemi 2000 CS; Carl Zeiss, Jena, Germany) with low-power (50×) stereo magnification using an incident light. The modes of failure were classified as follows: root fractures, involving just the root; facial fractures, involving just the crown in its facial aspect; longitudinal fractures, involving the crown and extending into the root; and cervical fractures, at the level of the CEJ.

After having checked that data were normally distributed (Kolmogorov-Smirnov test), two different one-way analyses of variance were performed to analyze the influence of the different treatments on failure load and failure deflection. Post hoc multiple comparisons were performed using the Tukey test, with the significance level set at $\alpha = 0.05$.

Results

Fracture strength test results are shown in Table 1. Concerning the maximum load, specimens from group 4 achieved significantly higher mean values if compared with teeth prepared for veneer, either with or without endodontic treatment (group 3 and group 1, respectively). No statistically significant differences were reported among the other groups.

As far as deflection is concerned, the highest results were recorded in group 3. Preparation for veneer (group 1) significantly increased the deflection values of the specimens. Fiber-reinforced post restorations associated with veneer preparations (group 4) did not show statistically significant differences with group 0.

Specimens from group 0 showed 7 root fractures and 8 longitudinal fractures. In veneer-prepared group 1, 4 specimens underwent facial fractures. Three cervical fractures were recorded: 1 in group 2 and 2 in group 3. In group 4, 7 longitudinal fractures, 7 facial fractures, and 1 root fracture were reported.

Discussion

The results of this investigation suggest that fracture resistance and deflection parameters do not have similar behavior under the same experimental design. The study showed that conservative veneer preparations within the enamel and endodontic treatment do not signifi-

TABLE 1. Mean Values (SD) for Experimental Groups

	Group 0 control	Group 1 veneer preparation	Group 2 endodontic therapy	Group 3 endodontic therapy and veneer preparation	Group 4 endodontic therapy, veneer preparation, fiber post placement
Maximum Load (SD)* (N)	778.31[a,b] (109.99)	753.77[b] (118.60)	774.08[a,b] (115.82)	671.07[b] (164.63)	918.23[a] (201.43)
Deflection at Maximum Load (SD)* (mm)	1.17[c,d] (0.29)	1.61[b] (0.36)	0.94[d] (0.22)	1.97[a] (0.35)	1.29[b,c] (0.29)

*SD = standard deviation. The same superscripted letters indicate no significant differences ($p > 0.05$).

cantly influence fracture resistance of maxillary incisors. These data are in accordance with Baratieri et al. (18) who suggested that veneer preparation does not significantly weaken endodontically treated maxillary incisors.

On the contrary, teeth deflection values were significantly increased when preparations for veneer, even in the absence of endodontic treatment, were performed. This depends on the stiffness of incisors, which, in turn, is directly proportional to the residual enamel amount (27). The relation of the long axis of the tooth to the operating load renders the physiological load of upper incisors particularly disadvantageous (28). The horizontal vector of the load has much more influence on these teeth than the vertical vector (29). Ko et al. (30) concluded that, although posts reduced maximal dentin stress by as much as 20% when teeth were loaded vertically, teeth such as incisors are not normally subject to vertical loading. Thus, posts do not seem to reinforce endodontically treated teeth. To make allowance for these aspects, in the present study, the load was applied at a 45° angle (25, 26) to simulate a worst-case scenario (31). Loney et al. (32) showed that different load angles result in different fracture strengths. Moreover, the resistance of a restoration in the oral environment is not determined by failure load alone; hence, additional factors should be further considered, such as cyclic mechanical loading conditions.

With regard to tooth morphology, the palatal concavity and the incisal areas of maxillary anterior teeth are considered to be highly stressed during function (33). This circumstance is physiologically compensated by an increased thickness of the enamel in these areas (34). Dentin exhibits considerable plastic deformation beyond the yield point and is a weak, biologic ductile material whose strength and toughness can vary (5). An intact tooth is described as a hollow, laminated structure being deformed under load. During normal occlusal function, dentin responds like a prestressed laminate, able to resist higher loads than in an unstressed state because in the prestressed state it can flex with varying degrees and angles of load. However, each preparation destroys the prestressed state. The tooth gets more deformed and is finally more prone to fracture (5). Loads exceeding the ability of dentin for plastic deformation lead to fractures. Depending on the amount of remaining hard tissue, dentin fails first (5, 30). The most frustrating complication to root canal therapy is vertical root fracture (35). It is a longitudinal fracture of the root, extending throughout the entire thickness of dentine from the root canal to periodontal tissues, with an unfavorable prognosis, resulting almost inevitably in extraction of the tooth or resection of the affected root. Recently introduced resin-based obturation materials have proved to increase the resistance of root canal–filled teeth to vertical root fracture (36).

The higher deflection values reported for specimens prepared for veneers (groups 1 and 3) can be related to the reduction in enamel thickness. This partial reduction of tooth structure seemed to increase maxillary incisors deflection without influencing teeth fracture resistance.

Fiber-reinforced post restorations seemed to significantly increase mean maximum load values for specimens prepared for veneers, regardless of whether they were or not endodontically treated. Moreover, fiber post restorations were shown to significantly decrease deflection values when endodontic therapy and veneer preparation were associated (group 4 vs group 3). Fiber-reinforced post restorations were able to restore the mechanical properties in maxillary incisors treated with endodontic treatment and veneer preparation. With regard to the use of posts associated with veneer preparations, Baratieri et al. (18) concluded that posts do not increase the resistance of prepared teeth to fracture. However, their study evaluated the use of a titanium post, which has very different mechanical properties from those of a FRC post system. Unlike titanium posts, FRC posts have an elastic modulus similar to that of natural teeth (37) and are adhesively luted. However, there are quite a few studies that show at best mixed results comparing metal with fiber posts (36–39). Based on these findings, it seems that, even if veneer preparations and endodontic treatment do not significantly influence fracture resistance of maxillary incisors, preparation for veneer significantly increases teeth deflection.

The previously mentioned considerations on the physiological load of upper incisors show that deflection is an extremely important parameter because teeth can be deformed under low masticatory loads. On the contrary, fractures can be considered rare events that can happen under higher masticatory loads. Within the limitations of an *in vitro* study, it seems that a fiber-reinforced post restoration can be suggested when endodontic treatment of maxillary incisors is associated with veneer preparation.

References

1. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 1989;15:512–6.
2. Huang TJ, Schilder H, Nathanson D. Effects of moisture content and endodontic treatment on some mechanical properties of human dentin. J Endod 1992;18:209–15.
3. Papa J, Cain C, Messer HH. Moisture content of vital vs endodontically treated teeth. Endod Dent Traumatol 1994;10:91–3.
4. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod 1992;18:332–35.
5. Gutmann JL. The dentin-root complex: anatomic and biologic considerations in restoring endodontically treated teeth. J Prosthet Dent 1992;67:458–67.
6. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod 2004;30:289–301.
7. Sivers JE, Johnson WT. Restoration of endodontically treated teeth. Dent Clin North Am 1992;36:631–50.
8. Salameh Z, Sorrentino R, Papacchini F, et al. Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts. J Endod 2006;32:752–5.
9. 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.
10. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002;87:431–7.

11. Ferrari M, Vichi A, García-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. Am J Dent 2000;13:15B–18.
12. Bateman G, Ricketts DN, Saunders WP. Fibre-based post systems: a review. Br Dent J 2003;195:43–8.
13. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 1999;27:275–8.
14. Ross RS, Nicholls JI, Harrington GW. A comparison of strains generated during placement of five endodontic posts. J Endod 1991;17:450–6.
15. Thorsteinsson TS, Yaman P, Craig RG. Stress analyses of four prefabricated posts. J Prosthet Dent 1992;67:30–3.
16. Baratieri LN, De Andrada MA, Arcari GM, Ritter AV. Influence of post placement in the fracture resistance of endodontically treated incisors veneered with direct composite. J Prosthet Dent 2000;84:180–4.
17. Ho HH, Chu FC, Stokes AN. Fracture behavior of human mandibular incisors following endodontic treatment and porcelain veneer restoration. Int J Prosthodont 2001;14:260–4.
18. Giachetti L, Bertini F, Bambi C. An 8-year follow-up of a fractured endodontically treated incisor restored with a modified laminate veneer. Dent Traumatol 2008;24:104–7.
19. Stappert CF, Ozden U, Gerds T, Strub JR. Longevity and failure load of ceramic veneers with different preparation designs after exposure to masticatory simulation. J Prosthet Dent 2005;94:132–9.
20. Ferrari M, Patroni S, Balleri P. Measurement of enamel thickness in relation to reduction for etched laminate veneers. Int J Periodontics Restorative Dent 1992;12:407–13.
21. Brunton PA, Wilson NH. Preparations for porcelain laminate veneers in general dental practice. Br Dent J 1998;184:553–6.
22. Zarone F, Epifania E, Leone G, Sorrentino R, Ferrari M. Dynamometric assessment of the mechanical resistance of porcelain veneers related to tooth preparation: a comparison between two techniques. J Prosthet Dent 2006;95:354–63.
23. 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.
24. Tan PL, Aquilino SA, Gratton DG, et al. In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 2005;93:331–6.
25. Magne P, Douglas WH. Cumulative effects of successive restorative procedures on anterior crown flexure: intact versus veneered incisors. Quintessence Int 2000;31:5–18.
26. Korioth TW, Waldron TW, Versluis A, Schulte JK. Forces and moments generated at the dental incisors during forceful biting in humans. J Biomech 1997;30:631–3.
27. Takahashi N, Kitagami T, Komori T. Behaviour of teeth under various loading conditions with finite element method. J Oral Rehabil 1980;7:453–61.
28. Ko CC, Chu CS, Chung KH, Lee MC. Effects of posts on dentin stress distribution in pulpless teeth. J Prosthet Dent 1992;68:421–7.
29. Schmitter M, Huy C, Ohlmann B, Gabbert O, Gilde H, Rammelsberg P. Fracture resistance of upper and lower incisors restored with glass fiber reinforced posts. J Endod 2006;32:328–30.
30. Loney RW, Moulding MB, Ritsco RG. The effect of load angulation on fracture resistance of teeth restored with cast post and cores and crowns. Int J Prosthodont 1995;8:247–51.
31. Highton R, Caputo AA, Mátyás J. A photoelastic study of stresses on porcelain laminate preparations. J Prosthet Dent 1987;58:157–61.
32. Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent 1999;82:669–79.
33. Cohen S, Berman LH, Blanco L, Bakland L, Kim JS. A demographic analysis of vertical root fractures. J Endod 2006;32:1160–3.
34. Hammad M, Qualtrough A, Silikas N. Effect of new obturating materials on vertical root fracture resistance of endodontically treated teeth. J Endod 2007;33:732–6.
35. Pegoretti A, Fambri L, Zappini G, Bianchetti M. Finite element analysis of a glass fibre reinforced composite endodontic post. Biomaterials 2002;23:2667–82.
36. 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.
37. Cormier CJ, Burns DR, 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.
38. Raygot CG, Chai J, Jameson DL. Fracture resistance and primary failure mode of endodontically treated teeth restored with a carbon fiber-reinforced resin post system in vitro. Int J Prosthodont 2001;14:141–5.
39. Reid LC, Kazemi RB, Meiers JC. Effect of fatigue testing on core integrity and post microleakage of teeth restored with different post systems. J Endod 2003;29:125–31.