Fracture Resistance of Anterior Teeth Restored with a Novel Nonmetallic Post

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ABSTRACT

Objective: To determine the fracture resistance of endodontically treated anterior teeth restored with a novel nonmetallic post in combination with self-etching adhesives.

Materials and Methods: Extracted maxillary anterior teeth were sterilized with gamma irradiation, and each crown was severed 2 mm above the cementoenamel junction. Endodontic treatment was performed, and the teeth were divided into 7 test groups according to the post–adhesive combination used (n = 8 in each group). The following combinations of posts and adhesives were used: group 1, ParaPost stainless steel post with glass ionomer cement (control group); group 2, Light Post post with Clearfil SE Bond bonding agent and Panavia-F adhesive; group 3, Light Post post with Xeno-III bonding agent and Panavia-F adhesive; group 4, ParaPost Fiber White post with Clearfil SE Bond bonding agent and Panavia-F adhesive; group 5, ParaPost Fiber White post with Xeno-III bonding agent and Panavia-F adhesive; group 6, everStick post with Clearfil SE Bond bonding agent and Panavia-F adhesive; and group 7, everStick post with Xeno-III bonding agent and Panavia-F adhesive. Core build-ups to restore anatomic form were made from light-cured composite (TPH^3). Specimens were stored in water at 37 °C. The roots of each tooth were embedded in an acrylic base, and the teeth were mounted at 135° to the horizontal. The teeth were loaded in an Instron machine, and loading was applied to the point of fracture. Fracture loads were recorded, means and standard deviations (SDs) were calculated, and the data were analyzed with analysis of variance (ANOVA) and Tukey's tests.

Results: The mean fracture load (and SD) for each group was as follows: for group 1, 536.8 (75.1) N; for group 2, 1,000.1 (190.9) N; for group 3, 1,049.9 (231.5) N; for group 4, 1,548.5 (290.0) N; for group 5, 1,171.3 (296.9) N; for group 6, 1,711.7 (516.7) N; and for group 7, 1,825.7 (527.3) N. ANOVA revealed significant differences among the groups ($p < 0.001$). In addition, the mean fracture value for group 7 was significantly higher than those of the other groups ($p < 0.05$) except for groups 4 and 6.

Conclusions: Use of a novel glass fibre post (the everStick post) was associated with the highest mean fracture force for maxillary anterior teeth, regardless of the bonding agent used, whereas the stainless steel post was associated with the lowest mean fracture force.

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The colour of metallic posts may be visible through the structure of endodontically treated teeth, particularly in the anterior region. Depending on the thickness and opacity of the core, the cement and the crown, this may have clinical significance when all-ceramic crowns are used for restoration.[1,2] The use of nonmetallic posts reinforced with materials such as glass fibre, quartz or silica can overcome this problem. Compared with metallic posts, nonmetallic posts are less rigid, having modulus of elasticity values approximating that of dentin.[3] This characteristic may result in better distribution of stress and may help to prevent root fracture over the long term.[4,5]

When posts are bonded well to root dentin, the post, cement and dentin form a monoblock. A similar situation can be created in the crown portion of the tooth if the core build-up is made of bonded resin composite. The components of such a monoblock behave as one unit under functional forces, with better distribution of stress and enhanced resistance to fracture. Previous studies have shown that resin composite cores have a fracture resistance comparable to that of amalgam and cast cores, with fracture patterns showing less involvement.[6] Composite core build-ups are also esthetically pleasing and allow immediate preparation of the teeth for crown restorations.

Teeth that have received post-and-core restorations are reportedly weaker than intact teeth.[7] However, the material used for the post (metallic or nonmetallic) can significantly affect the fracture resistance of teeth. In a previous study, fibre-reinforced posts were superior to titanium, ceramic and cast gold posts in terms of the fracture resistance of anterior teeth.[8]

When crowns are bonded to radicular dentin with traditional etch-and-rinse bonding agents, the results may be inconsistent. Moisture must be maintained on the etched dentin surface, since exposed collagen fibrils may collapse if they dry out and may prevent penetration of resin monomer into the partially demineralized dentin zone, which will in turn reduce the strength of the bond.[9–11] Alternatively, self-etching adhesives, which are less sensitive to technique, can simultaneously condition the dentin and deposit resin monomer into the affected zone without the need for rinsing.[11–13]

A novel glass fibre post (the everStick post, StickTech, Turku, Finland) was recently introduced. This post is made of glass fibres embedded in an unpolymerized resin matrix. The post is supplied in a soft form and hardens upon polymerization with light. The aim of this investigation was to determine the fracture resistance of endodontically treated anterior teeth restored with this novel fibre-reinforced post. The effect of 2 different self-etching adhesives on fracture resistance was also investigated.

Materials and Methods

Maxillary anterior teeth extracted for periodontal reasons were sterilized with gamma irradiation (Gamma cell 220, Atomic Energy Ltd., Chalk River, Ont.). Teeth of similar size that were free of cracks, caries and fractures were selected for this study; very small and very large teeth were avoided. A total of 56 teeth were divided into 7 equal groups (n = 8 per group), with a similar mix of tooth types (central, lateral, canine) among the groups. The anatomic crown of each tooth was cut horizontally to the long axis 2 mm incisal to the cementoenamel junction with a water-cooled diamond fissure bur (DiaSwiss FG, Geneva, Switzerland) in an air-turbine handpiece (Star 430K, Stardental, Lancaster, Penn.). For endodontic treatment, the K3 nickel–titanium file system (Sybron Endo, Orange, Calif.) was used; 2.5% sodium hypochlorite solution was used for irrigation. The canals were then dried with paper points (Union Broach, Montgomeryville, Penn.); K3 gutta-percha points (Sybron Endo) coinciding with the size of the master files used were coated with AH 26 eugenol-free sealer (Dentsply DeTrey GmbH, Konstanz, Germany) and placed into the canals to the full working length using the lateral condensation technique. Each group of teeth was randomly assigned to undergo 1 of 7 restorative treatment regimens. Twenty-four hours after initial preparation, the teeth were prepared to receive posts according to standard techniques for channel-hole preparation, leaving 4–5 mm of gutta-percha as the apical seal. The teeth in group 1 (the control group) received metallic posts (ParaPost stainless steel posts, 1.2 mm diameter, Whaledent Coltene, Langenau, Germany), which were cemented with Fuji Plus glass ionomer cement. Each root canal was first conditioned for 20 s with Fuji conditioner and rinsed with water. In accordance with the manufacturer's instructions, Fuji cement capsules were mixed in an amalgamator (Vari-Mix III, Caulk/Dentsply, York, Penn.) for 20 s and placed into the canal with a Lentulo spiral. The radicular portion of the post was then covered with cement and immediately inserted into the canal. The post was maintained under pressure until initial hardening of the cement had occurred.

For teeth in group 2, quartz–reinforced posts (Light Post posts, 1.2 mm diameter, RTD, St. Egreve, France) were cemented with a 2-step self-etching adhesive (Clearfil SE Bond, Kuraray, Okayama, Japan) applied in conjunction with a dual-polymerized resin cement (Panavia-F, Kuraray), in accordance with the manufacturer's instructions. Light from a quartz–tungsten–halogen (QTH) light-curing unit with output of 700 mW/cm^2 (Optilux 501, Kerr, Orange, Calif.) was applied from above along the length of the post for 60 s. In group 3, Light Post posts were cemented with a one-step self-etching adhesive (Xeno III, Dentsply DeTrey GmbH in conjunction with the same resin cement [Panavia-F]). In group 4, another type of glass fibre posts (ParaPost Fiber White posts, 1.14 mm diameter, Whaledent Coltene) were cemented with the same agents as were used for group 2 teeth (Clearfil SE Bond and Panavia-F). In group 5, ParaPost Fiber White posts were cemented with the same agents as were used for group 3 teeth (Xeno III and Panavia-F). In group 6, glass fibre posts supplied in a soft unpolymerized form (everStick post, 1.2 mm diameter) were cemented with the same agents as were used for group 2 teeth (Clearfil SE Bond and Panavia-F). Light was first applied to the 2 opposite sides of the post for 20 s each, to harden the coronal aspect of the post. Light was then applied parallel to the long axis of the post for 60 s. In group 7, the everStick posts were cemented with the same agents as were used for group 3 teeth (Xeno III and Panavia-F), and light polymerization was applied as for group 6. Core build-ups for all specimens were created incrementally from a light-polymerized hybrid resin composite (TPH³, Caulk/Dentsply) along with the same bonding agent as used for the posts in each group. Light from the QTH light curing unit (Optilux 501) was applied for 40 s per increment. The crowns of the teeth were restored to their original anatomic form with the composite material and were finished with rotary instruments. The specimens were stored in water at 37 °C for 48 hours.

For testing of fracture resistance in the Instron universal testing machine (model 8501, Instron Corp, Canton, Mass.), special metallic attachments were made in a milling machine. These allowed positioning the specimens at 135° to the horizontal, so that the load could be applied with a stainless steel stylus at the centre of the lingual fossa. Compressive loading was applied at a cross-head speed of 2 mm/min until failure. The failure force for each tooth was recorded, and means and standard deviations were calculated for all groups.

The data were analyzed with analysis of variance (ANOVA) ($p < 0.05$) followed by Tukey's test. Specimens were visually examined after loading by one investigator (OAAE) and the extent of fracture was determined according to a 3-point scale. Minor fractures were limited to the coronal portion of the tooth, and the tooth was readily restorable. Moderate fractures were those that extended onto the cervical aspects of the crown or root but the tooth was still restorable. Major fractures were severe horizontal or oblique fractures of the crown, with involvement of the root structure; these teeth were deemed nonrestorable.

Results

The mean fracture force (and SD) varied from 536.8 (75.1) to 1,825.7 (527.3) N (**Table 1**). ANOVA revealed a significant difference in mean fracture force among the groups ($p < 0.001$). The highest mean fracture force (1,825.7 N) was recorded for group 7, in which the teeth were restored with everStick posts, Xeno III bonding agent and Panavia-F adhesive; however, this value was not statistically significantly different from the mean value for group 6 teeth (1,711.7 N), which were restored with everStick posts, Clearfil SE Bond bonding agent and Panavia-F adhesive, or group 4 teeth (1,548.5 N), which were restored with ParaPost Fiber White posts, Clearfil SE Bond bonding agent and Panavia-F adhesive (**Table 2**). The lowest mean fracture force was recorded for group 1 teeth (536.8 N), which were restored with ParaPost stainless steel posts and glass ionomer cement; however, this value was not statistically significantly different from the mean value obtained for group 2 teeth (1,000.1 N), which were restored with Light Post posts, Clearfil SE Bond bonding agent and Panavia-F adhesive, or group 3 teeth (1,049.9 N), which were restored with Light Post posts, Xeno III bonding agent and Panavia-F adhesive.

Table 1 Mean fracture force for 7 post–adhesive combinations

Group no.	Post–adhesive combination	Mean fracture force (SD) (N)
1	ParaPost stainless steel, glass ionomer	536.8 (75.1)
2	Light Post, SE Bond, Panavia-F	1,000.1 (190.9)
3	Light Post, Xeno-III, Panavia-F	1,049.9 (231.5)
4	ParaPost Fiber White, SE Bond, Panavia-F	1,548.5 (290.0)
5	ParaPost Fiber White, Xeno-III, Panavia-F	1,171.3 (296.9)
6	everStick post, SE Bond, Panavia-F	1,711.7 (516.7)
7	everStick post, Xeno-III, Panavia-F	1,825.7 (527.3)

SD = standard deviation

In group 1 (control), 7 specimens underwent major fracture involving most of the root structure, whereas most of the teeth in the remaining groups underwent minor fracture, with few moderate or major fractures (**Table 3**).

Discussion

The loading angle of teeth with post restorations can strongly affect fracture resistance.[14,15] Specifically, mean failure loads increase as the loading angle approaches an orientation parallel to the long axis of the teeth.[15] However, Guzy and Nicholls[16] reported that for incisor teeth a loading angle of 135° simulates the contact angle observed clinically for Class I occlusion between the maxillary and mandibular anterior teeth. Therefore, in the present study, the teeth were loaded lingually at 135° to the horizontal to simulate as closely as possible the loading that would be observed under clinical conditions.

The extracted human teeth used in this study were sterilized with gamma irradiation. According to White

Table 2 Results of statistical analysis with Tukey's test comparing mean fracture force among the 7 test groups ($p < 0.05$ was deemed to represent statistical significance)

	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Group 1	$p = 0.10$	$p = 0.05$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
Group 2		$p > 0.99$	$p = 0.02$	$p = 0.96$	$p < 0.001$	$p < 0.001$
Group 3			$p = 0.06$	$p = 0.99$	$p < 0.001$	$p < 0.001$
Group 4				$p = 0.30$	$p = 0.97$	$p = 0.68$
Group 5					$p = 0.32$	$p < 0.001$
Group 6						$p = 0.99$

Table 3 Extent of fracture for various post–adhesive combinations

		Extent of fracture; no. of fractures		
Group no.	Post–adhesive combination	Minor	Moderate	Major
1	ParaPost stainless steel, glass ionomer	0	1	7
2	Light Post, SE Bond, Panavia-F	7	1	0
3	Light Post, Xeno-III, Panavia-F	4	2	2
4	ParaPost Fiber White , SE Bond, Panavia-F	5	1	2
5	ParaPost Fiber White, Xeno-III, Panavia-F	4	3	1
6	everStick, SE Bond, Panavia-F	7	0	1
7	everStick, Xeno-III, Panavia-F	6	1	1

and others,[17] this method does not cause any structural changes to the teeth. To approximate clinical conditions, all teeth were first subjected to endodontic therapy, whereby the intraradicular surfaces were first subjected to irrigation with sodium hypochlorite solution during canal preparation and were subsequently smeared with the endodontic sealer during canal obturation, as would be the case in clinical practice. If such treatment affected bond strength, the effect would be evident under the testing conditions of this study. Also, the teeth were kept moist throughout the experiment, since drying can adversely affect bonding.

Loading to fracture represented a "worst case" scenario. Although it does not replicate what takes place in the oral environment, where teeth are subjected to forces of mastication that over a long period of time may cause fatigue resulting in tooth fracture,[18] this method of testing has been widely used by previous researchers.[3,6,16,19] The large standard deviations reported here are most likely due to the use of different types of teeth (centrals, lateral and canines).

In the present study, the teeth in group 1 (with stainless steel posts) exhibited the lowest mean fracture force and underwent the most severe fractures. This result is in agreement with the findings of a recently published study in which the performance of metallic posts was inferior to that of nonmetallic fibre posts.[19] The relatively higher modulus of elasticity of metallic posts and the lack of bonding to the glass ionomer cement are the most likely causes of this result.[20] Of the 3 types of nonmetallic posts used in this study, the everStick post was associated with the highest fracture forces. This could be due to the unpolymerized form in which this post is supplied, which allows the resin monomer at the surface to react well with monomers in the resin cement. The 2 other posts were supplied in a hardened form (with pre-polymerized monomer), which might have reduced their potential for bonding to the resin cement and thus might have allowed relatively lower fracture forces.

Mannocci and others[20] compared the degree of penetration of bonding resins applied for different times on glass-reinforced posts with either an interpenetrating polymer network (everStick post) or a cross-linked polymer matrix (C-Post Millennium post, Sogeva, Varese, Italy). The degree of penetration of bonding resins into the everStick post increased with increasing time of contact, whereas no penetration of bonding resin occurred with the C-Post Millennium post. The penetration of bonding resins into the everStick post matrix allowed the establishment of a good link between the post and the resin cement.[20] This finding is in accord with the findings of the present study.

Lassila and others[21] determined the flexural properties of different types of nonmetallic posts when combined with composite cores for comparison with the everStick fibre-reinforced post, which is supplied in an unpolymerized form. The greatest flexural strength was exhibited by the novel fibre-reinforced post,[21] another result that supports the findings of the present study. In addition, in a recent study, the inclusion of posts in composite cores resulted in a significant reduction in the diametral tensile strength of the composite cores.[22] Metallic posts had the most detrimental effect, while some nonmetallic posts had a lesser effect.[22] Similarly, in the present study, teeth containing a metallic post had the lowest fracture resistance.

The results of the present study, which clearly favour the novel nonmetallic post (everStick), must be interpreted with caution. In the oral environment, restored teeth are subject to a variety of challenges in addition to the masticatory load, including prolonged exposure to moisture, temperature and pH fluctuations with intake of different foods, and exposure to a variety of bacteria and enzymes. Collectively, these factors may have detrimental effects on the strength of bonding between the post and the root dentin, which may in turn have clinical consequences. Further studies taking these challenges into account are needed. However, given the naturally protected location of the bond interface within the root portion of the tooth, such challenges may play a minor role in weakening the intraradicular bond. In a recent study of fatigue resistance of 30 teeth restored with fibre posts, none of the posts underwent separation after 2 million loading cycles of 50 N each.[23] Furthermore, a recent short-term (up to 30 months) clinical evaluation of fibre posts in conjunction with resin composite for the restoration of endodontically treated anterior and posterior teeth without crown restorations yielded promising results.[24] Long-term clinical observations of the performance of nonmetallic posts are desirable.

Conclusions

Use of a new glass fibre post supplied in a soft, unpolymerized form (the everStick post) resulted in significantly higher fracture resistance of maxillary anterior teeth, regardless of the type of bonding agent used, relative to a group of metallic and nonmetallic posts. A stainless steel post cemented with glass ionomer cement resulted in significantly lower mean fracture resistance of maxillary anterior teeth relative to nonmetallic posts. Tooth fractures were less severe with nonmetallic posts than with the stainless steel posts.

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