Original Article

Effect of Translucency and Opacity of Fiber Reinforced Intracanal Posts on Fracture Resistance of Compromised Teeth

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Abstract

Background and Aim: Severely damaged teeth with no support at the coronal portion of root canal are very difficult to restore. The aim of this in-vitro study was to evaluate intraradicular reinforcement by dual cure composite resin and two different types of fiber reinforced composite (FRC) posts (translucent and opaque) in structurally compromised roots.

Materials and Methods: Root canal therapy was performed for 48 maxillary central incisors. The teeth were divided into four groups, and specimens from three groups were prepared to simulate the teeth with flared canals. In the 1st group, no weakening was done. In the 2nd group, the compromised area of the root canal was filled with gutta percha. In the 3rd and 4th groups, universal DT light and DT white posts were used respectively in the root canal to 8 mm below the margin of the palatal wall. The posts were cemented with dual-cure composite. In all groups, the access cavity was restored with light-cure composite resin. After being mounted, all specimens were pressed at an angle of 45° relative to the long axis of the teeth. The amount of force at fracture was recorded. Results of fracture load were evaluated by one-way ANOVA and LSD post hoc test and the results of mode of fracture were evaluated by chi–square test.

Results: The mean fracture load for the four groups was 170.12, 71.40, 125.8 and 148.59 kgf, respectively. There was a significant difference between the mean fracture load of 1st and 2nd groups and that of other groups (p=0.001). The mean fracture load of the 4th group was significantly (p=0.002) higher than that of the 3rd group. The frequency of restorable fractures was significantly different between these two groups (p<0.001).

Conclusion: Using dual cure composite resin and FRC posts in roots with thin walls will reinforce the compromised teeth but the type of post will affect the outcome.

Key Words: Compromised teeth, Fracture resistance, Fiber reinforced post, Translucency

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Introduction

Anterior teeth play an important role in smile esthetics and speech. Fracture, discoloration or loss of anterior teeth can adversely affect the smile appearance of patients. Pulp necrosis due to trauma or caries during root formation can result in thin root walls. Teeth with thin dentinal walls and weak root structure are more susceptible to fracture and restoration of these teeth has a questionable long-term prognosis. It has been confirmed that in spite of a successful root canal treatment, 28-77% of these teeth, depending on the degree of root formation, undergo fracture during or after treatment [1]. Despite reports on the re-vitalization of necrotic, infected and immature permanent teeth [2], apexification of teeth with immature apices is a routine treatment [3]. Restoration of these teeth following apexification is not possible with placement of conventional intracanal posts like other endodontically treated teeth due to thin dentinal walls and weak root structure [4]; because placing a thick, prefabricated or cast post exerts high pressures to the thin root walls and leads to fracture. On the other hand, loads applied to the anterior teeth are compressive and shear loads that tend to separate the crown from the root at the cementoenamel junction (CEJ). Thus, intracanal post placement to reinforce the cervical part of the root is necessary due to the weak dentin structure in this area. Evidence shows that restoration of these teeth must include reinforcement of the compromised coronal portion of the root and cervical one third of the crown [5-7] to allow placement of thinner intracanal posts. Application of dentin adhesive materials like glass ionomers, composite resins, polyethylene bands, fiber posts and adhesive resin cements to the root canal system reinforces the thin root structure. By doing so, pressures due to post placement and occlusal loads would be better distributed onto the tooth structure and the tooth would be more resistant to fracture. To benefit from the placement of tooth colored restorations in the root area, non-metal intracanal posts along with dentin-adhesive composite resins are suggested. FRC posts are among the non-metal posts with glass or quartz reinforcing fibers in their structure. These posts have acceptably high fracture resistance [8] and due to having a modulus of elasticity similar to that of dentin, they provide high esthetics in endodontically treated teeth [9, 10]. Also, due to the absence of metal in their structure, corrosion products will not be present to cause discoloration of the tooth or the full ceramic restoration over it and the tooth would not exhibit an opaque appearance.

At present, many researchers have focused on the application of tooth colored intracanal posts for reinforcement of compromised teeth. FRC posts are highly popular for this purpose. They have a high percentage of reinforcing fibers trapped in a polymer matrix. The polymer matrix is often made of epoxy resin or other polymers with high degree of conversion and numerous side chains [11].

Several studies have assessed the degree of light transmission through the lucent and opaque posts in the root canal system to polymerize the resin material around the posts [12-14]. Considering all the above, this study aimed to assess the effect of placement of two glass fiber composite posts (lucent and opaque) with similar morphologic characteristics on fracture resistance of compromised teeth.

Materials and Methods

This in-vitro, experimental study was conducted on 48 maxillary central incisors that were free from caries, fractures, cracks, enamel erosion or hypoplastic defects especially at the cervical area and had mature apices. To prevent cross contamination, the collected teeth were stored in 0.2% thymol solution at room temperature until the experiment. Prior to the study, the teeth were removed from the thymol solution and soft tissue residues were cleaned using a scalpel. Debris and calculus were removed by a curette and the teeth were cleaned by pumice paste and prophylactic brush. The extracted teeth were randomly divided into 4 groups of 12 and separately stored in saline solution during the study. To decrease errors, we selected specimens with almost equal mesiodistal and occlusogingival dimensions in both crowns and roots. All teeth underwent endodontic treatment and root canals were filled up to the level of the CEJ with gutta percha and AH26 sealer (Dentsply, USA) using the lateral condensation technique.

After 24 hours, specimens in all groups except for group 1 were flared at the coronal portion of the roots using a flame diamond bur and high speed handpiece under water and air spray in such way that the thickness of the labial area of the access cavity was 2.5mm. The thickness of mesial and distal marginal ridges was 1.5 mm and the thickness of the palatal wall was 2mm. Using #1-4 Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), gutta percha was removed to 5mm below the CEJ. Numbers 4, 5 and 6 peeso reamers (Dentsply Maillefer, Ballaigues, Switzerland) were used in the root canal system, respectively. Using a laboratory bur (Ivomil, Ivoclar, AG, Germany), the cervical one third of the root canal was flared in such way that the 5-6mm of the root canal below the CEJ had approximately one millimeter thickness of dentinal wall. To control dentinal wall thickness, a gauge used in fixed prosthodontics was repeatedly used. The access cavity walls were also thinned until the palatal wall height from the CEJ was 2mm, the thickness of the buccal wall of the access cavity was 2mm, the thickness of the palatal wall of the access cavity was one millimeter and the thickness of mesial and distal marginal ridges was one millimeter as well.

In this study, group 1 was considered as the positive control group and the teeth in this group remained intact (no weakening). After endodontic treatment of teeth in this group, access cavity was only restored with light cure composite resin to the level of CEJ.

In group 2 (negative control), to simulate wide-canal teeth, the compromised area was filled with gutta percha alone to the level of the CEJ. No other restorative material or post was placed in the root canals. The access cavity was only restored with light cure composite resin to the level of the CEJ.

In group 3, using specific drills of the intracanal post system, root canal preparation was done apical to the compromised area in the root canal system along the longitudinal axis of the root to 11-13mm length from the palatal margin of the access cavity. After testing and adjusting the height of intracanal post (Light Post, RTD, France), dual cure composite resin (Luxa Core, Smart Mix Dual, DMG, Hamburg, Germany) was applied to the root canal. To bond the composite to root canal walls, Single Bond dentin bonding agent (Single Bond, 3M Dental Product, USA) was applied according to the manufacturer's instructions. To ensure complete setting of the dentin bonding agent, light was directed into the root canal system for 40 seconds using a light curing unit (Coltolux 2.5, Coltene, USA). Dual cure composite was injected into the root canal by up to 0.5mm below the CEJ using a syringe. A translucent quartz fiber post soaked with Single Bond was placed at the center of the root canal. The apical half of the post had adequate fit with the root canal system; thus, the post was stable at the middle of the root canal system. After 5 minutes, curing was done for 40 seconds using a light curing unit in order for the resin cement to completely polymerize. Access cavity was restored as in other groups.

In group 4, all procedures were done as in group 3; the only difference was that opaque intracanal posts (White Post, RTD, France) were used instead of translucent ones. Access cavity in all groups was restored with light cure composite (InTen-S, Ivoclar, Vivadent, Switzerland) following acid etching and application of Single Bond.

After preparation, specimens were placed in an incubator at 37°C for 24 hours. For mounting the specimens, PVC cylinders with 2.5 cm diameter were used. After mounting, to assess fracture resistance, the teeth were transferred to a universal testing machine (Dartec, HC10, England) and subjected to increasing compressive loads at a crosshead speed of 1mm/min at 45° angle relative to the longitudinal tooth axis until fracture. The load was applied from the palatal direction directly to the mesial and distal marginal ridges right above the cingulum. To apply force, a cylindrical crosshead with 5mm diameter was used.

The fractured teeth were visually examined to differentiate restorable and non-restorable ones.

Data were analyzed using SPSS version 16, one-way ANOVA and LSD test (for pairwise comparisons). $P \leq 0.05$ was considered statistically significant. To assess the mode of failure in different groups as a qualitative variable, chi square test was applied.

Results

One-way ANOVA with $\alpha=0.05$ showed significant differences in fracture resistance among groups (F-ratio=72.793, $p<0.001$). LSD post hoc test was used for pairwise comparison of groups. Table 1 shows the fracture resistance (Kgf) and the modes of failure in different groups. The highest fracture resistance value belonged to group 1 (control) while the lowest fracture resistance belonged to group 2 (compromised, not reinforced). In groups reinforced with lucent post, fracture resistance was significantly higher than that in not-reinforced teeth and significantly lower than that of healthy teeth ($p<0.001$). In groups reinforced with opaque post, fracture resistance was significantly higher than that in non-reinforced teeth ($p<0.001$) and significantly lower than that of healthy teeth ($p=0.004$). In the two groups reinforced with intracanal posts, the group reinforced with opaque

Table 1. Fracture resistance in Kgf and the frequency of mode of failure in different groups

Test result / Groups	Mean	Standard deviation	Absolute frequency of restorable teeth	Absolute frequency of non-restorable teeth
1	170/12	12/44	12	0
2	71/40	17/00	0	12
3	125/84	12/97	11	1
4	148/89	24/04	8	4

post had significantly higher fracture resistance than the group reinforced with lucent post (p=0.002).

Chi square test was used to compare the reinforced groups in terms of fracture resistance and mode of failure (treatable) and significant differences were noted in this regard among groups (p<0.001). Post fracture, bond failure, or composite fracture were not observed in groups 3 and 4 (opaque and lucent posts) specimens.

Discussion

In this in-vitro study, intracanal reinforcement of compromised teeth with composite resin and lucent and opaque posts was evaluated. A total of 12 specimens were evaluated in each group based on the sample size calculation formula and previous studies. Studies have shown that dentin adhesives can reinforce compromised tooth structure at the coronal portion of the root and enable using posts in wide canals. Of all materials capable of bonding to dentin, composite resins form the most suitable bond to dentin [15]. Composite resins have a modulus of elasticity close to that of dentin and are tooth colored [15, 16]. Compressive strength of composites is much higher than that of cements to resist functional loads. Thus, teeth treated with composite have less tensile stress in the surrounding composite and lower stress, less strain and fewer cracks are created over time [16, 17].

Thus, composite resin was used in the current study. Use of dual cure composite ensures its complete polymerization even in distant areas from the light source. As the result, optimal apical seal and better distribution of loads along the canal walls are obtained [16, 18].

Mechanical properties of fiber posts depend on the matrix properties, its fiber content, bond strength at the fiber-matrix interface, orientation of reinforcing fibers and length, direction and concentration of fibers. Adding fibers to polymer matrix significantly increases the fracture strength, toughness and fatigue resistance of composites [19].

Study of the structure of opaque and lucent posts revealed that in lucent posts, diameter of fibers was more than that in opaque posts and the fiber-resin ratio in the opaque posts is higher than that in lucent posts. Thus, the number of fibers in each square millimeter of an opaque post diameter is twice the rate in a lucent post. Due to the higher concentration of fibers compared to resin, opaque posts have a whiter appearance [15].

In this study, translucent and opaque fiber posts were used; because based on the differences in the structure of these two posts, one is opaque and the other is lucent. Some studies have shown that degree of light transmission and subsequent polymerization of resin around posts are higher in lucent compared to opaque posts [12-14]. Thus, a post-resin monoblock is more likely to form in deeper areas when lucent posts are used and thus, they show higher fracture resistance than opaque posts.

In the current study, posts were not silanized before use because the manufacturer did not recommend to do so. Moreover, some studies did not report any difference in retention of silanized and non-silanized posts [12]. Also, silanization is more effective for posts subjected to surface treatments like chemical dissolution of resin component or mechanical retention by air abrasion. Thus, silane is used to increase wetting of the post with resin cements or composite in such cases [20]. The manufacturer of these posts claim that by applying a layer of bonding agent to the surface, a strong bond with composite is formed and this was confirmed in the current study as well because post-composite debonding did not occur in any case neither in the translucent nor in the opaque post groups. However, it should be noted that understudy teeth were manually compromised to simulate compromised teeth in the clinical setting and this may be responsible for composite-dentin debonding prior to composite-post bond failure. Many previous studies have reported weaker bond of resin cement to dentin than resin cement to post [21-23].

Since fibers are incorporated for reinforcement, posts with higher concentration of fibers are expected to have higher fracture resistance than those with less fiber content [24]. In processing of lucent compared to opaque posts, difference in fracture resistance may be attributed to the amount and orientation of fibers and the amount of resin resulting in semi-lucent view of these posts [15, 20].

In the current study, in group 1 with endodontically treated, but not compromised teeth, fracture resistance was significantly higher than that in other groups. This indicates the role of dentin and residual tooth structure in tooth resistance to fracture. In this group, all specimens could be restored after the fracture. In a study by Dietschi et al, on 4 types of prefabricated posts, it was found that teeth with sound structure had the highest resistance to fracture [24] and endodontic treatment per se has no effect on mode of fracture. Also, the mode of failure of endodontically treated teeth was similar to that of vital teeth. The results showed that even in non-compromised teeth, the weakest part of the teeth to load application was the cervical area.

The fracture resistance of compromised, non-reinforced teeth (group 2) was significantly lower than that of other groups. Thus, we may conclude that dentin elimination significantly affects fracture resistance of teeth and both methods of reinforcement used in this study may be applied to reinforce endodontically treated teeth with thin root walls. In this group, failures mostly occurred at the weakest part of the tooth and the mode of failure was in such way that the tooth was not restorable anymore. This indicates weakness of the tooth structure at the cervical area and emphasizes the need for reinforcement of teeth in this area.

Fracture resistance of group 3 (dual cure composite resin and translucent quartz fiber post) was significantly higher than that of group 2; which indicates that this method is effective for tooth reinforcement. However, the fracture resistance in group 3 was significantly lower than that of group 4 (opaque quartz fiber post). Studies on the mechanical properties of these two posts revealed that the flexural strength of opaque posts was higher than that of lucent ones [15]. However, 91.7% of specimens in translucent post group and 66.7% of specimens in opaque post group were restorable again after fracture. Thus, it appears that opaque posts are superior for reinforcement of compromised teeth; however, these posts also have a higher frequency of non-restorable fractures. Such difference in percentage of non-restorable fractures despite the higher fracture resistance question the superiority of opaque posts. Opaque posts tolerate high flexural loads and transfer these loads to the surrounding dentin during flexure resulting in dentin fracture; whereas, flexural loads in lucent posts are not high enough to cause fracture of the surrounding dentin. Due to flexure, cement-dentin bond fails and post-cement complex is extracted from the root canal without fracturing it. Previous studies have also demonstrated a reverse correlation between fracture resistance and percentage of restorable fractures [20].

Another point regarding the mode of failure in groups 3 and 4 is that in contrast to the claims of the manufacturers of quartz posts that by load application to a tooth treated with these posts, fracture occurs in the post rather than in the tooth structure, no fracture occurred in posts in groups 3 and 4 specimens. This may indicate that these posts have a modulus of elasticity higher than that of dentin. But, it should be noted that understudy teeth had lost significant amount of their dentin to simulate compromised teeth in the clinical setting and this might have affected the modulus of elasticity of dentin due to thickness loss resulting in bond failure at the composite-dentin interface without post fracture. The difference between our results and those of Luiz et al, in 2012 was attributed to the different types of posts and the amount of residual tooth structure. In the mentioned study, non-compromised teeth and dentin as the most important part conferring

resistance could have significantly contributed to the results [25].
By using lucent posts compared to opaque posts, we expected greater light to reach the root area for curing of dual cure composite and higher fracture resistance was expected in translucent post group; however, our results did not confirm these hypotheses because the distance of light source from the interface was equal in both groups and by increasing the distance, light intensity decreased. In other studies, no difference in curing of dual cure resin cement was observed in the middle and apical parts of the root between translucent and opaque posts [12, 20, 26-28].
To simulate compromised teeth, mature intact teeth were used. However, long-term clinical trials are required to be performed on immature teeth with different reinforcing protocols.

Conclusion

Within the limitations of this study, using dual cure composite and opaque quartz fiber post yielded higher mean fracture resistance in endodontically treated teeth with thin root walls compared to the use of dual cure composite and lucent quartz fiber post. However, since flexural strength of opaque posts is higher than that of lucent posts, non-restorable fractures have a higher frequency in this group.

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