Influence of Fiber-reinforced Composites on the Resistance to Fracture of Vertically Fractured and Reattached Fragments

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Abstract

Introduction: The aim of this *in vitro* study was to evaluate the fracture type and test the effects of 2 different fibers on fracture strength of roots with reattached fragments. The null hypothesis was that adding suitable fibers to the content of dual-cure adhesive resin cement increases the fracture resistance of reattached fragments under vertical forces. **Methods:** Root canals of 45 teeth were prepared, and the teeth were intentionally fractured into 2 separate fragments. Control groups (n = 7 each) consisted of unfractured teeth with instrumented and obturated or only instrumented root canals. The fractured teeth were divided into 3 groups (n = 15 each), and separated fragments were reattached by using (1) dual-cured resin cement (Clearfil SA), (2) dual-cured resin cement + polyethylene fiber (Construct), or (3) dual-cured resin cement + glass fiber (Stick-Net). Force was applied at a constant speed of 0.5 mm/min to the root until fracture. Mean load was recorded and analyzed statistically by using Kruskal-Wallis and Dunn tests (P = .05). Fracture types were analyzed by using χ^2 analysis with Yates correction. **Results:** Stick-Net demonstrated the lowest fracture resistance (P < .05), whereas Construct and Clearfil SA had similar fracture strengths (P > .05). The roots in the control group showed the highest fracture resistance. However, there was no statistically significant difference between the Construct, Clearfil SA, and control groups (P > .05). **Conclusions:** Separated fragments of vertically fractured teeth can be reattached by using a dual-cured resin or by adding polyethylene fiber (Construct). *(J Endod 2011;37:549–553)*

Key Words

Fiber-reinforced composites, fracture resistance, reattachment, vertical root fracture

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0099-2399/$ - see front matter

doi:10.1016/j.joen.2011.01.014

Endodontically treated teeth show a lower fracture resistance to intraoral forces. Post-endodontic tooth fractures usually occur as a result of weakened tooth structure, large dental caries, tooth wear, and physical changes in tooth structure caused by aging, vital pulp tissue loss, and endodontic therapy procedures (1). Overinstrumentation of root canals with excessive removal of dentin and the prolonged use of high concentrations of ethylenediaminetetraacetic acid and NaOCl canal irrigants might increase the risk for root fracture (2). In addition, irregularities of the external curvature and difficulty of using posts with the recommended lengths are important factors in the occurrence of root fractures (3).

A vertical root fracture (VRF) manifests as a complete or incomplete fracture line that originates at the apical end of the root and propagates coronally to stress direction (4). If a VRF occurs in a multi-rooted tooth, it can be conserved by resecting the involved root (5). On the other hand, a single-rooted tooth with a VRF usually has a poor prognosis, leading to extraction in 11%–20% of cases (6).

Although several methods have been used to preserve vertically fractured teeth, no specific treatment modality has been established (7–10). Successful short-term (7) and long-term (8–10) treatment outcomes have been reported for VRF reconstruction with adhesive resin cement (ARC). These studies (7–10) suggest an alternative approach to tooth extraction: extraction of the tooth with minimal damage to periodontal tissues, removing the root-filling material and granulation tissue with a sharp scalpel, extraoral bonding of the separated segments with an ARC, and intentional replantation of the tooth after reconstruction. However, resin adhesion to dentin has been reported to decrease with time *in vitro* (11) and *in vivo* (12) as a result of thermal, chemical, and mechanical stresses of the oral cavity. Therefore, the strength of the resin should be improved in some way. Adding suitable fibers to the content might be a solution (13). The placement of fiber-reinforced composites (FRCs) with adhesive resins might play a role in influencing interfacial bond failures to increase fracture strength of VRF-treated teeth (14). Fibers added to the polymer matrix might be woven polyethylene, glass, carbon, quartz, or silica and provide high-impact resistance, reduced vibration, increased fatigue resistance, and improved stress distribution (15).

Thus, the purpose of this study was to evaluate the fracture resistance of VRF-treated teeth on vertical forces restored by using (1) dual-cure ARC, (2) dual-cure ARC with a polyethylene fiber–based braid, or (3) dual-cure ARC with an E-glass fiber–based braid.

Materials and Methods

Specimen Preparation, Classification, and Control Group

Single, straight-rooted mandibular premolar teeth extracted for orthodontic reasons were selected and stored in 0.1% thymol until use. The age of patients was restricted to 15–20 years to minimize variations in dentin as a result of age that might affect the fracture patterns (16). Root length of the teeth was limited to 10 ± 1 mm. Root canals were prepared with nickel-titanium rotary instruments (ProTaper; Dentsply/Maillefer, Ballaigues, Switzerland) to the F3 file. The roots were embedded vertically in silicone mounts. The remaining dentin thickness of each root was measured mesiodistally and buccolingually by using calipers (17). Roots with a diameter of 4.2 ± 0.5 mm mesiodistally and 4.9 ± 0.5 mm buccolingually were selected for this study and randomly distributed into the groups. Roots in the control group 1 (n = 7) were obturated with a single F3 gutta-percha cone (Dentsply/Maillefer) and AH Plus sealer (Dentsply/Maillefer). Roots in the control group 2 (n = 7) were instrumented but not obturated.

Generating Vertical Root Fracture

Root fractures were generated in the vertical plane first in 76 teeth by a mechanical force with a hammer and tapered chisel, as described by Wenzel et al (18). The tapered chisel was placed in the center of the root canals, force was applied by the hammer, and VRFs were induced, separating the root into 2 fragments. Before root fracturing, each root was placed in a silicone mold and coded. However, 31 roots were excluded from the study. Seven roots had dissimilar crack lines. Two roots were fractured in the coronal, 8 in the middle, and 4 in the apical thirds. Ten teeth were separated into multiple pieces. Remaining 45 teeth were separated into 2 equal parts corono-apically and used in the study.

Preparation of Experimental Groups

The roots were divided into 3 groups (n = 15 each) according to the type of reinforcement: group 1: only dual-cure ARC (Clearfil SA; Kuraray Medical, Osaka, Japan); group 2: reinforced dual-cure ARC with Construct (Kerr Corp, Orange, CA); and group 3: reinforced dual-cure ARC with Stick-Net (StickTech Ltd, Turku, Finland).

The fibers used in this study had different properties in terms of base, surface, and thickness. Whereas Construct had woven preimpregnated silanized cold plasma-treated polyethylene fibers with 0.4-mm thickness, Stick-Net consisted of woven preimpregnated E-type glass fibers with 0.06-mm thickness. Stick-Net was cut into rectangular 10.0 × 2.0 mm pieces with scissors, and Construct (2 mm in width) was cut into 10.0-mm length pieces by using its special scissors.

Because Clearfil SA cement was a self-adhesive dual-cure resin cement, no bonding procedure was applied on root dentin. Construct was impregnated with Clearfil SA and covered until ready to use. Stick-Net was impregnated with a solvent-free resin (Clearfill SE Bond Primer; Kuraray Medical) for at least 10 minutes. When it became transparent, it was ready to use.

In group 1 (Clearfil SA), the halves of the fractured teeth were filled with Clearfil SA. Then, separated fragments were reattached by using finger pressure. Excess resin was removed with a periodontal curette, and teeth were placed into their individual silicone molds for proper polymerization.

In group 2 (Construct), the halves of the fractured teeth were lightly filled with Clearfil SA; 2 layers of impregnated Construct were then placed on the canals of both fragments, and separated fragments were reattached by using finger pressure. Excess resin was removed, and teeth were placed into their individual silicone molds for proper polymerization. Care was taken for fibers not to adhere on the side walls of the root canals, which might prevent proper reattachment.

In group 3 (Stick-Net), the halves of the fractured teeth were lightly filled with Clearfil SA; 2 layers of impregnated Stick-Net were then placed on both fragments, and teeth were reattached and polymerized as described above. All teeth were light-cured for 20 seconds (Elipar Free Light 2; 3M ESPE, St Paul, MN) for complete polymerization from the coronal direction. Samples were stored in a plastic dispenser with gauze at the bottom moistened with water, and dispenser was covered hermetically, generating a moist environment to prevent dehydration of teeth for 1 week.

Preparation of the Mechanical Test

Roots were removed from silicone molds and wrapped in 1 layer of plastic film (Reynolds Wrap; Reynolds Consumer Products Inc, Richmond, VA) to simulate the periodontal ligament (17). They were embedded in a block of self-curing acrylic resin (Meliodent; Bayer Dental, Leverkusen, Germany), exposing 2 mm of the coronal part (Fig. 1). The acrylic blocks were placed on the lower plate of a universal testing machine (Autograph AGS-J; Shimadzu, Tokyo, Japan), and a steel ball with a modified shape was mounted on the testing machine. The tip was lowered to contact the entire coronal surface of the roots and subjected to a gradually increasing axial force (0.5 mm/min), directed vertically parallel to the long axis of the roots. Force was applied to the root until it fractured. Fracture was defined as the point at which a sharp and instant drop greater than 25% of the applied force was observed. In addition, an audible crack was heard. Roots removed from the mount were visually inspected for fracture, first by eye and then by using a stereomicroscope (Leica DFC280; Leica Microsystems GmbH, Wetzlar, Germany) at a magnification of ×20 (Fig. 2). The location of re-fracture sites was marked for each specimen in all groups. If the root was re-fractured from the previously cemented site, it was labeled as original site. If the fracture site was different from the original, the code was new fracture site.

Data were analyzed by using the SPSS software (version 12.0; SPSS Inc, Chicago, IL). Because distribution was not normal and variances were not homogenous, the Kruskal-Wallis test was used. Once a significant difference was found, the Dunn test was carried out for pair-wise

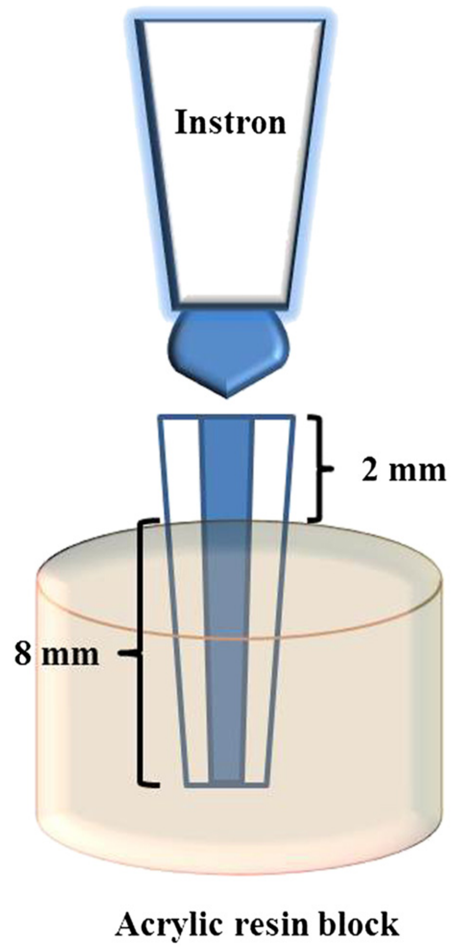

Figure 1. Diagrammatic representation of root segment for load to fracture test. The root was mounted vertically in 8 mm of cold-cure acrylic, exposing 2 mm of the coronal opening of the root for seating of the loading device of universal testing machine. By using a slowly increasing rate of 0.5 mm/min, the root segment was loaded to fracture.