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Evaluation of Fracture Resistance of Reattached Vertical Fragments Bonded with Fiber-reinforced Composites: An *in vitro* Study

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ABSTRACT

Aim: Aim of this *in vitro* study was to evaluate the resistance to fracture of vertically fractured and reattached fragments bonded with fiber-reinforced composites.

Materials and methods: Root canals of 45 teeth were prepared, and the teeth were intentionally fractured into two separate fragments. Control groups (n = 15 each) consisted unfractured teeth with instrumented and obturated. Fractured teeth were divided into three groups (n = 15) and were attached using (1) dual-cure resin cement (RelyX U100), (2) dual-cure resin cement and polyethylene fiber (Ribbond), (3) dual-cure resin cement and glass fibers (stick-net). Force was applied at a speed of 0.5 mm/min to the root until fracture.

Results and statistical analysis: Group 1 (RelyX U100 group) demonstrated lowest fracture resistance. Group 4 (control group) showed highest fracture resistance followed by group 2 (Ribbond group) and group 3 (Stick-Net groups). Statistically no significant difference was there between groups 2, 3 and 4.

Conclusion: Vertically fractured teeth can be treated by filling the root canal space with dual-cure adhesive resin cement or by adding polyethylene fiber or glass fiber to increase the fracture resistance of the reattached tooth fragments, an alternative to extraction.

Keywords: Dual-cure resin cement, Glass fiber, Polyethylene fiber, Reattached fragments, Vertically fractured.

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INTRODUCTION

Vertical root fracture is an untoward complication to root canal therapy that often calls for tooth extraction. 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. Over instrumentation of root canals with excessive removal of dentin and prolong use of high concentration of ethylene diamine tetraacetic acid and sodium hypochlorite canal irrigants might increase the risk for root fracture. 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.[1]

Depending on the nature of the stress factors, vertical root fractures (VRF) usually originates from the apical end of the root and propagate coronally or can originate from the cervical portion of the root with extension in an apical direction.

Several methods have been used to preserve vertically fractured teeth, but no specific treatment modality has been established. If a vertical root fracture occurs in a multirooted tooth, it can be conserved by resecting the involved root.[1] On the other hand, a single rooted tooth with vertical root fracture usually has a poor prognosis, leading to extraction in 10.9% of cases.[1,2]

Successful short-term and long-term treatment have been reported for vertical root fracture reconstruction with adhesive resin cement.[3] An ideal method would be extraction of the tooth with minimal damage to periodontal tissues, removing the root filling material and granulation tissue with a sharp scalpel and extraoral bonding of the separated segments with an adhesive resin cement, and intentional replantation of the tooth after reconstruction. However, resin adhesion to dentin has been reported to decrease with time as a result of thermal, chemical and mechanical stresses of the oral cavity.[1,4] Therefore, the strength of the resin should be improved in some way. Adding suitable fibers to the content might be a solution.

The placement of fiber-reinforced composites with adhesive resins might play a role in influencing interfacial bond failures to increase fracture strength of vertical root fractured treated tooth.[5]

Hence, the purpose of this study was to evaluate the fracture resistance of VRF-treated teeth on vertical forces restored by using (1) dual-cure adhesive resin cement (ARC), RelyX U100 cement, (2) dual-cure ARC, RelyX U100 cement and two layers of Ribbond (polyethylene fiber) and (3) dual-cure ARC, RelyX U100 cement and two layers of Stick-Net (glass fiber).

MATERIALS AND METHODS

60 single, straight-rooted mandibular premolar teeth extracted for orthodontic purpose were selected and stored in freshly prepared 0.1% thymol until use (to lower the permeability of the teeth). The age of patients was restricted to 15 to 20 years to minimize variations in dentin as a result of age that might affect the fracture patterns. Root length of the teeth was limited to 10 ± 1 mm. Root canals were prepared with nickel-titanium rotary instruments (ProTaper; Dentsply) to the F3 file. The roots were embedded vertically in silicon mold. The remaining dentin thickness of each root was measured mesiodistally and buccolingually by using calipers. 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 four groups.[1]

Root fractures were generated in the vertical plane in 45 teeth by a mechanical force with a hammer and tapered chisel. The tapered chisel was placed in center of the root canals, force was applied by the hammer, as described by Wenzel et al and VRFs were induced, separating the root into two equal fragments coronoapically.[6] Before root fracture, each root was placed in a silicon mold.[1]

The roots were divided into four groups (n = 15) according to the type of reinforcement. In group 1, only dual cure ARC (RelyX U100). Group 2 consisted of reinforced dual cure ARC (RelyX U100) with Ribbond and group 3 consisted of reinforced dual cure ARC (RelyX U100) with Stick-Net. Ribbond and stick net was cut into 10.0 mm length pieces and 2.0 mm width by using special scissors.

In group 1 (RelyX U100 Group), the two halves of the fractured teeth were filled with RelyX U100, and then separated fragments were reattached by using finger pressure. Excess resin was removed with a periodontal curette and teeth were placed in silicon molds.

In group 2 (Ribbond group), the two halves of the fractured teeth were lightly filled with RelyX U100 and 2 layers of impregnated Ribbond 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 in silicon molds.

In group 3 (Stick-Net Group), the two halves of the fractured teeth were lightly filled with RelyX U100 and two layers of impregnated Stick-Net 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 in silicon molds. All the teeth were light cured for 20 seconds for complete polymerization from the coronal direction.

In group 4 (control group) which was the control group consisted of unfractured teeth with instrumented and obturated with F3 Pro Taper gutta percha cones.

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.[1]

Preparation of the Mechanical Test

Roots were removed from silicon molds and wrapped in one layer of plastic film to simulate the periodontal ligament.[7] They were embedded in a block of self-curing acrylic resin, exposing 2 mm of the coronal part (Fig. 1). The acrylic blocks were placed on the lower plate of a universal testing machine and a steel ball with a modified shape was mounted on the testing machine (Fig. 2). 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. Roots were removed from the mount were visually inspected for fracture, using stereomicroscope (Olympus S2X12) at a magnification of 20×. The location of refracture sites was

Fig. 1: Acrylic resin block containing root segment exposing 2 mm of coronal opening of the root for seating of loading device of universal testing machine for load to fracture test

Fig. 2: Universal testing machine with acrylic resin block containing root segment

marked for each specimen in all groups. If the root was refractured from the previously cemented site, it was labeled as original site. If the fractured site was different from the original, the code was new fracture site.

Data was analyzed by using one way ANOVA and Tukey Post hoc test for vertical fracture resistance and Kruskal-Wallis and Mann-Whitney test for refractured site. The level of significance was set at $p = 0.05$.

RESULTS

Group 1 demonstrated lowest fracture resistance of 181.2 N followed by group 3 of 224.1 N and group 2 of 279.5 N fracture resistances. In group 4, the control group showed highest fracture resistance of 328.1 N. Group 1 showed statistically significant difference from all groups, except group 3. Statistically, there was no significant difference between groups 2, 3 and 4 (Table 1).

In group 2, all refracture occurred at 15 new sites, whereas there were four new refracture sites in group 1 and there was six new refracture sites in group 3. When the groups were compared according to the distribution of original or new fracture sites, there was statistical significant difference between groups (Table 2).

DISCUSSION

The choice of materials used in the restoration of endodontically treated teeth has changed from the exclusive use of very rigid material to material which have mechanical characteristics that more closely resemble dentin (composite resins and fiber posts). In this way, a mechanically homogenous unit can be created.[8]

Dual-cure adhesive resin cement RelyX U100 was used in this study, because it has an advantage, such as polymerization control, easy application and short curing time.

The reinforcing ability of the fibers is influenced by the orientation of the fibers, adhesion between the fibers and resin and impregnation of fibers with the resin.[9]

Fiber post is extensively used in combination with composite resins to directly restore endodontically treated teeth. The efficacy of silane coupling agents increases bond strength between fiber post and composite core restoration.[10]

In the present study, the reinforced fibers Ribbond and Stick-Net were impregnated in equal lengths by using different methods according to the manufactures instruction. Ribbond was directly impregnated with RelyX U100 and Stick-Net was impregnated by using a solvent-free resin before application. It was seen that group 2 (Ribbond group) showed higher fracture resistance when compared to group 3 (Stick-Net group) and group 1 (RelyX U100 group) (Graph 1). The decreased fracture resistance of group 3 (Stick-Net group) might be related to the residual monomer left inside the composite bulk.[1]

In the present study, it was seen that Ribbond group showed higher fracture resistance than Stick-Net group. These results are in accordance with the study conducted

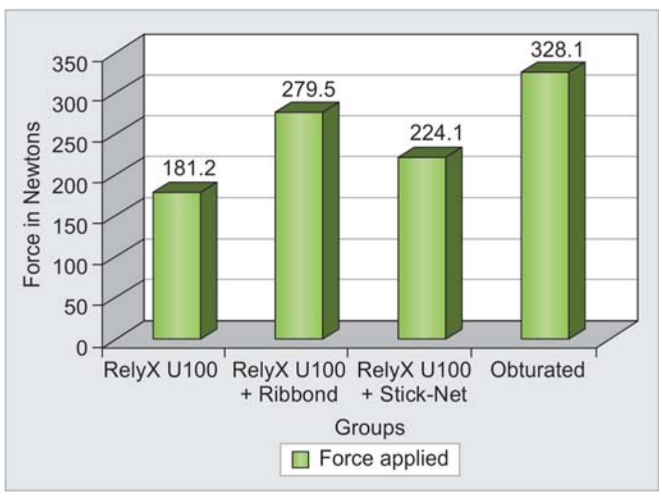
Table 1: Mean and standard deviation of vertical fracture resistance of various fibers tested

Sl. no	*N*	*Mean*	*Std. deviation*
1	15	181.264067	2.9049708
2	15	279.568667	0.8067826
3	15	224.098267	3.4331784
4	15	328.145000	1.0690450

$p = 0.05$

Table 2: The refracture sites

Groups	*Site*		*Total*
	Original site	*New site*	
1	11	4	15
2	0	15	15
3	9	6	15
Total	20	25	45

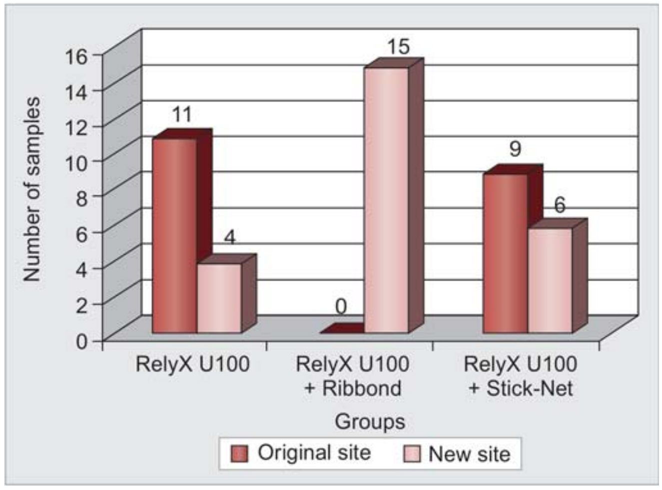


Graph 1: Mean vertical fracture strength of various fibers tested

by Pekka K. Vallittu et al stated that the mechanical properties of fiber composites depend on the direction of fibers in the polymer matrix. Continuous unidirectional fibers give the highest strength and stiffness for the composite only in the direction of the fiber orientation. Therefore, the reinforcing effect is anisotropic. Polyethylene fibers reinforce the polymer in all direction and the mechanical properties are isotropic.[11]

According to Van Heumen and Kreulen et al, fibers do reinforce resin composites. The flexural modulus was higher with the woven fiber architecture when compared to unidirectional fiber architecture. Hence, the architecture is more important than the type of fiber for flexural strength and flexural modulus.[12]

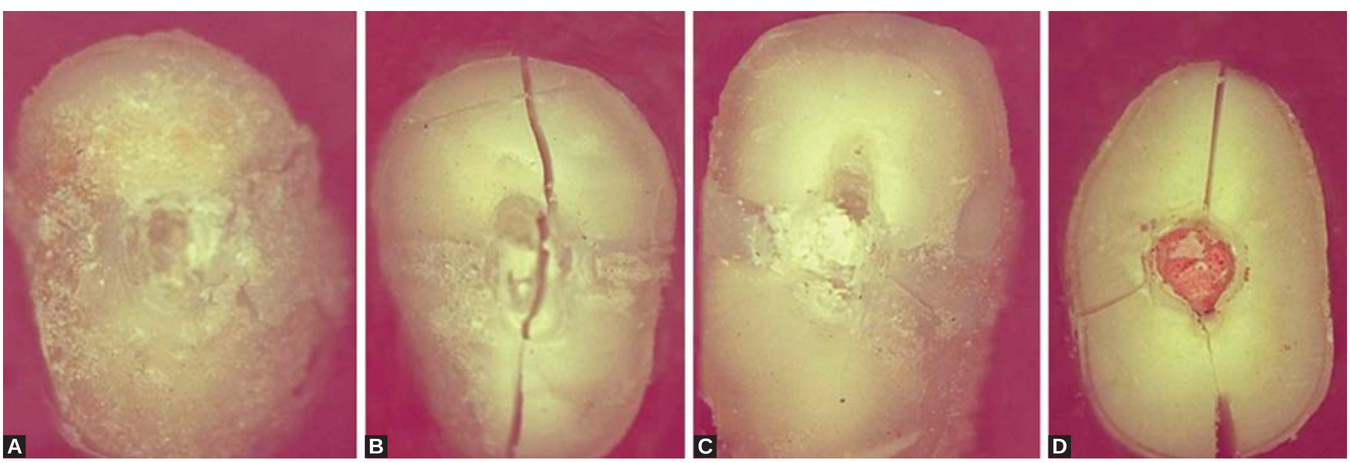
According to Karbharia and Strassler, fibers essentially act as staples that hold the adhered faces together, preventing further fracture. When these staples do not connect to the surfaces to be adhered, failure is seen. Group 2 (Ribbond group) successfully reinforced the restorations of VRF-treated roots, because all the refractures in the Ribbond group occurred at new sites (Figs 3A to D and Table 2). These staples hold the adhered faces together, preventing re-fractures at original sites. Ribbond samples usually showed good resistance to fracture, with minimal cracks on the surface, whereas in group 3 (Stick-Net) and group 1 (unreinforced groups), roots were distinctly separated (Fig. 3 and Table 2). Ribbond fibers had the capacity to adhere both to root dentin and resin, whereas Stick-Net fibers were clustered in the middle of the root canal space, leaving the adhesion responsibility to the resin alone. As a result of this, induced fracture site that occurred, was both in original and new site, in case of Stick-Net group and RelyX U100 group. There was statistical significant difference between the groups (Graph 2). The colonization of fibers in Stick-Net in the middle of root canal space caused a wedging effect, which reduced the resistance to fracture of Stick-Net group when compared to Ribbond group. This is in accordance with the study conducted by Sen and Yigit et al.[1,13]



Graph 2: Refracture sites

According to Sen and Yigit et al, fiber thicknesses play an important role in filling the root canal space in a condensed form. The more condensed the root canal obturation is the better the fracture resistance against VRFs.[1,14] Fibers used in this study were different in thickness, where in Ribbond was thicker and had more fibers by volume than roots reinforced with StickNet. This may have led to Ribbond group having better fracture resistance than the StickNet group.[1]

In the present study, it can be concluded that an alternative approach to extraction of vertically fractured teeth is extraction of teeth 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 adhesive resin cement or by adding polyethylene fiber and intentional replantation of the tooth after reconstruction.



Figs 3A to D: (A) sample representating group 1 showing refracture at original site, (B) sample representating group 2 showing refracture at new site, (C) sample representating group 3 showing refracture at original site, (D) sample representating the control group showing root fracture

CONCLUSION

Within the limitations of this investigation, the findings indicate that vertically fractured teeth can be treated by filling the root canal space with dual-cured adhesive resin cement or by reinforcing dual-cured adhesive resin cement with the addition of polyethylene fibers or glass fibers to increase the fracture resistance of the reattached tooth.

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