The effect of fibre insertion on fracture resistance of root filled molar teeth with MOD preparations restored with composite

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Abstract

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Aim To evaluate the effect of using flowable composite with or without leno woven ultra high modulus polyethylene fibre reinforcement on fracture resistance of root filled mandibular molars with mesio-occluso-distal (MOD) preparations.

Methodology Sixty sound extracted human mandibular molars were randomly assigned to five groups ($n = 12$). Group 1 did not receive any preparation. From groups 2 to 5, the teeth were root filled and MOD preparations were created. Group 2 remained unrestored. Group 3 was restored with a dentine bonding system (DBS; SE Bond, Kuraray, Japan) and composite resin (CR) (AP-X; Kuraray). In group 4, flowable composite resin (Protect Liner F; Kuraray) was used before restoring teeth with CR. In group 5, leno woven ultra high modulus polyethylene ribbon fibre (Ribbond, Seattle, WA, USA) was inserted into the cavities in a buccal to lingual direction and the teeth were then restored with DBS and CR. After finishing and polishing, the specimens were stored in 100% humidity at 37 °C for 1 day. Compressive loading of the teeth was performed using a universal testing machine at a crosshead speed of 0.5 mm min^{-1}. The mean load necessary to fracture the samples were recorded in newtons (N) and were subjected to analysis of variance (ANOVA) and Tukey *post-hoc* test.

Results The mean load necessary to fracture the samples in each group were (in N): group 1: 1676.75 ± 154.63^{a}, group 2: 376.51 ± 37.36^{b}, group 3: 733.23 ± 133.33^{c}, group 4: 786.48 ± 145.34^{c}, group 5: 943.63 ± 121.15^{d}. There were statistically significant differences between the groups annotated with different letters.

Conclusions (i) Use of flowable composite resin under composite restorations had no effect on fracture resistance of root filled molar teeth with MOD preparations, (ii) use of polyethylene ribbon fibre under composite restorations in root filled teeth with MOD preparations significantly increased fracture strength.

Keywords: flowable composite resin, fracture resistance, polyethylene ribbon fibre.

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Introduction

Compared to teeth with healthy pulps, root filled teeth are considered more susceptible to fracture as they possess reduced dentinal elasticity (Johnson *et al.* 1976), lower water content (Rosen 1961, Helfer *et al.* 1972), deeper cavities (Madison & Wilcox 1988) and substantial loss of dentine (Johnson *et al.* 1976, Assif & Gorfil 1994, Linn & Messer 1994, Assif *et al.* 2003). Root canal treatment should not be considered complete until the coronal restoration has been placed (Wagnild & Mueller 2002). Previous studies indicated that complete cast coverage (Goerig & Mueninghoff 1983, Hudis & Goldstein 1986), an indirect cast restoration covering the cusps (Reeh *et al.* 1989a), complex

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amalgam restorations (Starr 1990, Smales & Hawthorne 1997) or composite materials (Hernandez *et al.* 1994) can be used for final restorations. With recent advancements in adhesive technology and new and stronger composite materials, it is possible to create conservative, highly aesthetic restorations that are bonded directly to teeth. However, polymerization shrinkage remains a problem for extensive direct composite restorations (de Gee *et al.* 1993). As polymerization shrinkage is compensated by flow of composite (Davidson *et al.* 1984), a rigid bond between resin composite and tooth structures generates contraction stresses at the bonding interfaces (Feilzer *et al.* 1987, Kemp-Scholte & Davidson 1990). These stresses can be reduced by several methods. Dentine bonding agents are assumed to resist the contraction forces by forming a continuous hybrid layer between the restoration and tooth structure (Davidson 1996). Van Meerbeek *et al.* (1993) reported the hardness and elasticity of the resin–dentine bonding area using nanoindentation and concluded that the layer of collagen fibrils densely packed with resin may act as an inherent elastic buffering mechanism to compensate for the polymerization contraction of the restorative resin. One of the methods suggested for reducing debonding during polymerization shrinkage is the application of a low viscosity, low modulus intermediate resin between the bonding agent and restorative resin to act as an 'elastic buffer' or 'stress breaker' that can relieve contraction stresses and improve marginal integrity (Kemp-Scholte & Davidson 1990, Van Meerbeek *et al.* 1992). However, flowable composite did not produce gap-free resin margins in Black II slot cavities (Belli *et al.* 2001).

The development of fibre-reinforced composite (FRC) technology has increased use of composite resin materials in extensive preparations. FRC has been used in the laboratory for fabrication of single crowns, full and partial coverage fixed partial dentures (Valittu & Sevelius 2000, Edelhoff *et al.* 2001), fabrication of periodontal splints and chairside fixed partial dentures (Meiers *et al.* 1998, Belli & Ozer 2000, Meiers & Freilich 2001). FRC has been shown to possess adequate flexure modulus and flexural strength to function successfully in the mouth (Vallittu 1998, Freilich *et al.* 1999). A finite elemental stress analysis study also reported that FRC post and core systems provided more adequate restoration by protecting the remaining tooth tissue with its elastic modulus close to dentine when compared with the conventional rigid post–core systems (Eskitascioglu *et al.* 2002).

These new materials and techniques enable the practitioner to approach old problems from a different perspective and thereby achieve unique and innovative solutions. Although there are many studies with FRC in the literature, the effect of fibre insertion as a stress breaker within an extensive composite restoration has not been studied. In this study, it was hypothesized that creating an elastic layer under a composite restoration using a leno woven ultra high molecular weight (LWUHMW) polyethylene fibre ribbon and/or flowable composite would increase the fracture strength of endodontically treated teeth with mesio-occluso-distal (MOD) cavity preparations.

Materials and methods

Sixty freshly extracted human mature mandibular molar teeth with similar dimensions and without caries, abrasion cavities and injury from forceps or fractures were used. The teeth were cleaned of debris and soft tissue remnants and were stored in physiological saline at +4 °C until required. The 60 teeth were randomly assigned into five groups of 12 teeth each and were prepared as follows:

Group 1

This group did not receive cavity preparation or root canal treatment and were used as a control.

From groups 2 to 5: Access cavities were prepared using a high-speed bur and water spray and the canals were instrumented with K files to an apical size 35 using the stepback technique. Irrigation with 2 mL of 5.25% NaOCl preceded each file introduced into the canal. Following biomechanical preparation, canals were dried with absorbent paper points (Diadent Group International Inc., ChongJu City, Korea) and obturated with gutta-percha (Diadent Group International Inc) and AH Plus sealer (Dentsply De Trey, Konstanz, Germany) using cold lateral condensation. MOD cavities were prepared in the teeth down to the canal orifices so that the thickness of the buccal wall of the teeth measured 2 mm at the buccal occlusal surface, 2.5 mm at the cemento-enamel junction and 1.5 mm lingual occlusal surface, 1.5 mm at the cemento-enamel junction (Fig. 1). The teeth were then embedded in self-curing polymethylmethacrylate resin (Vertex; Dentimex Dental, Zeist, the Netherlands) to the level of the cemento-enamel junction.

Group 2

This group remained unrestored after MOD cavity preparation (Fig. 1).

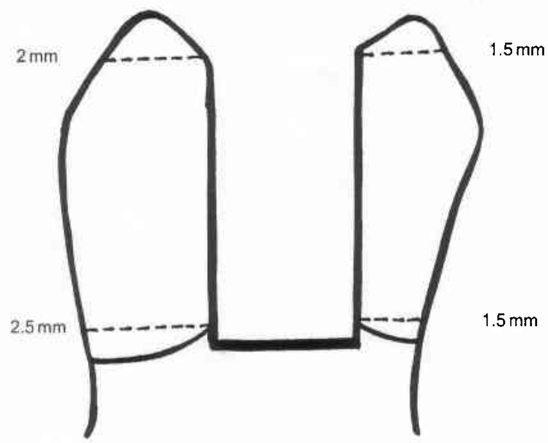

Figure 1 The schematic representation of MOD cavity in molar teeth.

Group 3

The cavities were cleaned and dried. After priming for 20 s (SE Primer; Kuraray, Tokyo, Japan) cavity surfaces were gently dried. SE Bond (Kuraray) was applied to the cavity surfaces and cured for 20 s. The cavities were then restored with a resin composite (Clearfil AP-X; Kuraray) using a bulk technique and cured for 40 s (Fig. 2).

Group 4

After priming and bonding procedures as in group 3, the cavity surfaces were coated with a layer of low viscosity resin composite (flowable composite resin, FCR) (Protect Liner F; Kuraray) and cured for 20 s. This low modulus liner was then covered with the same resin composite using a bulk technique as described in group 3 (Fig. 3).

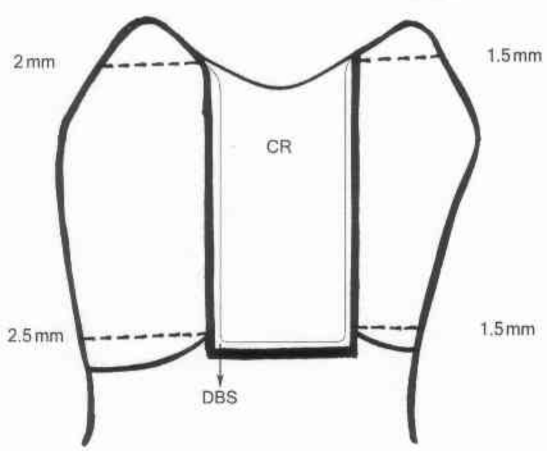

Figure 2 The restoration of teeth in group 3 with DBS and CR.

Group 5

After priming and bonding procedures as in group 3, the cavity surfaces were coated with flowable composite as in group 4. Before curing, a piece of LWUHMW polyethylene fibre (8 mm long, 3 mm width) (Ribbond; Ribbond Inc., Seattle, WA, USA) was cut and coated with adhesive resin. Excess material was removed and the fibre embedded inside the flowable composite in a buccal to lingual direction (Fig. 4). After curing for 20 s, the cavities were restored with composite as described above (Fig. 5).

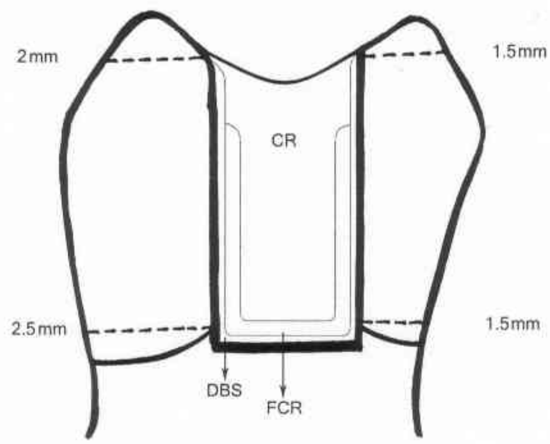

Figure 3 The restoration of teeth in group 4 with FCR, DBS and CR.

After storing in an incubator at 37 °C in 100% humidity for 24 h, the specimens were placed into a Universal Testing Machine (Instron, Canton, MA, USA) and loaded compressively at 0.5 mm min^{-1}. Compressive force was applied with a 5-mm diameter stainless steel bar. In all cases the force was applied to the occlusal surface of the restoration touching buccal and lingual cusps of the teeth. The force necessary to fracture each tooth was recorded in newtons (N) and the data were subjected to a one-way analysis of variance (ANOVA) and *post hoc* Tukey HSD test for the five experimental conditions.

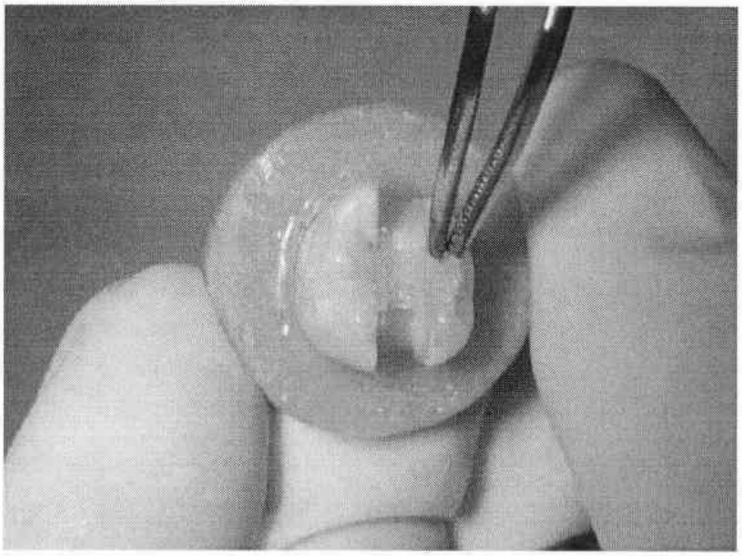

Figure 4 The application of 3-mm width polyethylene fibre with flowable composite resin from buccal to lingual direction.

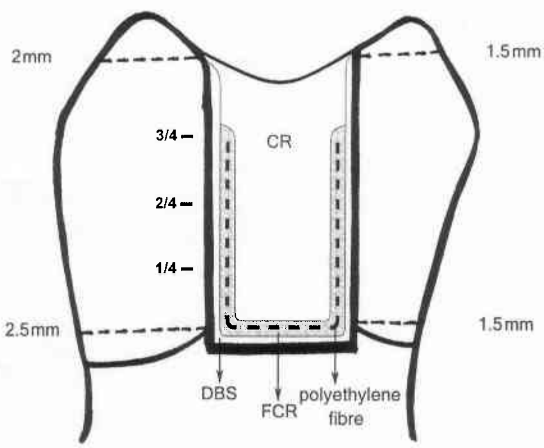

Figure 5 The schematic representation of teeth restored in group 5.

Results

The minimum, maximum and mean fracture resistance (N) and the standard deviation for each of the five experimental conditions are presented in Table 1. One-way ANOVA indicated that the fracture strength of group 1 was significantly higher than the other groups ($P < 0.05$). Restoring teeth with resin composite with or without a flowable composite lining (groups 3 and 4) increased fracture strength when compared with the nonrestored group (group 2) ($P < 0.05$). Use of flowable composite resin under the composite resin (group 4) did not increase fracture resistance in root filled teeth ($P > 0.05$). Inserting a piece of LWUHMW polyethylene fibre in a buccal to lingual direction under resin composite restoration (group 5) significantly increased fracture strength of molar teeth with MOD preparations ($P < 0.05$).

Discussion

Restoration of root filled molars is a challenge. Sound tooth structure removed during cavity preparation influences its strength and ability to resist loading (Mondelli *et al.* 1980, Larson *et al.* 1981, Reeh *et al.* 1989b). Preservation of tooth structure is important for protection against fracture under occlusal loads and for

Table 1 Minimum, maximum and mean fracture resistance (N) and the standard deviation for each of the five experimental conditions

Groups	Cavity	Restoration type	*n*	Minimum	Maximum	Mean ± SD
Group 1	Intact	intact teeth	12	1472.80	1932.50	1676.75 ± 154.63 a
Group 2	MOD	nonrestored	12	334.70	431.30	376.51 ± 37.36 b
Group 3	MOD	DBS + CR	12	513.80	886.00	733.23 ± 133.33 c
Group 4	MOD	FCR + DBS + CR	12	568.30	1064.60	786.48 ± 145.34 c
Group 5	MOD	polyethylene fibre + FCR + DBS + CR	12	733.70	1097.20	943.63 ± 121.15 d

DBS, dentine bonding system; CR, composite resin; FCR, flowable composite resin.
Similar letters indicate statistically similar values ($P > 0.05$).

its survival. The main factor endangering the survival of pulpless teeth is loss of dentine (Helfer *et al.* 1972, Carter *et al.* 1983, Greenfeld & Marshall 1983). During root canal treatment, there can be appreciable loss of dentine including anatomic structures such as cusps, ridges and the arched roof of the pulpal chamber. Dentine provides the solid base required for tooth restoration and so the fundamental problem is the increased quantity of sound dentine remaining to retain and support the restoration (Johnson *et al.* 1976, Assif & Gorfil 1994, Linn & Messer 1994, Assif *et al.* 2003).

Restoration of teeth is an important final step of root canal treatment. The purpose of a restoration is not only to repair the tooth, but also to strengthen the tooth and provide an effective seal between the canal system and mouth. In the present study, the strength of teeth was reduced significantly after cavity preparation, as shown in most previous studies (Mondelli *et al.* 1980, Gelb *et al.* 1986, Joynt *et al.* 1987, El-Sherif *et al.* 1988, Jagadish & Yogesh 1990). Reinforcement of the cavity with a restorative material is necessary to support the remaining tooth structure. Some studies have found that bonded composite restorations will strengthen a tooth when compared with amalgam (Trope *et al.* 1986, Reeh *et al.* 1989a, Hurmuzlu *et al.* 2003a) whereas others have been unable to show a difference (Joynt *et al.* 1987, Steele & Johnson 1999). Adhesive restorations better transmit and distribute functional stresses across the bonding interface to the tooth with the potential to reinforce weakened tooth structure (Hansen 1988). Trope *et al.* (1986) showed that the resistance to fracture of teeth increased significantly when MOD preparations were acid-etched before restoration with a composite resin. Hurmuzlu *et al.* (2003a) reported that teeth restored with packable composite resin had the highest resistance to fracture when compared with amalgam- or ormocer-based composite.

Polymeric adhesives for bonding to dentine are used in dentistry for a wide range of purposes. Applying most adhesive systems involves removing or modifying the smear layer and demineralizing the dentine surface. Current methods of dentine bonding use acids to demineralize the surface followed by the use of hydrophilic low molecular weight primers to penetrate the remaining collagen network. With the application of adhesive a resin-impregnated dentine hybrid layer results, and a micromechanical bond is formed with the dentine surface (Nakabayashi 1982, Duke 1993, Inokoshi *et al.* 1993).

When restoring with composite, many factors may effect the resistance of a tooth to vertical and/or cuspal fracture, such as cavity dimension (Mondelli *et al.* 1980, Purk *et al.* 1990) or restorative system utilized (Morin *et al.* 1984, Eakle 1986). An extensive cavity can be restored using a dentine bonding system (DBS) and a resin composite, however, the polymerization reaction of light cured composites leads to the development of higher stresses when the composite resin is bonded to the cavity walls. Joynt *et al.* (1987) suggested that the fracture resistance of premolar teeth with MOD cavity preparations restored with composite resin may increase if an incremental resin placement and curing method is used. Against the widely accepted belief that incremental composite placement results in reduced stress build-up at the tooth-restoration interface (Krejci *et al.* 1987). Versluis *et al.* (1996) reported that theoretically bulk fillings generate less volumetric shrinkage within identical cavity shapes. Although layering concepts have been described as mandatory when working with resin-based composites, the effect of layering technique was eliminated and bulk technique was used in this study to evaluate the stress modifying effect of flowable composite lining with or without fibre insertion.

High viscosity bonding agents may also provide a layer of substantial thickness that acts as a stress absorber (Alhadainy & Abdalla 1996) and flow of the composite may release contraction stresses (Takada *et al.* 1994, Uno *et al.* 1994). An advantage of bonding, coupled with composite core build-up, is the high bond strength to tooth structure and increased resistance to fracture (Hernandez *et al.* 1994). Hurmuzlu *et al.* (2003b) compared the effect of six different DBS on fracture resistance of teeth and showed that the type of DBS had no influence in the fracture resistance of teeth. In the present study, it was hypothesized that covering the surface with flowable composite or the addition of an LWUHMW polyethylene fibre before restoring teeth with resin composite would provide an increase in fracture strength. This was theorized on the concept that the presence of the glass or polyethylene network would create a change in the stress dynamics at the restoration/adhesive resin interface. This hypothesis was demonstrated in the LWUHMW polyethylene fibre group as inserting a piece of fibre in a buccal to lingual direction significantly increased fracture strength of root filled molar teeth with MOD preparations. The elastic modulus of polyethylene fibre with adhesive systems was previously measured by Eskitascioglu *et al.* (2002). The higher modulus of elasticity and lower flexural modulus of the polyethylene fibre might have a modifying effect on how the interfacial stresses are developed along the restoration/tooth interface.

With the concept that the presence of the glass or polyethylene network would create a change in the stress dynamics at the enamel/composite/adhesive interface, Meiers *et al.* (2003) tested shear bond strength of composite to flat bovine enamel surfaces with four different fibre reinforcement materials. Although three of the four materials had no effect on shear bond strength, one of the materials tested (Connect; Kerr, Orange, CA, USA) improved shear bond strength. As a result they concluded that the higher modulus of elasticity and lower flexural modulus of the polyethylene fibre may have a modifying effect on how the interfacial stresses are developed along the etched enamel/resin boundary. Haller *et al.* (1991) reported a reduction of the bond strength to dentine of some adhesive systems when applied to 3D cavities in comparison with flat surfaces. In the present study, MOD preparations were used. The results may be different if flat surfaces were used. On the contrary, lining the cavity surfaces with flowable composite did not change the fracture strength. The thickness of the elastic layer created by flowable composite might not be enough to compensate contraction stresses inside an MOD preparation or the physical properties of an LWUHMW polyethylene fibre might have a positive effect on distributing stress along the restoration-tooth interface.

This study was carried out in *in vitro* conditions and the test was performed 24 h after restoration. The thermal, chemical and physical stresses that the restoration could be subjected to over a longer period *in vivo* may adversely affect the results, therefore further investigation is necessary to predict the *in vivo* behaviour of this type of restoration.

Conclusions

Within the limits of this study, it can be concluded that:

1 MOD cavity preparation reduced fracture resistance of root filled teeth.

2 Use of flowable composite under composite restoration had no effect on fracture resistance of root filled molar teeth that had been restored with composite resin.

3 Inserting an LWUHMW polyethylene ribbon fibre in root filled molar teeth with MOD preparations significantly increased fracture strength.

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