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Fracture resistance of the buccal cusps of root filled maxillary premolar teeth restored with various techniques

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Abstract

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Aim To compare the cusp fracture resistance of teeth restored with composite resins and two post systems.

Methodology Eighty extracted single-rooted human maxillary premolars were randomly assigned to eight groups ($n = 10$). Group 1 (control) did not receive any preparation. From groups 2 to 8, the teeth were root filled and mesio-occluso-distal (MOD) cavities were prepared. Group 2 remained unrestored. Group 3 was restored with packable resin composite using a single-step adhesive. Group 4 was restored with packable resin composite using a single-step adhesive and a thin layer of flowable resin composite. Group 5 was restored with packable resin composite using a total-etch two-step adhesive. Group 6 was restored with ormocer resin composite using a total-etch two-step adhesive. Group 7 was restored with an endodontic glass fibre post and hybrid resin composite using a total-etch two-step adhesive. Group 8 was restored with an endodontic zirconium post and hybrid resin composite using a total-etch two-step adhesive. The teeth were then mounted in a universal testing machine, the buccal cusp loaded (30°) until fracture, and the data analysed statistically.

Results Group 1 had the greatest fracture resistance, and group 2 the poorest. Groups 5–8 had significantly greater ($P < 0.05$) fracture resistance than groups 3 and 4. No significant differences were found between groups 3 and 4, or amongst groups 5–8 ($P > 0.05$).

Conclusions For root filled maxillary premolars with MOD cavities, adhesive resin composite restorations, with and without glass and zirconium posts, increased the fracture resistance of the buccal cusps. A total-etch two-step adhesive increased significantly fracture resistance more than a one-step adhesive. For the one-step adhesive, an additional layer of flowable resin composite did not enhance fracture resistance.

Keywords: cusp fracture resistance, endodontically restored premolars.

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Introduction

Cusps deform due to occlusal forces and lateral excursions, even though intact teeth are stiff (Jantarat *et al.* 2001), and the stresses generated during friction between occluding surfaces are mainly absorbed in the periodontal ligament (Douglas *et al.* 1985). Caries, trauma and the excessive removal of dentine during root canal treatment produce a substantial reduction in tooth strength and increase cuspal fracture under occlusal load (El-Badrawy 1999, Mannocci *et al.* 2002). The association between extensive restorative procedures and high occlusal loads, combined with lateral excursive contacts, leads to a higher susceptibility to fracture (Sakaguchi *et al.* 1991). Accordingly,

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root filled teeth are considered especially at risk (Jantarat *et al.* 2001). Thus, root canal treatment should not be considered complete until the final coronal restoration has been placed (Wagnild & Mueller 2002). An optimal final restoration for a root filled tooth maintains aesthetics and function, preserves remaining tooth structure, and prevents microleakage (de Oliveria *et al.* 1987).

A number of dentine bonding systems have been developed recently. These bonding systems were introduced to increase the bond strength of composite resins to dentine, as well as to produce leak-free restorations. It is assumed that these bonding systems improve the adhesive capability and bonding strength of resins to tooth structure by promoting penetration, impregnation and entanglement of the coupling agents into dentinal substrates where they polymerize *in situ* and create zones of resin-reinforced dentine layers (Nakabayashi 1992). Hernandez *et al.* (1994) and Hurmuzlu *et al.* (2003a) reported that resistance to fracture of root filled premolar teeth with dentine bonding systems was increased significantly.

As many root filled teeth suffer extensive defects, clinicians often suppose that an endodontic post is necessary to supply adequate retention to the core and restoration (Schwartz & Robbins 2004). For this reason, several post and core systems have been described in the literature. Posts can be cast in a precious alloy, or prefabricated posts made of stainless steel, titanium, or precious alloy can be used. The construction of post and core castings is relatively more time consuming and demands extra clinic and laboratory resource (DeSort 1983). Prefabricated posts are rapid, inexpensive and simple (Kern *et al.* 1984), but they do not take into account the individual shape of the root canal and their adaptation is not ideal (Chan *et al.* 1993).

The post core systems include components of different rigidity. Because, the more rigid component is able to resist forces without distortion, stress is expected to be transferred to the less rigid substrate. The difference between the elastic modulus of dentine and a post material may, therefore, be a source of stress for the root structures. Recently, the preference of dentists has changed from very rigid materials to those which closely resemble dentine to create a mechanically homogenous unit. Research for new, less rigid materials resulted in the marketing of new materials, such as carbon and glass fibre posts (Sidoli *et al.* 1997, Stewardson 2001, Akkayan & Gulmez 2002, Mannocci *et al.* 2002, Yoldas & Alacam 2005). Further, a zirconium post which is much stiffer than metal posts (Asmussen *et al.* 1999), can be used for aesthetic reasons.

This *ex vivo* study was conducted to compare the cusp fracture resistance of root filled maxillary premolars restored with composite resins and two post systems.

Materials and methods

The materials used in this study and their composition are showed in Table 1. Eighty freshly extracted human mature maxillary premolars 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 teeth were then randomly assigned into eight groups of 10 teeth each and were prepared as follows.

Group 1

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

From groups 2 to 8: endodontic access cavities were prepared using a water-cooled diamond bur in a high-speed handpiece and the pulp tissue was removed with barbed broaches. A size 15 K-file was introduced into each canal until it could be seen at the apical foramen. The working length was determined by subtracting 1 mm from this length. The canals were prepared to a size 50 K-file at working length with a stepback technique. The coronal portion of each canal was enlarged with Gates Glidden burs (Mani Inc., Tochigi, Japan) sizes 1–3 in a slow-speed contra-angle handpiece. The canals were irrigated with 3 mL of 2.5% NaOCl solution using a 27-gauge endodontic needle after the use of each instrument. Following biomechanical preparation, the canals were irrigated with 3 mL of 15% EDTA (Pulpdent, Watertown, MA, USA) solution for 30 s to remove smear layer. Final canal irrigation was accomplished with 3 mL of 2.5% NaOCl solution. Canals were dried with absorbent paper points and filled with gutta-percha (Sure-Endo, Seoul, Korea) and AH 26 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 occlusal surface and 3 mm at the cemento-enamel junction (Trope *et al.* 1986, Hernandez *et al.* 1994, Hurmuzlu *et al.* 2003b) (Fig. 1). The dimensions of the cavities were

Table 1 The materials used and their composition

Material	Batch number	Composition	Manufacturer
Post			
Cosmopost	5662896-G-07511	ZrO_2, HfO_2, Y_2O_3 > 99	Ivoclar, Schaan, Liechtenstein
Ever Stick	2050630-P3-019	PMMA, Bis-GMA, E-glass, 60 vol.%	Stich Tech, Turku, Finland
Composite resin			
Admira (Ormocer)	450742	Monomer: Bis-GMA, di-UDMA, TEGDMA, Filler (78 wt%, 56 vol.%): Ba-Al-B-silicate glass (90%, *c.* 0.7 μm), SiO_2 (10%), three-dimensionally curing anorganic–organic copolymers, additive aliphatic and aromatic dimethacrylates	Voco, Cuxhaven, Germany
Solitaire 2 (Packable)	R-235602	Monomer: Bis-GA, UDMA, TEGDMA, Filler (75 wt%, 58 vol.%): Ba-Al-B-fluorosilicate glass (mean diameter 0.7 and 5 μm), porous SiO_2 glass	Heraus Kulzer, Wehrheim, Germany
Renew (Hybrid)	0400003469	Monomer: Bis-EMA, dimethacrylate, Filler (59 wt%, 73 vol.%): Bariumglass, silica, titanium dioxide	Bisco, Schaumburg, IL, USA
Flowline (Flowable)	010032	Monomer: Bis-GMA, TEGDMA, Filler (62 wt%, 41 vol.%): Ba-Al-B-fluorosilicate glass, pyrogenic SiO_2. Average particle size 0.7 μm	Heraus Kulzer, Wehrheim, Germany
Bond			
Admira Bond	351777	Bis-GMA, HEMA, organic acids complex, three-dimensionally curing anorganic–organic copolymers, acetone	Voco, Cuxhaven, Germany
Gluma Comford Bond	010065	UDMA, HEMA, 4-META, polyacrylic and dicarboxylic acids, ethanol/water	Heraus-Kulzer, Wehrheim, Germany
One-Step Bond	0400003390	Bis-GMA, HEMA, BPDM, initiator, and acetone	Bisco, Schaumburg, IL, USA
iBond	010075	4-META, UDMA, glutaraldehyde, acetone, water	Heraus-Kulzer, Wehrheim, Germany

UDMA, urethane-dimethacrylate; HEMA, hydroxyethyl methacrylate; Bis-GMA, bisphenol-A-glycidyl methacrylate; BPDM, biphenyl dimethacrylate; TEGDMA, triethyleneglycol dimethacrylate; Bis-GA, bisphenol-A glycidylpolhacrylate; 4-META, 4-methacryloxyethyltrimellitic acid; Bis-EMA, ethoxylated BisGMA.

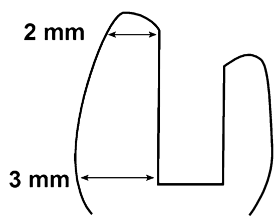

Figure 1 The schematic representation of MOD cavity in premolar teeth.

measured with a calliper (VIS, Warsaw, Poland) at 0.1 mm sensitivity.

Group 2

This group remained unrestored after MOD cavity preparation.

Group 3

The cavities were cleaned and dried. Two additional layers of iBond (Heraeus Kulzer, Wehrheim, Germany), were applied onto the cavities according to the manufacturer's instructions and light-cured for 20 s. The cavities were then incrementally restored with Solitaire 2 (Heraeus Kulzer). Each increment was cured for 40 s from occlusal surface using a curing unit (Hilux; Benlioglu Dental Inc., Ankara, Turkey). To standardize the curing distance, the tip of the polymerization unit was applied to the occlusal surface of the teeth. The intensity of light was at least 500 mW cm^{-2}. Verification of the unit light intensity output was checked with the digital read-out light meter available with the unit every 10 samples.

Group 4

Two additional layers of iBond were applied onto the cavities in accordance with the manufacturer's instructions and light-cured for 20 s. The cavity surfaces were coated with a layer (approximately a 1 mm thickness) of Flowline (Heraeus Kulzer) and cured for 20 s and then further restored with Solitaire 2 using a incremental technique and cured for 40 s.

Group 5

The cavities were total-etched for 15 s, rinsed and air dried with a brief jet of compressed air leaving the surface moist. Gluma Comford Bond (Heraeus Kulzer) was applied onto the cavity and light-cured for 20 s and the teeth then restored incrementally with Solitaire 2 and cured for 40 s.

Group 6

The cavities were total-etched for 15 s rinsed and air-dried with a brief jet of compressed air leaving the surface moist. Admira Bond (Voco, Cuxhaven, Germany) was applied onto the cavity surface in accordance with the manufacturer's instructions. The bonding agent was gently dried with an air syringe, followed by light curing for 20 s. Admira (Voco) was added into cavities in increments, each approximately 2 mm thick; each increment was cured for 40 s.

Group 7

Preparing the roots
The post spaces were prepared 24 h after completing the root canal and MOD cavity preparations. Gutta-percha was removed from the filled canals with Peeso drills (Dentsply Maillefer, Ballaigues, Switzerland) to a depth of 8 mm as measured from the cavity floor. The post spaces were prepared with the Ever Stick Post System's special preparation drill (Stich Tech Ltd, Turku, Finland). The root canal walls were etched with 35% phosphoric acid (Scotchbond Etchant; 3M Dental Products Division, St Paul, MN, USA) for 15 s, washed with water spray, and gently air-dried.

Preparing the posts
Similar sizes of posts in the various post systems were selected. The size of the glass fibre posts (Ever Stick Posts; Stick Tech Ltd) was 15 × 1.50 mm. Each post was fitted inside the root canal and light cured for 20 s. Then it was removed and light cured again on all sides for 40 s when it was removed. Then, on the coronal section of each post a mark was made on a distance 11 mm from its apical end. The coronal 3 mm of the post remained outside the root canal. A circumferential line was drawn around the posts at this level, and all posts were sectioned horizontally with a water-cooled diamond fissure bur. This standardized the post lengths and established similarity between post diameters of the tapered designs. The surface of the post was coated with light curing resin adhesive (Stick Resin). The light curing resin adhesive and post were then inserted into the post space, consecutively. After removal of the excessive resin adhesive, it was light cured for 10 s.

Cementing the posts
All posts were cemented into the root canal with Single Bond (3M Dental Products Division, St Paul, MN, USA) and Panavia F (Kuraray, Osaka, Japan) according to the manufacturer's guidelines, including ED primer (Kuraray). After the material had dried, excess was removed with a dry paper point and light cured for 60 s. Panavia F cement was mixed for 30 s and applied to the canal walls with the use of a periodontal probe. A thin layer of cement was also placed on the post surface before inserting slowly into the canal. Excess cement was removed, and the remainder was light-polymerized for 40 s.

The cavities were total-etched for 15 s rinsed and air dried with a brief jet of compressed air leaving the surface moist. Two additional layers of One-Step Bond (Bisco; Schaumburg, IL, USA), was applied on the cavities according to the manufacturer's instructions and light-cured for 20 s. The cavities were then restored with Renew (Bisco, Schaumburg, IL, USA) using an incremental technique and cured for 40 s.

Group 8

Post spaces were prepared with the Zirconia Post System's special preparation drill. The size of the Zirconia Posts (Cosmopost; Ivoclar, Schaan, Liechtenstein) was 20 × 1.70 mm. On coronal section of each post a mark was made at a distance 11 mm from its apical end. A circumferential line was drawn around the post at this level, and all posts were sectioned horizontally with a water-cooled diamond fissure bur. This standardized the post lengths and established similarity between post diameters of the tapered designs. All posts were etched with 9.5% hydrofluoric acid for 2 min. The procedures for cementing the post and placing the resin composite were identical to that of group 7.

The restored teeth were stored in a incubator at 37 °C in 100% humidity for 48 h. All specimens were thermocycled for 500 cycles between 5 and 55 °C using a dwell time of 30 s. Copper rings, 25 mm in length and 10 mm in diameter, were filled with a self-curing polymethylmethacrylate resin (Vertex; Dentimex Dental, Zeist, The Netherlands), and the teeth were placed into the resin to the level of the cemento-enamel junction. The copper rings with the teeth were then placed into a Universal Testing Machine (Instron, Canton, MA, USA). The buccal walls of the teeth were then subjected to a slowly increasing force (1 mm min^{-1}) at the junction of the buccal cusp and the filling material. The load was applied at the middle of the mesiodistal width of the buccal cusp and at a 150° angle to the long axis of the teeth; the fracture load for each tooth was recorded. Statistical analysis of the data was accomplished using Kruskall–Wallis test and Pairwise comparisons (significance 0.05) were made.

Results

The minimum, maximum and mean fracture resistance (N) and standard deviation for each of the eight experimental groups are presented in Table 2.

Group 1 had the greatest fracture resistance; group 2 the lowest. Groups 5–8 had significantly greater ($P < 0.05$) fracture resistance than groups 3 and 4. No significant differences were found between groups 3 and 4, and amongst groups 5–8 ($P > 0.05$).

Discussion

Restoration of teeth is an important final step of root canal treatment. Reeh *et al.* (1989) and Steele & Johnson (1999) demonstrated that endodontic access cavity preparation in an otherwise intact tooth had a minimal effect on the strength of the tooth. Steele & Johnson (1999) also reported that the mean fracture strength for unrestored teeth with MOD preparations was 50% less than that of unaltered premolar teeth.

Several factors have been reported to affect the fracture resistance of teeth including: the amount of tissue lost and its location (Reeh *et al.* 1989, Panitvisai & Messer 1995), the magnitude and duration of the load (Jantarat *et al.* 2001), tooth type, direction of applied load, slope of the cuspal inclines (Panitvisai & Messer 1995). Therefore, the measurement of crown deformation associated with caries removal and cavity preparation procedures is important in operative dentistry to optimize cavity designs and subsequent restoration.

In this study, the applying force speed was 1 mm min^{-1}. Espevik (1978) stated that lower speeds are accompanied by greater plastic deformation and, thus, higher fracture resistance measurements will be recorded.

In recent years, the choice of materials used for restoration of root filled teeth has changed from the exclusive usage of very rigid materials to materials with mechanical characteristics more like dentine (Eskitascioglu *et al.* 2002). In this study restoring teeth with composite resins (total etch system), with and without posts, increased fracture strength when compared with composite resin (one bottle self etch system) with or without flowable resin. Micromechanical retention is considered the most important mechanism for bonding to dentine (Hansen 1988). It has been stated that adhesive restorations transmit and distribute functional stresses across the bonding interface to the tooth better with the potential to reinforce weakened tooth structure (Eakle 1986, Hansen 1988). Several studies have found that the resistance fracture of the teeth increased significantly when MOD cavities in the teeth were acid-etched prior to the restoration with a composite resin (Trope *et al.* 1986, Ausiello *et al.* 1997, Hurmuzlu *et al.* 2003b).

Laboratory testing of ormocer resin composite suggests a significantly lower wear rate compared with hybrid composites (Watts & Marouf 2000). On the other hand, Cattani-Lorente *et al.* (2001) found that the shrinkage of ormocer resin composite was equal to that of hybrid composites despite having less filler

Table 2 Minimum, maximum and mean fracture resistance (N) and the standard deviation (SD) for each of the eight groups

Groups	Cavity	Restoration type	*n*	Minimum	Maximum	Mean ± SD
Group 1	Intact	Intact teeth	10	456.00	1162.00	732.20 ± 61.36[a]
Group 2	MOD	Unrestored	10	94.00	169.00	119.20 ± 7.87[b]
Group 3	MOD	S2 + IB	10	281.00	391.00	321.50 ± 12.10[c]
Group 4	MOD	S2 + FL + IB	10	224.00	367.00	279.30 ± 14.27[c]
Group 5	MOD	S2 + GCB	10	320.00	770.00	407.50 ± 39.04[d]
Group 6	MOD	A + AB	10	270.00	729.00	477.70 ± 52.01[d]
Group 7	MOD	EP + R + OSB	10	319.00	708.00	498.00 ± 36.66[d]
Group 8	MOD	CP + R + OSB	10	392.00	616.00	504.70 ± 26.48[d]

The same superscript letters indicate statistically no significant values ($P > 0.05$). S2, Solitaire 2; iB, ibond; FL, Flowline; A, Admira; AB, Admira Bond; GCB, Gluma Comfort Bond; EP, Ever Stick Post; R, Renew; CP, Cosmo Post; OSB, One-Step Bond.

content. The authors attributed their findings to the difference in the resin matrix of ormocer resin composite. As a result, it was suggested that the advantages of ormocer resin composite include low shrinkage, high abrasion resistance, biocompatibility, and protection against caries (Hickel *et al.* 1998). According to this study, ormocer resin composite increased fracture strength in line with other composite resin groups.

Studies have evaluated the fracture resistance of root filled teeth restored with different posts. Several authors reported that high fracture resistance was obtained when the elastic moduli of the post and dentine were compatible with each other (Ferrari *et al.* 2000, Cormier *et al.* 2001, Akkayan & Gulmez 2002, Maccari *et al.* 2003). The fracture values of composite resin (self etch) with or without flowable resin may be associated with the one bottle self-etching adhesive iBond single application system. It is also possible that the low bond strength recorded with iBond indicates that the single component adhesive cannot yet fulfil all requirements for the production of effective adhesive layers, probably because they fail to penetrate the smear layer (Bouillaguet *et al.* 2001). In addition, iBond contains desensitizing agents that may reduce the bond strength of dentine bonding adhesives substantially (Pashley *et al.* 1993, Seara *et al.* 2002). In group 4 lining the cavity surfaces with flowable composite resin did not alter the fracture strength. This might be due to the inferior mechanical properties of flowable composites compared with hybrid and packable composite resin. However, Belli *et al.* (2005) found that use of flowable composite resin under composite restorations had no effect on fracture resistance of root filled teeth with MOD preparations.

In the mouth, the load capability of root filled teeth is influenced by the number of adjacent teeth (Caplan *et al.* 2002), the number of occlusal contacts (Iqbal *et al.* 2003), tooth position in the dental arch (Sorensen & Martinoff 1984), crown placement Mannocci *et al.* 2002), type of abutment (Decock *et al.* 1996), apical status (Eckerbom *et al.* 1991), collagen degradation (Ferrari *et al.* 2004), intermolecular cross-linking of the root dentine (Gutmann 1992), and crucially by the amount of lost tissue (Bolhuis *et al.* 2001, 2004, 2005, Fernandes & Dessai 2001). The present study was carried out *ex vivo* and the test was performed 48 h after restorations were placed. Thermocycling was performed to simulate moisture and temperature changes encountered intraorally. However; clinical trials are necessary to validate the results.

Conclusion

For root filled maxillary premolars with MOD cavities, adhesive resin composite restorations, with and without glass or zirconium post, increased the fracture resistance of buccal cusps. When a total-etch two-step adhesive was used this increase was significantly greater than a one-step adhesive. For the one-step adhesive an additional layer of flowable resin composite did not enhance the fracture resistance.

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