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RESEARCH ARTICLE

FRACTURE RESISTANCE OF MOLARS WITH DIFFERENT DIRECT CUSPAL COVERAGE RESTORATIONS

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ABSTRACT

Objective: The purpose of this study was to compare the fracture resistance of four different restorations.
Method: Thirty-two extracted human upper molar teeth of similar size and free of caries were used. These were randomly divided into four groups of eight specimens each. Teeth in Group I were restored using a hybrid composite resin (Filtek Z250, 3M ESPE, USA) with polyethylene fiber (Ribbond THM, USA). In Group II, an amalgam with self-threading pins was used. Teeth in Group III were restored using a hybrid composite resin with a self etch adhesive (G bond, Japan). The final restoration used amalgam and a meta adhesive system (Panavia $F_{2.0}$, Kuraray, Japan) (Group IV). Each specimen was loaded in compression at a 90^{o} angle in a universal testing machine (Instron, Corporation, USA) with a cross head spread of 0.5 mm/min. Data were analyzed using one-way ANOVA and the Duncan test for fracture resistance.
Result: Group IV exhibited the lowest fracture resistance ($p<0.05$). Although group III exhibited the highest resistance, there was no statistically significant difference among group I, II and III ($p>0.05$).
Conclusion: The results showed that a bonded composite restoration should be first choice for cuspal replacement.

INTRODUCTION

Preservation of remaining tooth structure is of paramount importance, because all of restorations rely upon the strength and integrity of remaining tooth structure for retention. The choice of restoration will depend on remaining tooth structure, with direct restorations limited to teeth with substantial coronal dentine (Taha *et al.,* 2011). Removal of tooth structure by cavity preparation has been shown to weaken teeth and to increase their susceptibility to fracture (Eakle *et al.,* 1992). Bonding restorative material to the tooth structure can reduce or even eliminate microleakage. In addition chemical bond between the restorative material and dentine enhances retention, the bond preserves tooth structure. Protection of the remaining tooth substance may be as important as retention of the restorative material in badly worn teeth. A balance must therefore be established between the factors that increase retention and those that preserve dentin (Sen *et al.,* 2002).

Composite resins have esthetic properties and combine the ability to preserve and reinforce sound tooth structure (Deliperi and Bardwell 2006). Composite resin restorations bonded to etch enamel increase the fracture resistance of teeth (Eakle *et al.,* 1992). Amalgam has been the most widely used dental restorative material for the restoration of posterior teeth due to straightforward handling procedures, well tested material properties, and clinical success which has been documented for over a century despite esthetic shortcomings. Low material price and rapid application also make it the most economic dental filling material (Celik *et al.,* 2010). Conventionally placed amalgam restores tooth contours and occlusion, but has no adhesion to tooth structure and thus does not strengthen the prepared tooth. A restoration with the durability of amalgam and that increases the fracture resistance of the tooth by bonding cusps and restoration together is most desirable (Eakle *et al.,* 1992).

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Bonding has been shown to strengthen teeth restored using composite (Eakle 1986). Bonding materials developed for the purpose of bonding amalgam to tooth structure, provide a strong bond between the two (Pashely *et al.,* 1991). Bonding amalgam restorations promise less need for mechanical retention features and provide a resistance which conserves sound tooth tissues. Such restorations help to restore tooth integrity and enhance fracture resistance. They also assist in the improvement of the marginal seal with potentially less sensitivity (Setcos *et al.,* 1999). Several chemical bonding agents have been manufactured capable of being bonded to enamel or dentine (Sen *et al.,* 2002). One such system is Panavia $F_{2.0}$ a dual curing resin based cement system that promotes chemical adhesion to dentin, enamel, porcelain and metals.

Resin based adhesives have been simplified to the extent where only one bottle is used to simultaneously condition, prime and bond enamel and dentine. These are often referred to as ‘all in one’ systems. One of the most recent ‘all in one’ systems is G bond (GC Corporation, Japan), which is unusual in that does not contain HEMA. In addition, it has an extremely short application time. However, a strong air blast is needed to evaporate the solvent and spread the resin over a very thin layer (Burrow and Tyas 2007).

Composite resins are frequently used as restorative materials by clinicians. The material is highly esthetic. In addition, the introduction of different filler particles has greatly improved the physical properties (Segura and Riggins 1999). Early direct resin based composites suffered from high wear rates. Wear of current direct composite resin is estimated at around 10 to 15 µm per year, and that of amalgam at about 10 µm per year more than occlusal enamel (Leinfelder and Yarnell 1995).

Fiber-reinforced composites (FRC) are used for a number of alternative treatments, including periodontal splinting, restoration reinforcement, intracoronal pins and cores, denture repair and resin bonded metal free prosthesis (Goldberg and Freilich1999).

Ribbond is a first generation fiber reinforcement system and remains popular, although new fiber reinforcement systems have exhibited superior mechanical properties. The application of FRCs may prevent undesirable fractures in cuspal replacement (Brunton *et al.,* 1999). Retentive pins are widely used in restorative dentistry to retain dental restorations in teeth that have suffered extensive coronal destruction. Various pins and techniques are available. Self-threading pins have many advantages compared with other pin types; they are self-retentive, require no cement and have superior retention to cemented pins (Webb *et al.,* 1989). The purpose of this study was to compare the fracture resistance of four different restorations.

MATERIALS AND METHODS

Thirty-two extracted human upper molar teeth of similar size and free of caries were used in this study. Teeth were cleaned and stored in thymol solution (% 0.01) at room temperature until use. They were also kept wet during the entire experiment. All teeth were embedded at 2 mm below the cement-enamel junction. Teeth were randomly divided into four groups of eight specimens each. A standard mesio-occlusal preparation including the palatinal cusp was prepared on all teeth. The isthmus width was one-third the intercuspal distance. Proximal box forms were 4 mm wide, faciolingually and 1.5 mm deep at the gingival floor. This was located in enamel 1 mm coronal to the cement-enamel junction.

The following procedures were performed in applying of the restorations:

Group I

Specimens were restored with a hybrid composite resin (Filtek Z250, 3M ESPE, St. Paul, MN, USA) with two layers of pretreated reinforcing fiber (Ribbond THM, Ribbond Inc., Seattle, USA). A self-etch adhesive, G bond (GC Corporation, Japan), was applied to the cavity surface in accordance with the manufacturer's instructions. Fiber orientation was bucco-palatal and mesio-distal. Ribbond THM pretreating reinforcing fiber was used, again in accordance with the manufacturer's instructions. A thin layer of flowable composite resin (Tetric Flow, Ivoclar, Vivadent) was applied to the cavity surface. Two fiber layers were then pressed into the cavity and light polymerized (Elipar Freelight II, 3M-ESPE, St. Paul, MN, USA) for 20 s. Excess flowable composite resin was removed. After application of the fibers, group I was restored with a hybrid posterior composite resin.

Group II

Small diameter titanium self-threading pins (Stabilok Fairfax Dental, Dublin, Ireland) were used. Amalgam was then used to restorate the teeth (Cavex Alloy Non Gama 2, Cavex Haarlem, Holland). One self threading pin was placed in each tooth.

Group III

All teeth in this group were restored with a hybrid posterior composite resin (Filtek Z250) and self-etch adhesive (G bond) following the manufacturer's directions.

Group IV

In the bonded amalgam group an amalgambond (Panavia $F_{2.0}$ Kuraray, Osaka, Japan) was used in accordance with manufacturer's directions. Teeth were then restored with amalgam (Cavex Alloy Non Gama 2, Cavex Haarlem, Holland). Teeth were mounted in stainless steel molds with autocuring acrylic resin to within 2 mm of the cement-enamel junction. Once all restorations were complete, the specimens were stored in distilled water for 24 h. Each specimen was loaded under compression at a 90^{o} angle in a universal testing machine (Instron, Corp., Canton, Mass, USA) with a cross head spread of 0.5 mm/min. The load was applied with a 5 mm diameter stainless steel cylinder at right angles to the inclined cuspal plane. Load until fracture was registered for each specimen. Data were analyzed using one-way ANOVA and the Duncan test for fracture resistance. $p<0.05$ was considered as statistically significant.

RESULTS

The results are presented as failure loads in KiloNewton (kN) (Table 1). Data were analyzed using one-way ANOVA to test the four restorative procedures. The fracture resistance (mean ± SD) of groups I–IV was 1.06 ± 0.46, 1.27 ± 0.29, 1.34 ± 0.36 and 0.88 ± 0.21respectively. Although group III exhibited the highest resistance, there was no statistically significant difference among group I, II and III ($p>0.05$). The lowest fracture resistance was observed in group IV ($p<0.05$). Resistance increased significantly when a pin was placed into the amalgam ($p<0.05$), whereas disposing fiber below the composite did not increase the resistance ($p>0.05$).

Table 1. Statistical analysis of the fracture resistance of 4 different types of restoration

Restorations	Mean ± SD (kN)	F	p
Group I Fiber / Composite	1.06 ± 0.46^{ab}	29.57	0.049*
Group II Dentin Pin/Amalgam	1.27 ± 0.29^{b}		
Group III G bond / Composite	1.34 ± 0.36^{b}		
Group IV Amalgambond/Amalgam	0.88 ± 0.21^{a}		

Within each column, means with the same superscript letters are not statistically different from each other.
n=8, SD: Standard Deviation

*One-way ANOVA, *$p<0.05$

DISCUSSION

The anatomic forms of posterior teeth with cusps and fossae tend to deflect the cusp under stress. Sound teeth rarely fracture from the stresses of mastication. However, teeth that have been weakened by carious lesions and cavity preparation may suffer cusp fracture (Zidan and Abdel-Keriem 2002). The fracture strength of materials depends on several factors, including the elastic modulus of the supporting substructure, the properties of the luting agent, the thickness of restoration, and the preparation design (Karaarslan *et al.,* 2011). In this study was compared the fracture resistance of four different restorations (Fiber / Composite, Dentin Pin/Amalgam, G bond / Composite and Amalgambond/Amalgam). As a result it was determined that teeth restored with composite resin–adhesive (Group III-1.34 kN) exhibited higher resistance values than the other groups. Segura and Riggins (Segura and Riggins 1999), compared the fracture resistance of four different restorations (pin retained amalgam, amalgam-meta adhesive, composite resin-beta quartz insert and composite resin-adhesive) for cuspal replacement. They determined the highest values for fracture resistance in composite resin-adhesive (15.95 kN). This finding is in agreement with our own study. Batalocco *et al.* (2011) restored fractured incisor teeth using composite resin and porcelain veneer. They then compared the teeth but found no significant difference between them. Kuijs *et al.* (2006) compared the fractural resistance of premolar teeth (with the buccal tubercule removed) using direct and indirect composites. They also observed a similar fractural resistance for each group. Shafiei *et al.* (2011) compared the fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques and they reported that combined composite-amalgam for cuspal coverage of endodontically treated premolars was similar to direct composite coverage in strengthening restored teeth, however, composite onlay had the highest fracture resistance. Ghule and Thakore, (2010) compared the fracture resistance of teeth with class II hybrid composite, packable composite, admix high copper bonded amalgam and admix high copper amalgam with varnish and they reported that dentin bonded posterior hybrid and packable composite resins produced the best fracture resistance of teeth followed by bonded amalgam and amalgam with varnish.

The bonding ability of amalgam to dentin is documented in literature. (Sen *et al*., 2002; Imbery *et al.*,1995). In amalgam bonding the mechanism by which the bonding resin attaches to the tooth structure is identical to that by which resin-based composite attaches to dentin and enamel. The attachment of the bonding resin to amalgam however, is quite different from that of bonding resin to resin based composite. The bonding of amalgam to resin is entirely mechanical rather than chemical. Unset amalgam is condensed into the bonding resin on the tooth surface before it polymerizes. Fingers of resin are thus incorporated into the amalgam at the interface (Summitt *et al*., 2001). Retention of amalgam restorations is entirely dependent on mechanical interlocking. In conservative preparations, the remaining sound tooth tissue will avoid any amalgam displacement caused by lateral force occlusion. If there is insufficient tooth tissue to mechanically retain an amalgam restoration, additional means of retention will be necessary. Pins secured in dentin have been widely used to retain amalgam (Galindo *et al.,* 1980). Properly placed pins will resist dislodging of the restorative material caused by masticatory forces. However, pins will not eliminate microleakage and weaken restorations (Sen *et al.,* 2002).

Ianzano *et al*. (1993) conducted experiments on the fracture strength of cusps restored with silver amalgam and pins, with or without the use of an amalgam adhesive agent. They concluded that the inclusion of a pin had no effect on the fracture strength of a silver amalgam restoration regardless of whether an adhesive agent was used; however, the use of an adhesive agent did correlate with increased fracture resistance. In a study on complex amalgam restorations, Burgess *et al.* (1997) evaluated the fracture resistance provided by adhesive and mechanical techniques. They concluded that adhesives combined with pins provided significantly greater resistance to fracture than pins or adhesive alone. Imbery *et al.* (1995) also advocated the combined use of adhesive and mechanical retention in complex amalgam restorations. The use of a minimum number of pins in conjunction with a dentine adhesive appears to conserve tooth structure and also to increase the compressive strength of amalgam. The combined use of dentin pins and a specific bonding agent has been reported to significantly increase the retention of amalgam core material (Sen *et al.,* 2002). Although we used bonding for amalgam, sufficient retention could not be achieved. However, it has been determined that using pins significantly increases fracture resistance, in accordance with our study.

The application of FRCs may prevent undesirable fractures in cuspal replacement (Brunton *et al*., 1999). Studies have shown that if fracture of tooth substrate was involved, higher percentages of specimens with FRC tended to fracture above the cement-enamel junction than those without FRC. The level of fracture with respect of the cement-enamel junction is important in terms of the clinical prognosis of a tooth. A fractured tooth below the cement-enamel junction is more difficult to restore, and restoration may even be impossible (Fennis *et al.,* 2005). Furthermore, the fibers can only bear load if they are oriented in the load direction (Behr *et al.,* 2003). Reported that the load in their study was applied axially, representing the most frequently encountered direction. Crosswise or perpendicular oriented fibers weaken the reconstruction and it has been suggested that single molar crowns made of composite materials do not benefit from fiber reinforcement. FRC restorations require considerable time and skill. Higher forces can only be withstood if the composite matrix and fibers are perfectly bonded. Failures during fiber impregnation, which lead to voids, or missing drain for the surplus matrix during the vacuum pressure process, degrade the reinforcement.

Badakar *et al.* (2011) compared the fractural resistance of teeth that were restored using different composite types and composite supported by fibers with teeth. They reported that these exhibited almost the same levels of fractural resistance. Fennis *et al*. (2005) reported that the load bearing capacity of premolars with cusp replacing restorations is not a factor increasing the incorporation of glass FRC. Pereira *et al.* (2003) compared hybrid composite and fiber composite laminate, and reported that fiber composite laminate did not exhibit enhanced flexural strength. This is in agreement with the results of other authors who tested fiber reinforcement of composites (Sirimai *et al.,* 1999). We also determined that the simultaneous use of fiber and composite does not increase fracture resistance. The advent of adhesive dentistry has greatly increased the bond strength of amalgam and composite resins. The other advantages of bonded restorations include conservation of tooth structure, reduced microleakage and less post-operative sensitivity. Moreover, adhesives have increased bond strength to tooth structure. Many studies have reported increased fracture resistance with bonded restorations (Eakle 1986; Eakle *et al.*,1989). Because bonded restorations reduce cusp fracture, there should be less long-term structural fatigue of the tooth at the base of the cusp, and therefore fewer cuspal fractures (Eakle *et al.,* 1992)

Composite restorations have shown a greater capacity to absorb compressive loading force compared with bonded restorations, or when combined with pin-amalgam restorations. Composite has a lower elastic modulus than FRC or amalgam restorations. Composite therefore transmits less of the applied load to the underlying tooth structure. This may account for composite-adhesive exhibiting the greatest fracture resistance. More flexible and less rigid materials may be desirable to the restoration of posterior teeth, given the inherent ability of teeth to flex under occlusal loading (Brunton *et al*., 1999). Composite-adhesive restoration have shown a greater capacity to absorb compressive loading forces compared with pin retained amalgam restorations and FRC restoration.

The resistance to fracture exhibited by teeth has been attributed to the teeth cusps which are simply elevations or mounds on the tooth. The degree of cuspal movement occurring in weakened cusps, owing to cavity preparation, reduces tooth strength. The incremental placement technique of composite resins reduces the contractional stresses arising during polymerization, thereby reducing cuspal displacement (Bharadwaj *et al.,* 2002)

In conclusion, this study shows that a bonded composite restoration should be the first choice for cuspal replacement. Additionally, it was found that the resistance increased significantly when a pin was placed into the amalgam, whereas disposing fiber below the composite did not increase the resistance. If amalgam is to be used as restoration material, a disposing pin immediately below the restoration material prior to application increases fracture resistance.

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