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Effect of bonded restorations on the fracture resistance of root filled teeth

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Abstract

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Aim To evaluate the fracture resistance of root filled maxillary premolars restored with different techniques.

Methodology One hundred and twenty single-rooted maxillary premolar teeth were divided randomly into six groups of 20 teeth and subjected to the following procedures: group 1: intact teeth. Group 2: endodontic access cavities prepared. Group 3: MOD cavities were prepared, root canals were filled and no restoration was placed. Group 4: teeth were prepared as group 3 and restored conventionally with amalgam. Group 5: teeth were prepared as group 3 and restored with amalgam using a bonding material. Group 6: teeth were prepared as group 3 and restored with composite resin using the same bonding material. Teeth were embedded in acrylic resin and the loads for fracture strength were applied vertically with a constant speed of 1 mm min^{-1}. Data were evaluated statistically with ANOVA and Tukey's tests.

Results The mean force of fracture values were 1191.41, 599.86, 233.03, 494.72, 962.81 and 856.48 N for groups 1, 2, 3, 4, 5 and 6, respectively. The fracture resistance of group 5 was similar to group 1 ($P > 0.05$). The mean force at fracture of group 5 and group 6 was not significantly different. The fracture resistance of groups 5 and 6 was significantly higher than group 4 ($P < 0.001$).

Conclusions The group, restored with conventional amalgam, had the weakest resistance to fracture when compared with the bonded restorations. No statistically significant differences were found between the bonded amalgam and composite resin groups.

Keywords: bonded restorations, fracture resistance, root-filled teeth.

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Introduction

Root canal treatment should not be considered complete until the permanent coronal restoration has been placed (Wagnild & Mueller 2002). Root filled posterior teeth are more susceptible to fracture than teeth with intact pulps. The reason most often cited for this finding has been the dehydration of dentine after the endodontic procedures (Helfer *et al.* 1972) and the removal of tooth structure during the restorative and root canal procedures (Oliveira *et al.* 1987, Reeh *et al.* 1989). Root canal treatment changes the actual composition of the remaining tooth structure (Gutmann 1992). The combined result of these insults is the common clinical finding of increased fracture susceptibility in teeth with no pulps (Wagnild & Mueller 2002). Restoration of root filled teeth is an important step that complements a technically sound root canal treatment. Fracture of unsupported tooth structure can lead to restorative difficulties and occasionally requires the extraction of the tooth (Steele & Johnson 1999).

Although different restorative materials are suggested for restoration of root filled teeth, amalgam and composite resins are the most commonly used. It has been suggested that composite resin restorations adhere to enamel and dentine and strengthen the remaining tooth structure (Morin *et al.* 1984, Eakle 1986, Jagadish & Yogesh 1990, Fissore *et al.* 1991).

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A number of new dentine bonding systems have been developed and marketed. These bonding systems were introduced to increase the bond strength of composite resins to dentine. Materials developed for bonding amalgam to tooth structure provide a strong bond between amalgam and tooth structure (Pashley *et al.* 1991, Al-Moayad *et al.* 1993, Vargas *et al.* 1994, Cobb *et al.* 1999). It was reported that amalgam bonding can result in strengthening of teeth (Boyer & Roth 1994, Oliveira *et al.* 1996). Also, the effectiveness of bonded amalgam restorations has been reported in several clinical studies (Belcher & Stewart 1997, Staninec *et al.* 1997).

The aim of the present investigation was to evaluate whether bonded restorations reinforced the root filled teeth compared with the conventional restorations.

Materials and methods

In this study, 120 freshly extracted, intact, non-carious human maxillary premolar teeth with similar anatomic characteristics were selected. All soft tissue and debris on the teeth were removed using a scaler and teeth were stored in distilled water at room temperature until required. To minimize the influence of size and shape variations on the results, the teeth were classified according to their mesiodistal and bucco-lingual dimensions. Teeth were randomly divided into six experimental groups of 20 teeth each and subjected to the following procedures.

Group 1

Unaltered teeth (control).

Group 2

Standard endodontic access cavities were prepared with ISO 14 burs (Diatech, Coltene Whaledent, Altstatten, Switzerland) and constant water cooling.

Group 3

MOD (Mesial-Occlusal-Distal) cavities were prepared with ISO 14 burs so that the bucco-lingual width of the occlusal isthmus was one-third of the width between buccal and lingual cusp tips and the bucco-lingual width of the approximal preparations was one-third of the bucco-lingual width of the crown. The approximal boxes were prepared straight (non-undercut) and in depth limited to 2 mm coronally from the cemento-enamel junction. An endodontic access cavity was then prepared and the root canals instrumented to a size 40 file (Mani, Inc, Tochigi, Japan) and filled with gutta-percha (SPI Dental Mfg. Inc., Inchon, Korea) and AH 26 root canal sealer (Dentsply DeTrey, Konstanz, Switzerland) using a lateral condensation technique.

Group 4

The teeth were prepared and the root canals were filled as in group 3. Cavities were restored conventionally with high copper amalgam (Cavex Avalloy-LC, 2003 RW; Haarlem, the Netherlands) according to the manufacturer's instructions.

Group 5

The teeth were prepared and the root canals were filled as in group 3. Prior to restoration with amalgam, a dual cure bonding agent, Super-Bond D-liner II Plus (Sun Medical Co. Ltd, Shiga, Japan) (Table 1) was applied to the cavity preparations according to the manufacturer's instructions. First, a conditioner (activator) containing 10% citric acid and 3% ferric chlorite was applied to enamel, after 30 s it was applied to dentine as well and 10 s later the cavities were washed thoroughly and dried. Base and catalyst were mixed in a ratio 2 : 1 and then applied to the cavity walls using the small sponges followed by polymer powder using the same sponges. During application of the bonding material, the amalgam was mixed and placed before the bonding material had set. The restorations were then polished.

Group 6

The teeth were prepared and the root canals were filled as in group 3. The cavities were cleaned and dried, etched with 37% phosphoric acid for 30 s and air dried for 10 s. Super-Bond D-liner II Plus was then applied according to the manufacturer's instructions and the

Table 1 Components of superbond D-liner II plus

Component	Ingredient
Conditioner	Citric acid, ferric chlorite
Base	Metacryloxyethyltrimethyl acidanhydride (4-META), methyl methacrylate (adhesive)
	2-Hydroxyethyl metacrylate (Primer)
Catalyst	Tri-*n*-buthylborane (adhesive)
Polymer	Polymethyl methacrylate (adhesive)

cavities were restored with a light cured-hybrid composite resin (3 M ESPE Valux Plus, Seefeld, Germany). Composite resin was placed into the cavities in four increments, each approximately 2 mm thick, and each increment was light cured for 40 s. The restorations were contoured and polished.

Teeth were stored in 100% humidity at 37 °C for 7 days. Cylindrical moulds (20 mm diameter and 40 mm length) were prepared using the elastomeric impression material (Provil P-Soft, Heraeus-Kulzer, Dormagen, Germany). Self-cure acrylic resin (Meliodent; Bayer Dental, Leverkusen, Germany) was used to fill the mould and the teeth mounted to a level 1mm apical to the cemento-enamel junction. The mounted teeth were then placed on the lower plate of a Universal Testing Machine (Lloyd, LRX, Fareham, UK) (Fig. 1). The upper part of the machine housed a round tip that had a diameter of 6 mm. The tip was placed in contact with the occlusal inclines of the buccal and lingual cusps and subjected to a slowly increasing force (1 mm min^{-1}) vertically down the long axis of the tooth until the fracture occurred. The force required to fracture each tooth was recorded in Newtons. Statistical analysis was performed using the ANOVA, followed by the Tukey's test to compare the differences between the groups.

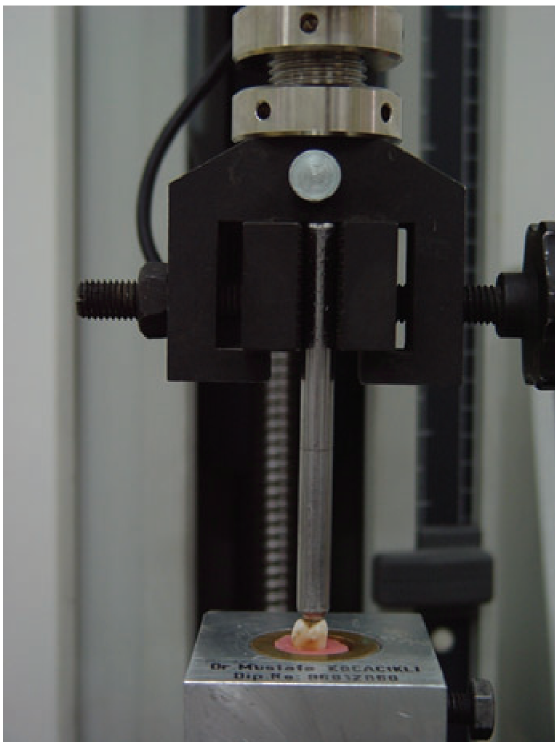

Figure 1 Experimental set-up.

Results

The mean forces at fracture, minimum and maximum values and the SD for each group are presented in Table 2. The mean forces at fracture were: group 1 (1191.41 N), group 5 (962.81 N), group 6 (856.48 N) followed by group 2 (599.86 N), group 4 (494.72 N) and group 3 (233.03 N), respectively. Overall significant difference between the groups was found at the 0.001 level ($P < 0.001$). According to Tukey's test results, significant differences were found between the teeth restored with conventional amalgam or bonded amalgam (groups 4 and 5, $P < 0.001$) and those restored with conventional amalgam and composite resin (groups 4 and 6, $P < 0.001$). There were no significant differences between the unaltered teeth and bonded amalgam groups (groups 1 and 5) or between groups 2 and 4. In addition, no statistically significant difference between the bonded amalgam and composite resin groups (groups 5 and 6) was found. The mean force at fracture in group 3 (MOD plus access cavity) was significantly lower than the other groups ($P < 0.001$). Groups with significant difference are shown with different superscripts in Table 2.

Discussion

In the past decade, introduction of new bonding agents has led to the suggestions that the root filled teeth may be restored with a bonded restoration instead of a crown or onlay restoration. The ability to predictably restore a root filled tooth to its original strength and fracture resistance without placement of a full coverage restoration could provide potential prosthodontic and economic benefits to patients.

Previous authors have noted the difficulty in obtaining uniform fracture strengths for human teeth because of the natural variations in tooth morphology (Eakle 1986, Marshall 1993). In a retrospective clinical study

Table 2 Mean, minimum and maximum forces at fracture values and SDs. Groups with no statistical difference are shown with the same superscripts

Groups	*n*	Mean ± SD	Minimum	Maximum
Group 1[a]	20	1191.41 ± 378.1	599.50	1746.3
Group 2[b]	20	599.86 ± 281.52	231.43	1192.4
Group 3[d]	20	233.03 ± 115.63	74.24	541.23
Group 4[b]	20	494.72 ± 133.76	271.35	782.35
Group 5[a,c]	20	962.81 ± 303.04	467.99	1407.70
Group 6[c]	20	856.48 ± 254.21	308.20	1260.80

performed by Hansen *et al.* (1990), the lowest 20-year survival rate was found in maxillary premolars. In this study, maxillary premolar teeth were selected for study and MOD cavities were cut to simulate the extensive preparations often found clinically and reproduced in other laboratory studies (Eakle *et al.* 1992, Hernandez *et al.* 1994, Oliveira *et al.* 1996, Steele & Johnson 1999).

A large SD was found in the present study and has also been reported in previous studies (Oliveira *et al.* 1987, Hernandez *et al.* 1994, Costa *et al.* 1997). Authors usually associate this finding with morphological variations amongst natural teeth and to difficulties associated with the standardizing cavity preparations.

Several studies have shown that applying the force to the long axis of the tooth transmits the force uniformly (Chen *et al.* 2000, Lindemuth *et al.* 2000, Dias de Souza *et al.* 2002). In the present study, the force was also applied vertically in a constant speed using a Universal Test Machine. However, the experimental model used in this study can be criticized because the forces required to fracture teeth *ex vivo* are nonphysiological. It is also worth noticing that none of the samples or those in other studies where teeth were mounted in a rigid material ever exhibited the true root fracture.

The bonding material used in this study is a fifth generation bonding material with primer and adhesive components being combined. 2-hydroxyethyl methacrylate (HEMA) in the adhesive is hydrophylic and it is suggested that it provides both mechanical and chemical adhesion (Nakabayashi & Takarada 1992, Kameyama *et al.* 2002). It has also been shown that the component 4-metacryloxyethyltrimethyl acidanhydride/methyl methacrylate-tri-n-buthylborane provides adhesion to metalic surfaces (Nakabayashi *et al.* 1992). In previous studies (Nikaido *et al.* 1995, Tarım *et al.* 1996), successful results on the bonding and fracture resistance of Superbond D-liner II were reported. Based on these studies, Superbond D-liner II Plus reinforced with polymer powder was used in this study.

In the present study, the highest mean fracture value was found in intact teeth (group 1); this is obviously because there was no loss of tooth structure. The difference between groups 5 and 1 was not statistically significant implying that the teeth restored with bonded amalgam were as strong as intact teeth. The fracture resistance of group 6 that was restored with composite resin using the same bonding material was not significantly different from group 5. Group 4 restored with conventional amalgam had significantly less fracture resistance than groups 5 and 6, probably because the restorations did not adhere to tooth structure.

Hernandez *et al.* (1994) restored the groups with composite resins and bonded amalgam and similar to the present study, they found no significant difference between the fracture resistance of these groups.

Ausiello *et al.* (1997) restored the maxillary premolar teeth with bonded amalgam in one group and with composite resins in the other groups using the various bonding materials. In contradiction with the current study, it was found that teeth restored with composite resins were more resistant to fracture than teeth restored with bonded amalgam. The researchers suggested that adhesive systems could be used successfully to restore the root filled teeth.

Steele & Johnson (1999) evaluated the *ex vivo* fracture strength of root filled premolar teeth restored with amalgam or composite resin in the presence or absence of a bonding agent. They reported that there was no statistically significant difference in fracture strength between the experimental groups. This finding is different than the results of the present study. However, it is not possible to compare the results with those of other studies on the restoration of root filled teeth using the different materials.

A bonded composite resin restoration could be considered as a first choice for aesthetic reasons. If for some reason the clinician would choose amalgam, bonding amalgam to tooth structure could be expected to produce a higher fracture resistance compared with a conventional amalgam restoration.

Conclusions

1. The teeth restored with conventional amalgam were significantly weaker than those teeth restored with bonded amalgam and composite resin ($P < 0.001$).
2. No statistically significant differences were found between the bonded amalgam and composite resin groups and also between the bonded amalgam group and sound teeth.

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