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Fracture Resistance of Maxillary Premolars Restored by Various Direct Restorative Materials and Techniques

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ABSTRACT

Background and Objective: During the reconstruction of the lost tooth structure in deep mesio-occluso-distal (MOD) cavities, a combination of amalgam-composite restorations is suggested to simultaneously benefit from the composite resin and amalgam and to minimize their shortcomings. The aim of this study was to evaluate the fracture resistance and fracture mode of premolar teeth with MOD cavities restored by two combined amalgam-composite methods and compare it with intact teeth, amalgam and composite restorations.

Methods: In this experimental in-vitro study, 60 intact maxillary premolars, which were extracted for orthodontic treatments, were randomly divided into 5 groups (n=12): Group I (control) included intact teeth and in the other groups, MOD cavities were prepared. Group II: amalgam restoration, Group III: composite restoration (Opalis, incremental filling), Group IV: 2 mm of gingival boxes were restored with amalgam and the rest of the cavities were filled with composite, Group V: 3 mm of gingival boxes were restored with amalgam and the rest of cavities were filled with composite. The samples were stored in distilled water for 24 hours at 37 ^{o}C and underwent thermocycling (500 cycles). Specimens were subjected to a compressive load until fracture, and the fracture resistance was recorded in Newton. The fracture mode of samples was also recorded.

Findings: The highest fracture resistance was seen in control group (817±120.3 N) and the lowest was in amalgam group (593±236.9 N), which was significantly lower than the control group (p=0.048). The difference in the fracture mode between the control group and the other groups was significant (p=0.006).

Conclusion: Combined amalgam-composite restorations in MOD cavities can restore tooth strength to a level comparable to intact teeth and similar to conventional composite. The fracture mode was completely favorable only in the control group.

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Introduction

Restored teeth tend to transfer tensions differently from sound teeth. Cusp fractures due to fatigue in the weak structure of teeth and microcrack propagation under occlusal loading are more frequent in teeth with Class II cavities. Premolar teeth are more susceptible to cusp fractures due to their unique anatomic form, crown-root ratio, and crown size, and preparing MOD cavity decreases 63% of cusp strength on average (1-3).

Amalgam restorations do not reinforce the remaining tooth structure due to their high elastic modulus and inability to bond to the tooth structure. In addition, amalgam requires more extensive preparation by eliminating sound tooth structure, and making small teeth susceptible to fractures (4). Amalgam's self-sealing property over time is due to oxide deposition by corrosion. However, its unpleasant aesthetic is a major complaint (5). Previous studies have shown that complete cusp fractures in amalgam-restored teeth, especially in teeth with extensive restorations, are relatively frequent. The conventional approach to managing these fractures is complete replacement of the restoration, resulting in more extensive direct restorations or tooth preparation for indirect restorations. Both these approaches increase the preparation size, weaken the tooth structure and adversely affect the dental pulp (6).

The clinical performance of composites has significantly improved in the past decade to provide adequate strength to resist masticatory forces, with lower polymerization shrinkage and a better curing depth. Composites strengthen the cusps, which increases the fracture resistance of MOD cavities (7). Despite the better initial adaptation of composite compared to amalgam, recurrent caries is more common in composite restorations (8). Bonding at the gingival margin of Class II cavity with composite restorations is difficult to manage due to the differences in etching patterns in the non-prismatic enamel, minimal or absence of enamel, moisture control challenge and optimized resin polymerization. The polymerization shrinkage stress is one of the main factors for microleakage (9-11). The cavity size and composite volume influence on the level of polymerization stress and cuspal deflection (12).

To achieve both amalgam and composite advantages in deep MOD cavities, combined amalgam-composite restorations are suggested. Also, successfully adding composite to existing perfect amalgam restorations, which remain in deep class II boxes, might be the most conservative treatment. If the main part of amalgam restoration is satisfactory, the part of the restoration that is defective or poses esthetic concerns is removed up to a proper depth, and the cavity can be restored with composite with no need to remove sound tooth structure. In addition, when it is not possible to isolate the gingival floor of the box, this combination technique can be useful (1, 13).

Firoozmandi et al. concluded that amalgam thickness in combined amalgam-composite restorations did not influence the fracture resistance of teeth and fracture resistance of premolar teeth restored with combined amalgam-composite restorations was similar to composite restoration and superior to amalgam restorations (4). Geiger et al. showed that fracture resistance in root canal treated teeth, which was restored with combined amalgam/composite restoration, was 51% higher than amalgam restorations (14).

The results of a study by Coheil indicated that the fracture resistance of premolar teeth with MOD cavities restored with combined amalgam-composite restorations was higher than amalgam or composite restorations (15). Gholam et al. reported that combined amalgam-composite restorations show better results compared to composite restorations (8).

Considering the advantages of combined restorations and the lack of similar studies, the present study investigated the fracture resistance and fracture mode of premolar teeth with MOD cavities restored by two combined amalgam-composite methods and compared it with intact teeth, amalgam and composite restorations. The null hypothesis stated that the fracture resistance and fracture mode of teeth under the above conditions was not different.

Methods

After approval by the Ethics Committee of Kerman University of Medical Sciences with code IR.KMU.REC.1401.281, this in-vitro experimental study was conducted on 60 sound human maxillary premolar teeth extracted for orthodontic treatments at most three months before starting the study. The teeth were caries-free and had no previous restoration, hypoplastic defects or visible cracks. The teeth selection was based on having similar mesiodistal and buccolingual dimensions. After removing residual soft tissues, the teeth were disinfected with 5.25% NaOCl for 5 minutes and stored in saline solution at room temperature until the experiment. To mount the teeth, the apical area of each tooth was placed in molten wax so that a 0.3-mm-thick layer of wax was deposited on the roots. Then, the teeth were mounted in self-cured acrylic resin (Acropars, Tehran, Iran) in a cylindrical mold, so that the cemento enamel junction (CEJ) was placed 3 mm above the acrylic resin surface and the long axis of teeth was perpendicular to the horizontal line. In the next stage, the wax around the root was eliminated. Then, a silicon impression material (Speedex, Colten, Switzerland) was injected into the cavity in the resin block, and the teeth were placed within the cavity again. Therefore, a homogeneous silicon layer was formed around the roots to simulate the periodontal ligament. The teeth were randomly assigned to five groups:

Group 1 (control): intact teeth with no preparation.

In other teeth, MOD cavities were prepared using a diamond fissure bur 01 (Teezkaran, Tehran, Iran) in the high-speed handpiece under air-water coolant. A new bur was used for every five cavity preparations. The pulpal depth was set at 2mm, with parallel facial and lingual walls; the width of cavity in the occlusal area was $\frac{1}{2}$ distance between the two cusp tips; the width of the proximal box was $\frac{1}{3}$ of the tooth faciolingual width at the height of contour area; the axial depth measured 1.5 mm, and the gingival floor of the box placed 1 mm below the CEJ. The cavity dimensions were confirmed using a periodontal probe.

Group 2 (amalgam restoration): After rinsing the cavity and placing the matrix band with a Tofflemire holder, the amalgam was triturated in the amalgamator (Ultramat 2 SDI, Melbourne, Australia) and the cavities were restored with admixed high-copper amalgam (GS-80 SDI, Melbourne, Australia). After carving and final burnishing, the samples were stored in water.

Group 3 (composite restoration): First, a matrix band was placed using a holder. After acid etching the enamel margin with 37% phosphoric acid (Condac 37, FGM, Joinville, Brazil) for 20 seconds and irrigation with water for 20 seconds, the cavity was dried with cotton pellets. Two adhesive layers (Amber Universal APS, FGM, Joinville, Brazil) were homogenously applied to all cavity walls with a micro-brush, gently air dried and after eliminating excess adhesive with a new micro-brush, light-cured in an overlapping manner in different areas for 20 seconds in each region using a light emitted diode (LED) light-curing unit (Woodpecker, China) at a minimum light intensity of 800 mW/cm^2. The light intensity was checked periodically with a radiometer (Demetron LED Radiometer, Kerr, Orange, USA). The cavities were restored incrementally with Opalis composite (shade A1, FGM, Joinville, Brazil). The first layer was placed horizontally on the gingival floor, with a maximum thickness of 1 mm and cured for 20 seconds. The next layers were placed in the oblique direction so that each layer had a maximum thickness of 1.5 mm and cured. After the restorative procedure, the excess restorative materials were removed with the diamond finishing bur. Then a mullet was used for polishing, and the samples were stored in the water.

Group 4 (2-mm amalgam-composite): First, 2 mm of the gingival floor of proximal boxes was filled with amalgam. After condensing, the mercury-rich layer was removed from the surface using an excavator. After 5 minutes, the cavity was cleaned and rinsed thoroughly. After etching the enamel margin with 37% phosphoric acid for 20 seconds and irrigation with water for 20 seconds, two adhesive layers (Amber Universal) were applied to all cavity walls and amalgam surface and light cured, then composite restoration procedure was performed, similar to group 3.

Group 5 (3-mm amalgam-composite): The proximal boxes were filled with amalgam up to 3 mm. After 5 minutes, the cavity was cleaned and rinsed thoroughly. After etching the enamel margin with 37% phosphoric acid for 20 seconds and irrigation with water, two adhesive layers (Amber Universal) were applied to all cavity walls and amalgam surface and light cured, then composite restoration procedure was performed, similar to group 3.

Thermocycling and Fracture Resistance Test: After the restorative procedures, the samples were stored in distilled water at 37 ºC for 24 hours and underwent thermocycling (Baradaran Pouya, Tehran, Iran) for 500 times (5-55 ºC) (16). In the next step, the samples were placed in a universal testing machine (Testometric M350-10 CT, Rochdale, England) to test the fracture resistance. A compressive force was applied parallel to the tooth long axis at a crosshead speed of 1 mm/min using stainless steel balls measuring 4 m in diameter on the occlusal surface, contacting the cuspal slopes. The maximum force (fracture resistance) was recorded in Newton at the fracture point. In the next stage, fracture modes were determined by two operators under magnification, and classified as:

Favorable fracture: fracture coronally to1 mm below the CEJ; unfavorable fracture: fracture apically to 1 mm below the CEJ (4).

Data were analyzed by Statistical package for social science (SPSS) version 20 using one-way ANOVA, Chi-squared and Tukey's post hoc test. P<0.05 was considered statistically significant.

Results

The highest and lowest values of fracture resistance were obtained in the control (817.5±120) and amalgam group (593±236), respectively. Comparison of the groups based on Tukey test showed a significant difference between the control and amalgam groups (p=0.048). However, there were no significant differences between the other groups (Table 1).

The fracture mode was completely favorable in the control group, but in the amalgam group, the fracture mode was mostly unfavorable (Figure 1). The results of statistical analysis showed significant differences between the fracture mode of control group and the other groups (p=0.006).

Table1. Fracture resistance in different groups

Group	Newton Mean±SD
Control	817.5±120.3[a]
Amalgam	593.0±236.9[b]
Composite	794.0±195.6[a,b]
Amalgam 2mm-Composite	792.0±194.8[a,b]
Amalgam 3mm-Composite	777.5±145.7[a,b]

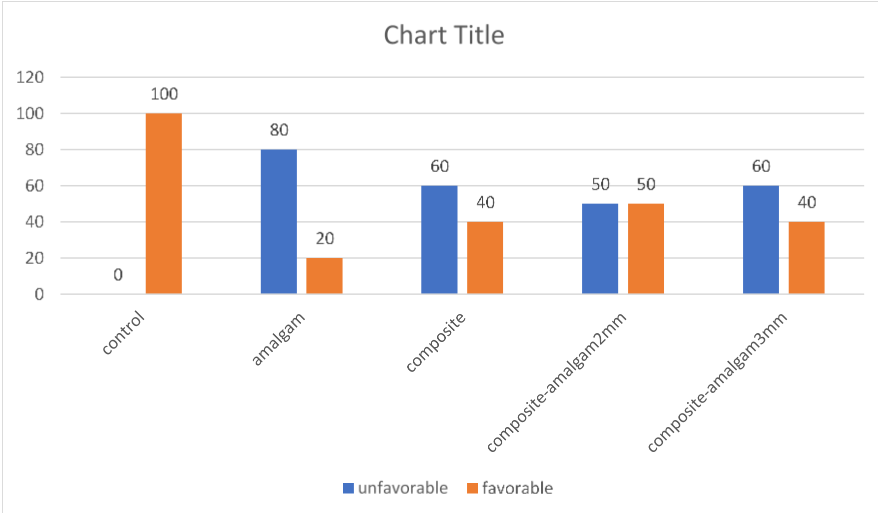

Figure 1. Fracture modes in the study groups

Discussion

The results of the present study showed that the lowest fracture resistance was in the amalgam group, which was statistically significantly different from the control group. In the present study, the numeric values of fracture resistance in the adhesive restoration groups (3, 4 and 5 groups) were lower than intact teeth; however, the difference was not significant. Similar results have been achieved in other studies, showing the importance of cuspal reinforcement with adhesive procedure. The adhesive systems and composites can transfer and distribute functional tensions properly and strengthen the tooth structure by improving the structural integrity of the buccal and lingual cusps (17-19).

Firoozmandi et al. concluded that the fracture resistance of premolar teeth restored with combined amalgam-composite restorations was similar to composite restoration and superior to amalgam restorations (4). Geiger et al. showed that fracture resistance in root canal treated teeth restored with combined amalgam-composite restorations was higher than amalgam restorations (14). The results of a study by Coheil indicated that the fracture resistance of premolar teeth with MOD cavities restored with combined amalgam-composite restorations were higher than amalgam restorations (15), which are consistant with the present study.

It appears that the presence of amalgam on the gingival floor decreases the polymerization shrinkage by reducing the composite volume and decreases the polymerization stress that affect the fracture resistance of teeth (3, 20).

Considering the results of the present study, also in the 3-mm amalgam-composite group, the composite volume can lead to structural integrity between the buccal and lingual cusps, preventing the wedging effect. In addition, more reliable proximal contacts will be possible in clinical cases.

Kaur et al. reported that amalgam-composite restorations were better than composite restorations in terms of proximal contacts and proper contour. However, there were no significant differences between the groups concerning the recurrence of caries, postoperative sensitivity and marginal adaptation (18).

Despite the absence of a proper chemical bond between amalgam and composite, an in vitro study has shown good adaptation and proper efficacy of these two materials at their interface (3). According to a study by Cehrili et al. (13), using alloy primers does not necessarily improve the seal and decrease microleakage at amalgam-composite interface; however, it is expected that using a hydrophobic adhesive without

2-hydroxyethyl methacrylate (HEMA), similar to the adhesive used in the present study (Amber universal) at the interface, is preferable to the other adhesive types. In addition, it has been demonstrated that universal adhesives, similar to the adhesive used in the present study, exhibit a proper bond strength with amalgam, which is attributed to 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) in their structure and long-term and reliable bonds to different substrates (21, 22).

Fresh amalgam-composite interface appears to provide a better bond and seal (11). According to Franchi et al., the low microleakage at amalgam-composite interface might be due to the hygroscopic expansion of composite, in addition to the presence of the adhesive layer that helps achieve better adaptation (23).

Fresh amalgam has a higher surface tension negatively affecting the surface wettability, the amalgam surface irregularities might entrap air, disrupting the interfacial adhesive layer (9), and therefore we restore composite after 5 minutes of initial amalgam setting.

The filler content percentage of composites affects their fracture resistance. Opallis composite was used in the present study with a filler weight of 78.5% and volume of 79.8%. The results showed favorable fracture resistance of it.

Another factor affecting the fracture resistance of samples is the occlusal loading pattern during the fracture resistance test. In-vitro studies cannot simulate normal occlusal forces, and the forces are increased until fractures occur. Such static loading differs from the ordinary dynamic fatigue loading of masticatory forces (combining shearing and compressive forces). However, the fracture resistance test is the most appropriate model to simulate clinical conditions (24).

In the present study, stress distribution in sound teeth resulted in favorable fractures in all samples, with significant differences with the other groups. These observations are similar to many other studies (25, 26). The fracture mode depends on the ability of tooth to distribute the applied load in the whole tooth structure. In weakened teeth, the masticatory or traumatic forces are easily transferred to the root (27). Therefore, with high fracture resistance, the fracture mode changes from favorable to unfavorable, making the tooth clinically unrestorable (28).

Axial forces have a lower destructive ability than oblique forces in restored teeth (29), therefore, the use of oblique forces are recommended in future studies to evaluate fracture resistance.

According to the results of this study, it was concluded that MOD combined amalgam-composite restorations can restore tooth strength to a level comparable to intact teeth and similar to conventional composite, and the fracture mode was favorable in the intact teeth, with significant differences with the other groups.

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