



Comparative Evaluation of Fracture Strength of Cusp Coverage with Composite Versus Unsupported Enamel Reinforced with Composite in Posterior Dental Restorations

Mansoureh Emami Arjomand¹, Amal Mahavi², Shahriar Jalalian^{3*}

1. Assistant professor, Restorative Dept, Tehran Medical Science, Islamic Azad University, Tehran, Iran

2. Dentist

3. Assistant professor, Restorative Dept, Member of Dental Material Research Center, Tehran Medical Science, Islamic Azad University, Tehran, Iran

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ABSTRACT

Background and Aim: Efficient bonding techniques should be employed for strengthening tooth structure. Whether to preserve intact dental tissue or to sacrifice some undermined parts can still be challenging. We aimed to evaluate the fracture strength of cusp coverage with composite versus unsupported enamel reinforced with composite in posterior restorations.

Materials and methods: In this in-vitro study, over-impressions were made from 36 sound human maxillary premolars using bleaching shields. The teeth were randomly divided into three groups (n=12): group 1) intact teeth, group 2) teeth with MOD cavities without cusp coverage, and group 3) teeth with MOD cavities and 1.5 mm of buccal and palatal cusp coverage. Wide MOD cavities were prepared such that only 1 mm of intact enamel was left unsupported at margins. The cavities were restored using light-cure glass ionomer and P60 composite using the over-impressions to achieve the normal tooth anatomy. The teeth were stored in water at 37°C for a week, and their fracture resistance was assessed using a universal testing machine. The load at fracture was recorded in Newton (N). Data were analyzed using one-way analysis of variance (ANOVA) and Tukey's test with a 95% confidence interval (CI).

Results: The mean±standard deviation (SD) of fracture load was 1834.62±104.04 N in group 1, 750.34±147.46 N in group 2, and 1211.30±210.85 N in group 3. One-way ANOVA revealed significant differences between the groups (P=0.001). Likewise, Tukey's test showed that the difference between the groups was statistically significant (P<0.05).

Conclusion: Using composite in restoring unsupported enamel must be combined with cusp coverage to increase fracture strength.

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*Corresponding author:

Shahriar Jalalian

shahriar.jalalian@yahoo.com

Introduction:

Premolars are more likely than molars to be subjected to lateral forces of more detrimental nature; therefore, fracture is a concern, particularly in maxillary premolars because their anatomy somehow eases separation of the cusps during mastication.^(1,2) Fractures in unsupported tooth structure, especially after MOD restorations, can lead to replacement of the restoration and even extraction if the tooth is unrestorable.^(3,4)

Cavity preparation design and the type of restorative material are among the important items influencing the fracture resistance of restored teeth.^(5,6) The fracture mainly occurs when the marginal ridge is thin or totally removed.⁽⁷⁾

Numerous studies have revealed the importance of residual dental structure in increasing fracture strength. Generally, the wider the involvement by caries or cavity preparations, the weaker the teeth.^(8,9)

Despite the successful use of amalgam in crown-root restorations and build-ups after root canal treatments in posterior teeth, new dental materials such as composite resins offer many advantages over amalgam, and because of their more appealing appearance, they have higher general acceptance.⁽⁹⁾ In addition, resin composites with good bonding ability transmit and distribute functional stresses and have the potential to reinforce weakened dental structures.⁽¹⁰⁾ Moreover, resin composites show good clinical survival rates (90% after two years and 55.1%-89.7% after 10 years), even when they are used for restoration of extensive cavities in posterior teeth.^(11,12) In large cavities, cusp coverage with direct or indirect composite restoration seems to be a safe approach.^(13,14) This procedure takes the restoration margins to the axial surfaces and protects the adhesive interface from early marginal misfits under loading.⁽¹³⁾ In the past, cavity preparation the same as conventional cavity preparation for amalgam was suggested for posterior composite restorations, but nowadays, researchers have suggested a more conservative approach, and because the retention is provided through the bonding to the tooth, cavity preparation becomes easier and shallower and with less

tooth structure removal.⁽¹⁵⁾

The most important issue in operative dentistry is to adhere to conservative principles. Restoring carious lesions or small dental defects with composite is more conservative compared to restoration with amalgam.^(16,17) Therefore, it has always been a question that whether we can keep the intact but unsupported enamel to maintain aesthetics in addition to having sufficient strength against occlusal forces.

Numerous surveys have been conducted in this field with some successful results.⁽¹⁸⁻²⁴⁾

However, some failures in the reinforcement of weakened dental tissue with composite bonding have also been observed.

This study is a comparative evaluation of the fracture strength of cusp coverage with composite resin versus unsupported enamel reinforced with composite resin in posterior dental restorations.

Materials and Methods:

This in-vitro experimental study was performed on 36 intact maxillary premolars without caries or visible fracture lines that had been extracted for orthodontic purposes.⁽¹³⁾

The teeth were disinfected in 0.5% chloramine-T solution and were kept in this solution at room temperature till the beginning of the experiment. The teeth were almost the same in mesiodistal and buccolingual widths (with a 0.5-mm error rate) as measured by a digital caliper (GUANGLU, Alberta, Canada). Teeth surfaces were debrided by scaling hand instruments and were polished with a rubber cup and pumice paste.

Then, the teeth were randomly divided into three groups of 12 specimens each:

- Group 1) intact teeth,
- Group 2) teeth with MOD cavities without cusp reduction,
- Group 3) teeth with MOD cavities with cusp reduction.

Before cavity preparation, an over-impression was made for all teeth using bleaching shields (Easy-Vac Gasket, Korea) and a vacuum machine (Easy-Vac Gasket, Korea).⁽²⁵⁾ The impressions were cut 1mm below the cemento-enamel

junction (CEJ) as a reference for reconstruction of margins and coronal structure. Using this method, the teeth were reconstructed according to their baseline size and morphology.

Cavity preparation:

An MOD cavity was prepared using a high-speed handpiece with cooling air and water system using a 1.0-mm diameter cylindrical bur (Diaswiss, Geneva, Switzerland). A new bur was used after every five cavity preparations.

The characteristics of the cavity were as follows:

The buccolingual width of the cavity: the cavity was prepared such that only 1 mm of enamel remained intact at margins. In order to ensure the absence of dentin at margins, we used both visual examination and measurement with the digital caliper. We placed sliding jaws of the caliper against marginal walls and opened it slightly to match and fit the shape, then, turned the lock screw; the value we measured was approximately 1 mm in all marginal wall length. As the width was not more than 1 mm, we could assure that there was no dentin left.

Pulpal depth from the cavosurface: 3 mm

The dimensions of proximal boxes were as follows:

Gingival floor width: the gingival floor of the cavity was prepared such that only 1 mm of enamel remained intact in buccal and lingual walls.

Gingival floor depth: 1 mm above the CEJ (Figure 1-A).

The same cavity preparation process was followed for the next group in addition to 2 mm cusp reduction for lingual and 1.5 mm cusp reduction for buccal enamel walls in order to strengthen unsupported enamel walls in both functional and non-functional cusps (Figure 1-B).

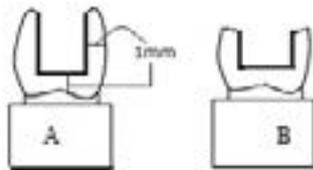


Figure 1. (A) Gingival floor depth is 1 mm above the cemento-enamel junction (CEJ). (B) Two mm cusp reduction for lingual and 1.5 mm cusp reduction for buccal enamel walls.

Afterwards, a thin layer (1 mm) of light-cure glass ionomer cement (GC Fuji II LC, Tokyo, Japan) was applied to the whole gingival floor of the cavity as stress breaker and light cured with energy density of 600 mW/cm² (Astralis 7, Ivoclar Vivadent, Lichtenstein, Switzerland) for 40 seconds. Then, the specimens were etched with 37% phosphoric acid (MORVABON, Tehran, Iran) for 15 seconds. The process was followed by rinsing with water for 10 seconds and air-drying using air spray. Then, Single Bond (3M ESPE, St Paul, MN, USA) was applied to the cavity floor and to the inner surface of dental walls and was dried for three seconds. The second layer of bonding was applied and light cured for 20 seconds using the light-curing unit. Filtek P60 composite resin (3M ESPE, St Paul, MN, USA) was applied to the cavity in 2-mm-thick increments and cured for 40 seconds. The final increment was cured along with the bleaching shield over-impression to contour the restoration the same as an intact tooth.

Testing procedure:

After one week of storage in normal saline, the specimens were mounted in cubic-shaped acrylic resin in order to be put in a universal testing machine (Zwick-Roell, Ulm, Germany).

The specimens were subjected to a compressive force at a crosshead speed of 1 mm/minute. The force was applied by an 8-mm-diameter round metal bar positioned parallel to the long axes of the teeth, in contact with the occlusal slopes of the buccal and lingual cusps (Figure 2).

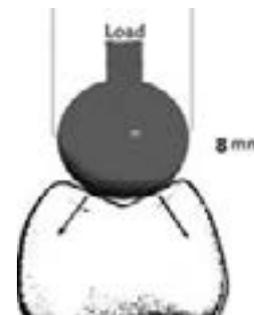


Figure 2. The force was applied by an 8-mm-diameter round metal bar positioned parallel to the long axes of the teeth, in contact with the occlusal slopes of the buccal and lingual cusps.

The peak fracture load was recorded in Newton (N) for each tooth. Data were analyzed using one-way analysis of variance (ANOVA) and Tukey's test with a 95% confidence interval (CI).

Results:

In the present study, the use of overlay direct resin composite provided 66% of the fracture resistance of sound teeth according to the following formula (Table 1):

The mean±standard deviation (SD) of fracture load was 1834.62±104.04 N in group 1 (intact teeth), 750.34±147.46 N in group 2 (no cusp coverage), and 1211.30±210.85 N in group 3 (buccal and palatal cusp coverage; Table1).

Table 1. The mean±standard deviation (SD) of fracture load (N) in the studied groups

| Groups | Fracture resistance (N) | | | |
|--|-------------------------|----------------|---------|---------|
| | Number | Mean±SD | Minimum | Maximum |
| Intact teeth | 12 | 1834.62±104.04 | 1702.88 | 2078.46 |
| Decapped and enamel reinforced with composite (no cusp coverage) | 12 | 750.34±147.46 | 489.76 | 943.95 |
| Buccal and palatal cusp coverage | 12 | 1211.30±210.85 | 684.37 | 1564.83 |

One-way ANOVA revealed significant differences between all three groups (P=0.001).

Tukey's test was used for pairwise comparisons and showed that the difference between the three groups was statistically significant (P=0.001; Table 2).

Group 1 had the highest fracture strength in

comparison with the other groups, and the fracture strength of group 3 was higher than that of group 2 that had the lowest fracture strength.

Table 2. Comparison of the studied groups according to Tukey's test

| Groups | Number | Mean | The mean difference | P-value |
|---|--------|---------|---------------------|---------|
| Natural teeth (G-1) | G-2 | 750.34 | -1084.28 | P<0.001 |
| | G-3 | 1211.30 | 460.95 | P<0.001 |
| Decapped and enamel reinforced with composite (G-2) | G-1 | 1834.62 | 1084.28 | P<0.001 |
| | G-3 | 1211.30 | -460.95 | P<0.001 |
| Buccal and palatal cusp coverage (G-3) | G-1 | 1834.62 | 623.32 | P<0.001 |
| | G-2 | 750.34 | -460.95 | P<0.001 |

Discussion:

Nowadays, one of the most important issues discussed in operative dentistry is the ability to maintain and strengthen weakened tooth structure and to adhere to conservative principles. Amalgam does not have the ability to strengthen weakened enamel structures, and cusp coverage is more recommended in non-bonded restorations than in bonded ones.^(17,21) Because of the role of enamel in aesthetics and as anterior teeth are not under severe occlusal forces, unsupported weakened enamel is preserved in these teeth.⁽²²⁾

The question is whether it is possible to prevent removing unsupported enamel walls due to the bond of resin materials to the dental structure in posterior teeth as well and whether composite resin can strengthen unsupported enamel in such teeth to avoid or postpone fractures.

Sometimes, due to various reasons, the resistance is decreased to the level that the tooth is no longer able to tolerate masticatory loads or even smaller forces.⁽²³⁾ Fracture resistance of teeth is influenced by several factors, of which, some are controllable and some are not. These factors include high compressive forces, unfavorable occlusal contacts in the centric occlusion, restorative problems, steep cusps, caries, etc.⁽²⁴⁾

In the present study, it has been shown that the fracture resistance of MOD restorations could be more improved by direct composite full coverage design compared to inlay composite restoration, which was in agreement with the results reported by Mondelli et al, Panahandeh and Johar, and Soares et al,^(13,25,26) but still was significantly lower than that of intact teeth. The results of the present study do not agree with those of previous studies that reported the fracture resistance of weakened teeth restored with resin composite without cusp coverage to be similar to that of sound teeth;^(5,18,20,27-29) this is probably due to the cavity size evaluated in the present study, which was larger than those examined in the mentioned studies.

Some other researchers have stated that cusp coverage may decrease the fracture resistance of teeth. In the mentioned studies, similar cavities were prepared in teeth, and specimens were evaluated in terms of cusp coverage.^(30,31) This difference can be explained by the fact that in the mentioned studies, a large volume (two-thirds) of the occlusogingival cusp was removed for cover-

age, and fracture resistance decreased due to significant tooth reduction (and not because of cusp coverage).

Our study results did not confirm this finding and showed that cusp coverage increases the fracture resistance of teeth; this can be explained as follows:

1) Since the orientation of enamel rods varies in different parts of enamel, the bond strength differs from place to place. The best adhesion is achieved when the end (terminal part) of the enamel rod is etched. In case that the inner surface of enamel is etched, the tags will have amorphous shapes and will not be able to establish a firm connection between the resin and the inner surface of enamel.⁽³²⁾ Therefore, the composite cannot be strongly fused to enamel as a result of a weaker bond and cannot strengthen the unsupported enamel. On the other hand, since the orientation of enamel rods in the occlusal one-third of the external surface of enamel is more appropriate for a successful etching pattern, a stronger bond can be obtained; the head of etched enamel rods provides the highest amount of porosity and the best etching pattern in enamel. Therefore, the produced tags have better shapes and sizes and can strengthen enamel walls through a higher bond to the resin.

2) Cusp coverage, similar to that in onlay restorations, provides the possibility of better force distribution and lower fracture rate.⁽³²⁾ Splinting the cusps together preserves the integrity of tooth structure, provides a single unit and leads to strengthening the weakened walls.

3) The anchorage promoted by the resin composite, protecting the buccal and lingual cusps of group 3 specimens, rendered a fracture resistance similar to that of sound teeth. The adhesive procedure was clearly not the only factor responsible for this resistance, and cusp protection that avoided the separation in consequence of the wedge effect caused by cusp elongation also plays a major role in this respect.⁽¹³⁾

Therefore, composite restoration with cusp coverage reinforces unsupported or weakened dental walls and increases tooth resistance against fracture. It should be considered that, in the clinic, we may rarely encounter teeth with only 1 mm of unsupported enamel, comparable to our tested specimens. Similar to all laboratory studies, there

were some limitations in the present study; for example, the intraoral aging factors were not taken into consideration. This laboratory study also did not completely mimic the occlusal forces during mastication.

Conclusion:

The overall results of our study showed that using composite resin in restoring teeth with unsupported enamel walls must be combined with cusp coverage in order to increase the fracture strength of such teeth. Cusp coverage in premolars reinforces the remaining tooth structure and significantly increases the fracture strength of these teeth; even if a fracture occurs, it is going to be less severe.

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