Effect of Different Liners on Fracture Resistance of Premolars Restored with Conventional and Short Fiber-Reinforced Composite Resins

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Keywords
Fracture resistance; liner; short fiber-reinforced composite.

Abstract

Purpose: To see whether applying four different liners under short fiber-reinforced composite (SFRC), everX Posterior, compared to conventional composite resin, Z250, affected their strengthening property in premolar MOD cavities.

Materials and Methods: Mesio-occluso-distal (MOD) cavities were prepared in 120 sound maxillary premolars divided into 10 groups (n = 12) in terms of two composite resin types and 4 liners or no liner. For each composite resin, in 5 groups no liner, resin-modified glass ionomer (RMGI), conventional flowable composite (COFL), self-adhesive flowable composite resin (SAFL), and self-adhesive resin cement (SARC) were applied prior to restoring incrementally. After water storage and thermocycling, static fracture resistance was tested. Data (in Newtons) were analyzed using two-way ANOVA (α = 0.05).

Results: Fracture resistance was significantly affected by composite resin type (p = 0.02), but not by the liner (p > 0.05). The interaction of the two factors was not statistically significant (p > 0.05). SFRC exhibited higher fracture strength (1470 ± 200 N) compared to conventional composite resin (1350 ± 290), irrespective of the application of liners. Application of SARC and SAFL liners led to a higher number of restorable fractures for both composite resins.

Conclusions: The four liners can be used without interfering with the higher efficacy of SFRC, compared to conventional composite resins, to improve the fracture strength of premolar MOD cavities.

Removal of tooth structure during cavity preparation, especially marginal ridges and increased height of cusps, decreases fracture resistance. Adhesive materials are capable of reinforcing the weakened teeth, resulting in partial or total recovery of fracture resistance. This, in addition to sufficient esthetics and mechanical performance of composite restorations, has led to their routine use in daily practice; however, polymerization shrinkage is still a persistent drawback inherent to the polymerization process. The resultant force exerted on the interfacial bond strength leads to negation of adhesive reinforcement of the weakened cusps. With higher bond strength, the resultant internal tension of the restoration creates cuspal deflection and possibly tooth fracture. Therefore, secondary caries and fracture were found as the most important reasons for failure of composite resin restorations. To control stresses of polymerization shrinkage and reduce stresses of the adhesive interface, resilient/low elastic modulus liners as an intermediate layer (stress breaker) have been recommended. Two conventional liners used in the literature are conventional flowable composite (COFL) and resin-modified glass ionomer (RMGI). The latter has additional benefits such as fluoride release, self-adhesiveness, and less technique sensitivity. However, capability of absorbing the polymerization shrinkage stress by these liners and their subsequent effects on cuspal deflection and fracture resistance have been reported with conflicting results. The weakening effect of RMGI base or liner on the strength of the restoration and its resultant higher fracture rate was demonstrated by clinical studies on the longevity of composite restorations.

On the other hand, use of low-viscosity self-adhesive (SA) composite resins as a liner for bonding to deep dentin may be preferred by clinicians because there is no need to remove the smear layer and also the limited technique sensitivity, contrary to conventional etch-and-rinse adhesives. They are able to bond to the dentin with no separate etching/conditioning and adhesive steps. The self-adhesiveness of these SA resins...
The teeth were numbered from 1 to 120 and then randomly distributed into ten experimental groups of 12 teeth each using random numbers generated by a computer program. ANOVA analysis of average size (BL and MD) values of teeth in the ten groups showed no significant differences between the groups ($p > 0.05$). Therefore, the effect of size and shape variations on the results was minimized. The teeth were subjected to the following restorative procedures (two composite resin types alone or combined with four types of liners): in groups 1 and 6 (no liner), after etching with 37% phosphoric acid for 15 seconds, rinsing and gently drying, Adper Single Bond 2 (3M ESPE, St. Paul, MN) was applied in two consecutive layers and gently dried, followed by light-curing for 10 seconds with a halogen light-curing unit (VIP Junior; Bisco, Schaumburg, IL) at 650 mW/cm² light intensity. The cavities were restored with a conventional composite resin (Filtek Z250; 3M ESPE) or SFRC (everX Posterior) using an incremental technique, using the Tofflemire matrix system. Each layer was light-cured for 40 seconds. For SFRC, the 1-mm occlusal part of the cavity was filled with Z250. In groups 2 and 7 (RMGI), before the bonding procedures, lining was carried out with RMGI (Fuji II LC; GC), followed by light-curing for 20 seconds. In groups 3 and 8 (COFL), after the bonding procedures, lining was carried out with a conventional flowable composite resin (Filtek Flow; 3M ESPE), followed by light-curing for 40 seconds. In groups 4 and 9 (SAFL), before the bonding procedures, lining was carried out with a self-adhesive flowable composite resin (Vertise Flow), followed by light-curing for 20 seconds. In groups 5 and 10 (SARC), before the bonding procedures, lining was carried out with self-adhesive resin cement (Clearfil SA), followed by light-curing for 20 seconds. In groups 1 to 5, Filtek Z250, and in groups 6 to 10, everX posterior composite resins were used to restore the cavities as previously described. All the liners were applied in a thin layer (approximately 1 mm) on the pulpal and axial walls according to the respective manufacturers’ instructions. After finishing the completed restorations with Sof-Lex discs (3M ESPE), they were stored in distilled water for 24 hours at 37°C and then thermocycled (Vafaie Inc, Tehran, Iran) for 1000 cycles at 5°C/55°C (dwell time: 15 seconds). The specimens were subjected to a continuous compressive axial loading at a 1-mm/min crosshead speed using a universal testing machine (Zwick Roell, Ulm, Germany). The force was applied by a smooth cylindrical head measuring 5 mm in diameter, parallel to the long axis of the teeth in contact with the occlusal slopes of the buccal and lingual cusps. Peak load to fracture for each tooth was recorded in Newtons as a fracture strength value. Data were analyzed with two-way ANOVA at a significance level of $\alpha = 0.05$, using SPSS 11.5 (SPSS Inc., Chicago, IL). The fractured teeth were then evaluated by two independent operators to determine the mode of fractures, as restorable (fractures ending above the CEJ) or nonrestorable (fractures ending more than 1 mm below the CEJ) (Figs 1–4).

Results

Fracture resistance values in Newtons (mean ± SD) for the ten groups are presented in Table 1. According to two-way ANOVA, fracture resistance was significantly affected by composite resin type ($p = 0.02$), not by liner ($p = 0.23$). Their
interaction was not significant ($p = 0.21$). Regardless of liner use, fracture resistance of SFRC was higher than conventional composite resin (1470 ± 200 N vs 1350 ± 290 N). Despite lack of significant effect of liner, the value of fracture resistance values of liner groups, especially SA resin cement (1470 ± 270 N) and SA flowable composite resin (1460 ± 300 N), were higher than that of no liner group for conventional composite resin (1190 ± 220 N).

Assessment of fracture pattern revealed that restorable mode was the major fracture mode in SARC and SAFL liner groups for both composite resins; in the rest of the groups, no differences were observed (Table 2). Four samples of the two types of fracture mode are shown in Figures 1 to 4.

**Discussion**

During adhesive restoration of deep and wide Class II cavities of maxillary premolars, use of low-viscosity SA material as a liner in association with new SFRC could be an attractive approach. These teeth are more prone to fracture due to construction in the cervical zone and cuspal inclination with high tensions on cusps.\(^2,3\) According to our results, irrespective of liner application, SFRC yielded a significantly higher fracture resistance compared to conventional composite resin. This might be attributed to lower polymerization shrinkage strain due to anisotropic fiber orientation.\(^25,27,32\) These fibers could provide an isotropic reinforcing effect because each fiber behaves as a crack stopper and stress transfer from the polymer matrix to stronger fibers.\(^24,27\) Furthermore, SFRC can absorb stresses and dissipate energy similar to dentin,\(^33\) improving mechanical performance by preventing brittle failure and preserving structural integrity.\(^34\) The combination of SFRC with an efficient adhesive system could contribute to the high performance obtained in the current study. A two-step etch-and-rinse adhesive was used for two types of composite resins used in this study. The results

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**Table 1** Fracture resistance (N) (mean ± SD) in the 10 groups (n = 12)

<table>
<thead>
<tr>
<th>Composite</th>
<th>No liner</th>
<th>RMGI</th>
<th>COFL</th>
<th>SAFL</th>
<th>SARC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional (Z250)</td>
<td>1190 ± 220</td>
<td>1390 ± 320</td>
<td>1270 ± 380</td>
<td>1460 ± 300</td>
<td>1470 ± 270</td>
<td>1350 ± 290(^a)</td>
</tr>
<tr>
<td>Short fiber-reinforced (everX)</td>
<td>1460 ± 190</td>
<td>1500 ± 200</td>
<td>1390 ± 290</td>
<td>1500 ± 170</td>
<td>1480 ± 220</td>
<td>1470 ± 200(^b)</td>
</tr>
</tbody>
</table>

In total mean column, different superscript letters indicate statistically significant difference; RMGI: resin-modified glass ionomer; COFL: conventional flowable composite; SAFL: self-adhesive flowable composite; SARC: self-adhesive resin cement.

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**Table 2** Distribution of fracture modes among the 10 groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Restorable</th>
<th>Nonrestorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Z250</td>
<td>12</td>
<td>5 (58.3%)</td>
<td>7 (41.6%)</td>
</tr>
<tr>
<td>(2) RMGI/Z250</td>
<td>12</td>
<td>6 (50%)</td>
<td>6 (50%)</td>
</tr>
<tr>
<td>(3) COFL/Z250</td>
<td>12</td>
<td>6 (50%)</td>
<td>6 (50%)</td>
</tr>
<tr>
<td>(4) SAFL/Z250</td>
<td>12</td>
<td>8 (66.6%)</td>
<td>4 (33.3%)</td>
</tr>
<tr>
<td>(5) SARC/Z250</td>
<td>12</td>
<td>9 (75%)</td>
<td>3 (25%)</td>
</tr>
<tr>
<td>(6) everX</td>
<td>12</td>
<td>7 (58.3%)</td>
<td>5 (41.6%)</td>
</tr>
<tr>
<td>(7) RMGI/everX</td>
<td>12</td>
<td>7 (58.3%)</td>
<td>6 (41.6%)</td>
</tr>
<tr>
<td>(8) COFL/everX</td>
<td>12</td>
<td>6 (50%)</td>
<td>6 (50%)</td>
</tr>
<tr>
<td>(9) SAFL/everX</td>
<td>12</td>
<td>9 (75%)</td>
<td>3 (25%)</td>
</tr>
<tr>
<td>(10) SARC/everX</td>
<td>12</td>
<td>9 (75%)</td>
<td>3 (25%)</td>
</tr>
</tbody>
</table>

of a recent study indicated a higher bond strength of SFRC to dentin by using etch-and-rinse and two-step self-etch adhesives than one-step self-etch.\textsuperscript{35} The lower marginal microleakage of SFRC Class II restoration compared to conventional composite (Z250) was reported by Garoushi et al; two types of composite resins were bonded using an etch-and-rinse adhesive.\textsuperscript{26} The low bonding efficiency of one-step self-etch (G-aenial Bond) used along with SFRC in a study by Atalay et al was reported as a possible explanation for no significant difference between SFRC and other restorations in terms of fracture resistance.\textsuperscript{28}

Kikuti et al revealed that the combination of Single Bond/P60 composite resin was capable of recovering the fracture resistance of premolars with MOD cavities, while silorane adhesive/silorane composite resin could not.\textsuperscript{36} The important role of adhesive system in fracture strength of the restored teeth was confirmed by these authors so that Single Bond as a filled adhesive is able to create a thick adhesive layer, acting as a stress absorbent.\textsuperscript{8,28,36} Furthermore, this layer resulted in more even distribution of stresses induced by polymerization shrinkage and load testing.\textsuperscript{36} The higher fracture resistance of SFRC restoration than conventional composite resin in endodontically treated teeth with MOD cavity has been shown.\textsuperscript{37,38} In the previous studies, SFRC was applied as a base with bulk technique (3 mm); however, in the current study, SFRC was used incrementally in the whole cavity except for 1 mm occlusally. This technique in vital molars did not result in significantly higher fracture resistance compared to conventional composite resins; however, a clear tendency toward higher value in oblique layering technique with SFRC was obtained. In that study in all the groups, 0.5-mm flowable composite was applied on the floor of the cavity as an intermediate layer.\textsuperscript{33} It was assumed the above-mentioned beneficial properties of SFRC could negate any positive effect of liners on fracture resistance in this study. Therefore, the strengths of three SA liner groups were very similar to that of the no liner group; however, the value of the COFL group was lower (not significant) than that of the no liner group. Similarly, different liners had no significant effects on fracture resistance of conventional composite resin restorations; however, the values for three SA groups, especially SA composite resin/cement, were slightly higher than the no liner group. Generally, these results support the null hypothesis of the current study. In a study with experimental design similar to our study, 0.5 mm RMGI and conventional flowable composite liner could increase fracture resistance of premolars with P60 composite resin restoration.\textsuperscript{18} However, no increase was observed in a study by Guray Efes et al, in which 1 mm of liner was placed on the gingival floor.\textsuperscript{17} The volumetric polymerization shrinkage with the elastic modulus affected the total stress on the restored teeth in opposite ways.\textsuperscript{9} The low filler content of conventional flowable composite resin resulted in more polymerization shrinkage than conventional composite resins and a lower modulus of elasticity.\textsuperscript{39} Therefore, the former may negate any beneficial effect of the latter on fracture resistance. Chuang et al reported a higher shrinkage cuspal displacement.
The lack of positive effect of flowable composite resin liner on fracture strength of endodontically treated teeth was attributed by Khan et al to gap formation between flowable composite resin and restorative composite resin. This gap or void could lead to deflection of the restoration and resultant flaw formation and fracture. The low-viscosity SA liners could provide better wettability/adaptation on the depth of cavities. Furthermore, each has specific properties, possibly leading to preference of these liners in clinical practice. SAFL was demonstrated to bond and polymerize simultaneously, leading to viscous-elastic flow reducing the negative effect of polymerization stress on the bonding. This property could be advantageous in terms of marginal adaptation. This can be speculated for the other SA resin used in this study (SARC). In addition, the slower rate of polymerization of SARC might control or decrease stress of polymerization. They have less sensitivity to moisture and capacity of fluoride release. SA resin cements are dual-curing and recommended for cementation of indirect restorations. Only one study evaluated marginal sealing of Class II composite resin restorations when SA resin cements were used as cavity liners on all the cavity walls. The reported result was promising for two SA resin cements. However, this effect was considered cement-specific due to different chemical compositions and pH. Although no study has reported the efficacy of SAFL (Vertise Flow) as a liner in Class II cavities, satisfactory results were recorded as a restorative material in Class I cavities.

The results of evaluation of fracture mode could support the application of SA resin liners, SAFL and SARC, because these liners were associated with a higher number of repairable fractures for both composite resin restorations. The experimental condition used in this study was considered a limitation of the study because of no simulation of the functional intraoral conditions. The axial compressive loading used in the fracture test did not reproduce dynamic fatigue loading. However, this can provide information on the structured integrity of the restored teeth. Further, a long-term investigation with simulation of thermal and mechanical fatigue is required to confirm the initial findings of this study.

### Conclusions

Within the limitation of the current study, the following could be concluded:

1. The four types of low-viscosity liners, especially SA, can be used without interfering with the higher efficacy of SFRC compared to conventional composite resins in fracture strength of the restored premolars.
2. This approach was able to provide benefits of the advantages of SA liners on internal deep dentin in large SFRC composite resin restorations.
3. This is true for conventional Z250 composite resin, even with a tendency to higher strength, especially for two SA resin liners.

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