Evaluation of Microleakage in Hybrid Composite Restoration with Different Intermediate Layers and Curing Cycles

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Abstract

Objective: To evaluate the impact of bulk or incremental curing of hybrid composite resin with different intermediate layers on interfacial microleakage. Materials and Methods: The recently extracted, sixty noncarious human mandibular molars were selected for the study. The standardized mesio-occluso-distal cavity with the occlusal cavity of 2 mm depth, 3 mm buccolingual width and proximal box dimension of 4 mm buccolingual width and 2 mm depth was prepared on all experimental teeth. The samples were divided into six groups of ten each. Group I was without an intermediate layer. Group II and III had 1 mm flowable composite liner, with incremental and bulk curing cycle, respectively. The Group IV, V, and VI had a self-cure composite liner with incremental and bulk curing. The teeth subjected to thermocycling and kept in 0.5% basic fuchsine dye for 24 h. The teeth were sectioned and observed under a stereomicroscope to grade them according to the extent of microleakage. The obtained data were statistically analyzed with Kruskal–Wallis and post hoc comparison test to understand the difference between the groups. Results: The Group II with flowable composite along incremental curing showed the least microleakage at both enamel (0.30) and cementum surface (0.50). The groups with self-cure composite liner were less effective than flowable composite. The microleakage at the enamel interface was less compared cementum interface across the groups. The groups with bulk curing were more prone to microleakage than incremental curing cycle. Conclusions: Within the limitation of the study, it was concluded that intermediate flowable composite with incremental curing was better suited to reduce microleakage.

Key words: Composite restorations, curing cycles, interface microleakage, intermediate layers

INTRODUCTION

The constant evolution and detailed research to improve the clinical performance of dental materials are the integral components of dental material science. The new materials and technics are developed in a continuous endeavor to overcome the shortcoming of the restorative materials. The strength and clinical performance of traditional metallic restorations are regarded as the benchmarks for the development of new restorative materials. In recent years, the composite resins are the first choice of restorative materials due to ever-growing esthetic demand from the patients.[6] Though the substantial improvements in esthetics, wear, and physical properties are achieved, the polymerization shrinkage is persisting as a major limitation.[7] The reported 3% volumetric shrinkage due to polymerization frequently lead to the marginal gap. The clinical consequences of the marginal gap include marginal leakage, postoperative sensitivity, secondary caries, discoloration, and cuspal strain.[3] The bonding of composites with enamel is clinically reliable and durable, while dentin bonding is still unpredictable.[4] The factors attributed to the compromised dentin bonding are the tubular structure, high organic content, intrinsic wetness, and the low surface energy of dentin. The prevalence of proximal and cervical caries is on the rise due to large elder population and improved survival of teeth.[3] Achieving clinically acceptable composite restoration on Class II cavities with the gingival margin extending on to the root is a critical part of restorative dentistry.
Several researchers have suggested the various techniques to reduce the polymerization shrinkage and consequently the better marginal integrity. The proposed methods are incremental placement,[6] three-sided light-curing,[7] centripetal build-up,[8] pulse-cure,[9] precured composite inserts, and intermediate layer sandwich. The recommended intermediate layers are glass ionomer cement,[10] auto polymerizing composites,[11] and flowable composites.[12] The researchers hypothesize that[13] the intermediate flowable composites helps in reducing marginal gap and microleakage due to its properties like better adaptation and formation of a stress bearing layer. The reduced filler content in flowable composites had multiple advantages like reduced viscosity, enhanced flow, and improved wettability of the material. The slower polymerization and the delayed stiffness development attributes of self-curing composites help in increased flow, lower polymerization stress, and less gap formation. It is speculated that the warmth of the tooth would enhance polymerization of the self-curing composite closest to the tooth. Thus, inhibit the tendency of the composite to shrink toward the center of its mass and pull away from the gingival wall. Few authors also suggested the bulk placement and curing to reduce the marginal gap and stress at the cavosurface margins.[14] The investigators have reported the reduced polymerization shrinkage with bulk curing methods.[15]

Obtaining optimum seal between composites and tooth structure is critical for the clinical longevity of restoration and will contribute significantly toward the improved public oral health. The microleakage under composite restoration is the topic of intense research for a long time, the results of various proposed techniques are contradictory in nature. Various researchers explored the influence of the intermediate layer underneath composite in microleakage.

The effect of bulk and incremental curing techniques with different intermediate layers on microleakage is yet to be analyzed. This in-vitro study was designed with the objective to evaluate the impact of bulk or incremental curing of hybrid composite resin with different intermediate layers on interfacial microleakage.

**Materials and Methods**

Sixty recently extracted noncarious, human mandibular molar teeth were selected for the study. They were examined under >10 magnification to eliminate the decayed or microcracked teeth. The teeth were cleaned with pumice slurry and soft polishing brush, subsequently washed thoroughly with water. The teeth were stored in 0.1% thymol solution at room temperature until the preparation for the study. The standardized mesio-occluso-distal (MOD) cavity was prepared on the experimental teeth using a water-air cooled high-speed handpiece with tungsten carbide #245 (Mani Inc., Japan) and (No. 014) inverted cone diamond burs. The burs used for cavity preparation were replaced with new ones after consecutive preparation of three specimens. All the teeth specimens were prepared by a single operator. The uniformly prepared cavity had 3 mm buccolingual width, 2 mm depth from the occlusal aspect. The proximal box had the buccolingual width of 4 mm and 2 mm in mesiodistal width and it was located 1 mm below the cementum-enamel junction. The uniformity of prepared cavity dimensions was confirmed with the help of the digital sliding caliper (Neiko, Ridgerock Tools Inc., USA) and a William’s graduated periodontal probe. The cavosurface margins were made at 90°, and all internal line angles were rounded.

All the prepared cavities were etched for 15 s with 37% phosphoric acid (Scotchbond Universal Etchant, 3M ESPE, St. Paul, USA), subsequently washed with water for 10 s. The cavity was gently air dried to leave the dentin surface slightly moist; two consecutive layers of dentin bonding agent (Single Bond 2, 3M ESPE, St. Paul, USA) were applied. The excess solvent was evaporated by soft air blowing for 10 s, so as to leave a thin uniform layer of dentin adhesive. The adhesive was light-cured for 20 s. A celluloid matrix was used with a retainer to seal the prepared cavity tightly.

**Restorative procedure**

The teeth were distributed randomly into six groups of 10 teeth each. They were classified according to different restoration techniques.

- **Group I**: Hybrid composite (Filtek Z 250, 3M ESPE, St. Paul, USA) was restored in three increments without an intermediate layer. One horizontal followed by two oblique layers in each proximal box, and two oblique increments in the occlusal cavity. Each increment was light-cured for 20 s at the light intensity of 600–700 mW/cm². The thickness of composite increment was verified by measuring the cavity depth before and after the placement of restoration through calibrated probe.

- **Group II**: The initial layer of flowable composite (Flow Line, 3M ESPE, St. Paul, USA) of 1 mm uniform thickness was placed in a horizontal increment at occlusal, gingival walls, and vertical increment on the axial wall. The intermediate layer was light-cured for 20 s. The restoration of the prepared cavity was completed with a hybrid composite as described for Group I.

- **Group III**: The uniform 1 mm thickness flowable composite was applied on occlusal, axial, and gingival wall followed by hybrid composite restoration. The flowable composite and hybrid composite layers were light cured simultaneously.

- **Group IV**: First, 1 mm intermediate layer of the self-cured composite (Alfocom, VOCO America, Inc., Indian Land, USA) was placed on the occlusal, axial, and gingival walls; it was allowed to cure for 5 min. Subsequently, the prepared cavity was restored with hybrid composite resin by an incremental method.

- **Group V**: The 1 mm of the self-cured composite was applied to the occlusal, axial, and gingival walls; the cavity was restored immediately by restoration of hybrid composite. The hybrid composite was not cured until the self-cure composite underwent polymerization for 5 min. Subsequently, the composite resin was light-cured for 40 s.
● Group VI: The restoration of the cavity was accomplished with self-cure composite, and hybrid resin similar to Group V. The overlying hybrid composite restoration was light-cured immediately without self-cure polymerization delay of 5 min.

The finishing and polishing of all restorations were achieved with the sequential use of fine diamond burs, abrasive discs, and rubber points. Proximal margins were finished with Sof-Lex discs.

**Thermocycling and microleakage evaluation**

Postrestoration, the teeth were stored in isotonic saline solution at 37°C water bath for 24 h. The root apices were sealed with glass ionomer cement, and the teeth were painted with two coats of nail varnish within 1 mm of the restoration. The specimens were thermocycled at 5 ± 1–55 ± 1°C for 500 cycles with a 30 s dwell time. After thermocycling, the teeth were immersed in 0.5% basic fuchsin dye for 24 h; later they were water rinsed thoroughly. Each tooth was sectioned buccolingually through the center of the class-I part of the restoration with a 0.5 mm thick diamond disk at low speed using copious amounts of water. Both hemisections were evaluated with a stereomicroscope at ×30 magnification. The dye penetration was assessed at the buccal and lingual enamel margins of the class-I part of the MOD restoration. The following criteria were observed for scoring cervical microleakage at enamel margin.

- 0 - No dye penetration [Figure 1]
- 1 - Penetration of the buccal/lingual wall up to the pulp wall [Figure 2]
- 2 - Penetration along the pulp wall [Figure 3].

Each hemisection was further sectioned in the mesiodistal direction through the center of the restoration. The cementum margin microleakage was determined using the following scoring criteria:

- 0 - No dye penetration [Figure 4]
- 1 - Penetration along the gingival wall up to the axial wall [Figure 5]
- 2 - Penetration along the axial wall [Figure 6].

Dye penetration in each restoration was evaluated at four geographic points along the enamel and cementum margins. The highest of the four enamel or cementum microleakage scores were considered to characterize a given restoration. The obtained data were analyzed with SPSS 18 software (IBM Corporation, New York, USA). The data were subjected to Kruskal–Wallis and Mann–Whitney U-test for the comparison of dye penetration between groups with a \( P \) value of 0.01 as the level of significance.

**RESULTS**

Both teeth samples restored with intermediate flowable composite and auto polymerizing composite restoration showed the microleakage at the margins.

Table 1 illustrates the mean microleakage scores for all the groups. The highest mean microleakage at the enamel margin was observed in Group VI (1.400) followed by Group V (1.300).
and Group I (1.200). The least enamel microleakage (0.300) was recorded in Group II. The microleakage at cementum was higher in Group I and Group VI; both groups recorded the microleakage score at 1.600. The Group II showed the least microleakage even at the cervical cementum margin with 0.500 scores. The microleakage at the enamel margin was significantly less in comparison to the cementum microleakage across all the groups.

The Kruskal–Wallis test [Table 2] was performed to explore the difference in mean ranks between the groups studied. The analysis showed the existence of a significant difference in ranks among the six groups with the $P$ value of 0.0007 for enamel surface and 0.0018 for cementum surface. The lowest mean rank was observed for Group II with the rank of 11.6, and 12.5 for enamel and cementum surfaces, respectively. Group VI recorded the highest mean rank with 38.4, and 38.5 for enamel and cementum surface.

Since Kruskal–Wallis showed the statistically significant difference, Mann–Whitney U-test was performed to understand the difference between the groups. Table 3 shows the pairwise Mann–Whitney test; the result confirms the statistically significant difference between Group II and all other groups. A significant difference was observed with Group II both in enamel and cementum surface microleakage. The $P$ values between Group II and Group I, Group III, Group IV, Group V, and Group VI was at 0.0035, 0.0014, 0.0020, 0.0008, and 0.0005, respectively, at enamel surface. The corresponding $P$ values at cementum surfaces were 0.0008, 0.006, 0.0035, 0.006, and 0.0008.

**Discussion**

The specialty of dentistry has always strived toward the perfect restorative material that can achieve an ideal form, function, and esthetics of natural dentition. Composite resins
are preferred restorative material over the earlier metallic restorations due to their chemical adhesion and improved esthetics. The marginal leakage is one of the main clinical limitations of composite restorations resulting in its limited clinical shelf life. Various researchers have proposed different material and alternative techniques to overcome the interface microleakage. The commonly used materials as intermediate layers are glass ionomer, self-cure composite resins, and flowable composites. The glass ionomer-composite resin interface bond is found to be stronger than the glass ionomer-dentin bond. Hence, cement liner tends to detach from the dentin wall during polymerization shrinkage process.\(^\text{[10]}\)

Consequently, few researchers advise against practicing glass ionomer as an intermediate liner. Numerous researchers are of the opinion; the composite bulk curing is observed to have reduced polymerization shrinkage, leading to reduced polymerization stress and less marginal gap than incremental curing. Therefore, it is prudent to know the effect of different restoration curing methods on the marginal leakage.

The dental researchers have proposed different methods to evaluate the microleakage. The methods include the dye penetration, dye extraction, radioactive isotopes infiltration, and bacterial leakage. The dye penetration method is most commonly used as well as a reliable method to evaluate the microleakage. The researchers have reported that no significant difference between dye penetration and dye extraction methods in determining the microleakage.\(^\text{[17]}\) The dye penetration method provides the information on the internal seal of restoration and allows the direct observation of dye penetration depth under the microscope.\(^\text{[18]}\) The methylene blue dye was used as a tracer to assess the microleakage due to its low cost, ease of application, and low molecular weight. The low molecular weight of the dye which is less than an average diameter of the bacterial cell is helpful in identifying even the smaller microleakage and narrow marginal gap.\(^\text{[19]}\)

The results of the present study show none of the investigated restorative techniques could eliminate the microleakage. All the study groups showed microleakage of varying degree, neither flowable composite nor the auto cure composite liner could accomplish the complete elimination of microleakage. The results are in agreement with the observation of Peutzfeldt and Asmussen.\(^\text{[20]}\) Hernandes et al.\(^\text{[21]}\) and Jain and Belcher.\(^\text{[22]}\) They reported that the intermediate layers successfully reduced not entirely exclude microleakage. The Group II with 1 mm flowable composite liner showed the least microleakage of 0.300 scores at the enamel, 0.500 at cementum surface. The microleakage scores of Group II were significantly less in compassion with all other evaluated groups with \(P \leq 0.05\).

Leevailoj et al.\(^\text{[23]}\) reported the similar report of the flowable composite with incremental curing help in controlling microleakage. The flowable composite is known for its lower modulus of viscosity and better flow. The results could be due to its better adaptation and favorable polymerization contraction stress release.\(^\text{[13]}\) These properties enable it to minimize the gap and debonding of the composite form dentin wall.

The Group IV with auto cure composite liner and incremental curing had a mean marginal leakage score of 1.100 at enamel surface and 1.400 at cementum surface. Though the outcome was inferior to Group II, it was better than other remaining groups. The polymerization of an auto-cure composite is facilitated by the warm cavity wall and polymerization shrinkage toward the dentin wall. Hence, the marginal gap between restoration and dentin is minimized. The self-cured composite is preferred over light cure composite resins in restoring large proximal cavities. Since the latter is known to contract toward the irradiation. The investigation of Hilton et al.\(^\text{[24]}\) and Beznos\(^\text{[25]}\) also showed the self-cure intermediate layer failed in controlling interface microleakage. The results of the study were not in agreement with reports from Alster et al.\(^\text{[26]}\) and Feilzer and Dauvillier.\(^\text{[27]}\) According to them, the self-cure resin recorded lower shrinkage due to slower polymerization rate, better flow, and oxygen inhibition. This variation in results could be due to the difference in cavity design and thermocycling procedure.

Few researchers are of the opinion; the bulk curing is beneficial to reduce stress at cavosurface margins and to limit composite polymerization shrinkage. They suggest the trans-enamel polymerization of the liner and composite resins simultaneously for better marginal adaptation. Many investigators attribute the reduced polymerization shrinkage to the incomplete polymerization of the composite at a deeper layer. The incomplete polymerization leads to compromised mechanical properties and leaching of monomer. The results of the present investigation revealed, the study groups, such as Group III, Group IV, and Group VI, with bulk curing recorded the higher microleakage score in comparison with the incremental curing method. The results of the study are in agreement with the findings of Eakle and Ito.\(^\text{[8]}\) They said

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### Table 3: Pair-wise comparisons using Mann–Whitney tests for each group

<table>
<thead>
<tr>
<th>Group</th>
<th>Enamel surface</th>
<th>Cementum surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>I</td>
<td>0.0035*</td>
<td>0.9698</td>
</tr>
<tr>
<td>II</td>
<td>0.0014*</td>
<td>0.0020*</td>
</tr>
<tr>
<td>III</td>
<td>0.8295</td>
<td>0.8295</td>
</tr>
<tr>
<td>IV</td>
<td>0.4569</td>
<td>0.8295</td>
</tr>
<tr>
<td>V</td>
<td>0.8295</td>
<td>0.2245</td>
</tr>
</tbody>
</table>

*Significant at \(P \leq 0.05\)

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the incremental curing was more efficient than bulk curing in controlling microleakage. The other investigators like Coli et al.,[28] and Manuel et al.[29] found no influence incremental or bulk filling technique on microleakage.

In corroborivation with results reported by Hilton et al.[24] and Beznos,[25] the microleakage in enamel margins was significantly less than microleakage at cementum margins. The structural difference between enamel and cementum is the reason for the difference in microleakage level between them. The previous authors record the bonding between resin and enamel is efficient and reliable while the bonding with cementum is compromised due to the V-shaped wedge defect at the margins. The results of the present study indicate that the intermediate flowable composite liner with incremental curing is the best option to reduce the microleakage along both enamel and cementum margins.

Limitations
The limitations of the study were it is in-vitro in nature. Although the study was conducted on sound natural teeth, it is hard to standardize the invisible microcracks, age changes, and moisture content. The teeth at clinical condition exposed to different functional and nonfunctional stress, its influence on the microleakage, the influence of these factors could not be simulated. Hence, further research is required to understand the effect of stress on an interface between composite and tooth surface and its impact on resultant microleakage.

Conclusions
Within the limitation of the study, following conclusions was drawn,

1. One millimeter flowable composite intermediate liner along with incremental curing produced the superior result in reducing the microleakage both at enamel and cementum interfaces
2. Both flowable composite and self-cure composite intermediate layers failed to totally eliminate the microleakage
3. The incremental curing method was significantly better than bulk curing method in reducing microleakage along the enamel and cementum surfaces
4. The microleakage at enamel surface was less compared to cementum surface among all the groups.

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Conflicts of interest
There are no conflicts of interest.

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