Microleakage of two types of low-shrinkage composite resins in class II cavities on primary molars

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Abstract

Introduction: In direct aesthetic restoration, microleakage resulting from polymerization shrinkage of resin composites is still challenging. Different strategies such as maximizing the amount of inorganic filler with prepolymerized filler and different silorane matrixes have introduced to overcome this issue. The aim of this experimental study was to compare the microleakage in low-shrinkage methacrylate-based (Clearfil AP-X) and silorane-based (Filtek P90) composite resins in class II cavities on primary molar teeth.

Materials & Methods: Classic class II slot cavity preparation was done on 60 healthy human primary molars. Specimens were randomly divided into two groups. For restoring the cavity in group I: methacrylate-based composite resin, and in group II: silorane-based micro-hybrid composite resin were used. The samples were thermocycled and soaked in 2% basic fuchsin dye for 24 h. They were longitudinally sectioned and observed at the gingival margins under ×10 magnification. Scores were assigned upon the amount of dye penetration. The Mann-Whitney U-test through SPSS19.0 was used for statistical analysis of data.

Results: In both groups, the major of samples showed score 0 of dye penetration. The comparison of gingival margin leakage indicated no significant difference between two groups.

Conclusion: Both restorative materials, irrespective of their type had microleakage. Given the comparable microleakage of silorane-based (Filtek P90) and low-shrinkage methacrylate-based (Clearfil AP-X) composite resins in Class II cavities of primary molars, the clinical efficacy of both materials seems to be similar.

Keywords: Silorane resins, Methacrylates, Composite resins
Introduction

In recent decades, the tendency to use esthetic restoration materials in comparison to the traditional amalgams has been increased. The term "composite resin" refers to multiphase materials that have three main components including resin matrices, filler particles and silane coupling agents. The most common resin matrices are bisphenol A-glycidyl methacrylate and urethane dimethacrylate. Most of the routinely used composites undergo 2.4-2.8% polymerization shrinkage. Some manufacturers have reduced the shrinkage range of 1.4-1.7% by adding higher filler loaded resins and used the term “low-shrinkage” for this type of composite resin materials. Nevertheless, others have altered the resin matrix with the help of silorane technology and claimed that it shows very low shrinkage. In this regard, 0.9% of this shrinkage results in decreased stress on the interface, and it is independent of increased filler loading. Monomers of the uncured methacrylate-based composites have intermolecular van der Waals force. By curing, these monomers form polymer networks with covalent intramolecular bonds.

References:
4. Monitors of the uncured methacrylate-based composites have covalent intramolecular bonds.
results in “polymerization shrinkage”; therefore, volume
reduction is an inherent trait. [5, 6] One of the most
common complications of shrinkage is microleakage
that may be accompanied by postoperative sensitivity,
staining, and recurrent caries. [1] Shrinkage determinants
consist of the C-factor, material placement technique,
particle size and volume of filler. [1] Numerous methods
are recommended to decrease the shrinkage through
technical approaches (e.g. incremental placement
technique for reducing the C-factor, applying a first
low-intensity light-curing exposure, using a low-elastic
modulus liner, and modification in resin structure).
Modification in resin structure includes maximizing the
amount of inorganic filler with prepolymerized filler
and low-shrinkage composites. [3, 7, 8]

The silorane-based resin composites have high filler
content by volume with a compound of fine quartz
particles and yttrium fluoride, driven from the fusion of
siloxane backbone and four cycloaliphatic oxiranes. [6, 9,
10] Polymerization through cationic photoinitiation,
cleavage, and opening of the oxiranes ring attains space
and reduces the shrinkage . [1] In addition, silorane has
traits such as hydrophobicity and biocompatibility. [1, 7]
They display lower water sorption and solubility, lower
compressive strength and microhardness, a lower degree
of conversion and polymerization depth, greater flexural
strength and fracture toughness, lower adhesion
potential of oral streptococci, and comparable adhesion
potential of Candida albicans, compared to
methacrylate-based resin composites. [10] The Filtek P90
composite resin is generated from this type. [2]

Therefore, the aim of this experimental study was to
compare the microleakage of the low-shrinkage
methacrylate-based (Clearfil AP-X) and silorane-based
(Filtek P90) composite resins in class II cavities in
primary molar teeth.

Materials & Methods

Permission to perform this research was received
from the Ministries of Health and Education. The
ethical approval was obtained from the Research Ethics
Committee and Faculty of Community Dentistry,
School of Dentistry, Qazvin University of Medical
Sciences, Qazvin, Iran. The study was registered under
the number of IR.QUMS.REC.1394.772.
a. Sample Selection: In the present experimental study,
60 extracted human primary second molars were
selected. The inclusion criterion was a sound tooth
without any caries, cracks, hypoplastic defects or
previous restorations. All of the specimens were hand-
scaled and cleaned from calculus and debris. Then, they
were examined under the direct light of the dentistry
unit. The teeth were soaked in 0.5% chloramine T at
4°C for 7-10 days and stored in a normal saline solution
at room temperature.

b. Cavity preparation: At the second step, the teeth
were mounted in self-cured acrylic resin blocks. Class II
slot cavity was prepared using the air/water-cooled
high-speed handpiece (Kavo 636CP, Germany) and 008
fissure diamond bur (Jota, Switzerland). The new bur
was utilized after the preparation of five teeth. The
buccolingual width of the cavity was the same as 2/3
intercuspal distance. The cervical margin was located at
1 mm coronal to the cementoenamel junction, and the
axial depth of the cavity was 1.5 mm in the gingival
surface. The dimension of the preparation was verified
using a Hu-Friedy probe (GF-W, USA).

c. Restorative procedure: Following the preparation,
the mounted samples were saved in a normal saline
solution until the restoration time. The teeth were
randomly assigned into two groups of 30 cases, and then
restored. The utilized materials in the present study are
presented in Table 1.

<table>
<thead>
<tr>
<th>Group I (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A primer (Clearfil SE Primer, Kuraray Medical, Tokyo, Japan) was applied in all the cavity surfaces for 20 sec, and then gently air-dried. After the application of the bonding agent (Clearfil SE Bond, Kuraray Medical, Tokyo, Japan) in the next stage, it was gently dried, and then light-cured (Guilin Woodpecker Medical Instrument Co., China) for 10 sec. The Clearfil AP-X A3 shade composite resin (Kuraray Medical, Tokyo, Japan) was placed using an oblique incremental technique in a layer thickness of 2 mm and cured using LED curing unit at a power density of 1,000 mW/cm² for 40 sec in a soft-start mode. Group II (n=30)</td>
</tr>
<tr>
<td>The self-etch primer (P90 self-etch primer adhesive system, 3M ESPE, Dental Product, ST Paul, USA) was utilized as per the manufacturer’s instructions, by a micro brush for 15 sec, then gently air-dried and light-cured for 10 sec. The P90 bond (3M ESPE, Dental Product, ST Paul, USA) was applied, air-dried, and light-cured for 10 sec. The Filtek P90 silorane-based A3 shade composite resin (3M ESPE, Dental Product, ST Paul, USA) was placed using the oblique incremental technique with 2-mm thickness for each layer and light-cured in a soft-start mode for 40 sec.</td>
</tr>
</tbody>
</table>

Materials & Methods
Table 1. Composition of the applied materials and their manufacturers

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silorane system adhesive</td>
<td>Primer: Phosphorylated methacrylates, Vitrebond copolymer, Bis-GMA, HEMA, water, ethanol, silanetreated silica filler, initiators, stabilizers; Bond: Hydrophobic dimethacrylate, phosphorylated methacrylates, TEGDMA, silane–treated silica filler, initiators, stabilizers</td>
<td>3M ESPE, Dental Product, ST Paul, USA</td>
</tr>
<tr>
<td>Filtek P90 composite resin</td>
<td>Resin matrix: 3,4-epoxycyclohexylethylcyclopolymerylsiloxane, Bis-3,4-epoxycyclohexylethylphenylmethyl silane; Filler: Silanized quartz, yttrium fluoride, 76.5 wt %</td>
<td>3M ESPE, Dental Product, ST Paul, USA</td>
</tr>
<tr>
<td>Clearfil SE Bond</td>
<td>Primer: MDP, HEMA, dimethacrylate monomer, water, catalyst; Bond: MDP, HEMA, dimethacrylate monomer, micro filler, catalyst</td>
<td>Kuraray Medical, Tokyo, Japan</td>
</tr>
<tr>
<td>Clearfil AP-X Composite resin</td>
<td>Resin matrix: Bis-GMA, TEGDMA, Catalysts, Accelerators, Photo initiator; Filler: Barium glass filler, Silica filler, Colloidal silica; 85.5% wt</td>
<td>Kuraray Medical, Tokyo, Japan</td>
</tr>
</tbody>
</table>

Bis-GMA: Bisphenol A-glycidyl methacrylate
TEGDMA: Triethylenglycol dimethacrylate

**Table 2. Dye penetration scoring criteria**

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No dye penetration</td>
</tr>
<tr>
<td>1</td>
<td>Dye penetration &lt;1/3 rd. of the gingival depth</td>
</tr>
<tr>
<td>2</td>
<td>Dye penetration 1/3 rd.&lt;x&lt;2/3rd of the gingival depth</td>
</tr>
<tr>
<td>3</td>
<td>Dye penetration ≥2/3rd of the gingival depth</td>
</tr>
</tbody>
</table>

**Results**

Based on the Kolmogorov-Smirnov two-sample test, the distribution of data was nonparametric. The scores were evaluated using descriptive statistics, and the groups’ dye penetration scores were compared using Mann-Whitney U test to identify any significant difference. Descriptive statistics of the dye penetration scores and result of inter-group comparison are shown in table 3. In both groups, the majority of the samples had a dye penetration score of 0 (group I=73.3%, group II=60%). However, the minority of the samples in group I (6.7%) obtained the scores of 2 and 3. Nonetheless, score 3 was not observed in any samples of group II (0.0%). There was no significant difference between two groups in terms of microleakage score (P=0.395).

d. Thermocycling and microleakage testing: After the restoration, the excess composite resin was eliminated; subsequently, finishing and polishing were carried out using the Sof-Lex discs (3M ESPE, Dental Product, ST Paul, USA). Afterward, the teeth were subjected to thermal cycling at 5-55°C, for 1,000 cycles with a dwell period of 30 sec. Two layers of nail-polish covered the entire tooth surface, except for 1 mm around the restoration margins.

The teeth were soaked in 2% basic fuchsin dye at 37°C for 24 h. After dye penetration, they were rinsed in tap water, and then sectioned longitudinally in the mesiodistal direction through the central fissure employing a diamond disc on a cutting machine (Mecatome, T201A, PRESI, France) under continuous irrigation water.

The sections were observed at the gingival margins with a stereomicroscope (MOTIC-SMZ-143-China) under 10× magnification to estimate the amount of microleakage. Then, microleakage scoring was measured and the obtained scores were named upon the amount of dye penetration (Table 2). The collected data were analyzed using SPSS 19.0. P-value < 0.05 was statistically considered significant.
Microleakage of two types of low-shrinkage composite resins

Discussion

In the present experimental study, the microleakage of two types of low-shrinkage composite resins including silorane-based and methacrylate-based was compared in terms of class II cavities in primary molars. The current study compared the microleakage of a low-shrinkage high-filled microhybrid methacrylate-based composite resin (Clearfil AP-X) with that of a low-shrinkage high-filled silorane-based composite resin (Filtek P90). They were different in matrix, volume, weight of fillers, and polymerization mechanisms. To eliminate the effect of adhesive as a confounder for both groups, the two-step self-etch adhesive system which was matched with composite manufacturer was used.

Our results revealed that both studied composite resins were indicative of microleakage at tooth-restoration interface, which could be due to the polymerization shrinkage of these materials. The majority of the samples showed a dye penetration score of 0 in both composite resins (group I [Clearfil]=73.3% and group II [Filtek P90]=60%) and the comparison of gingival marginal microleakage between two groups revealed no significant difference (P=0.395; Table 3).

The reduced polymerization shrinkage of the silorane-based composite resins which are claimed to decrease the microleakage is conflicted in the literature. In line with the results of the present study, some studies have shown no significant difference between the scores of microleakage and silorane-based and methacrylate-based composite resins. [8, 11-14]

Fahmy et al. evaluated the gingival microleakage in class II cavities in primary molars restored by the Filtek P90 (siloran-based) or Filtek supreme XT (nanohybrid methacrylate-based) composite resins. Although their study design was different from that of the present research, they reported that both materials represented the best marginal seal in accordance with the dye penetration scores. [14] However, the findings of the current study are disagreement with those of other studies. Palin et al. reported that the microleakage of the silorane-based composite material was lower than that of methacrylate-based composite. [15] Additionally, Bagis reported that silorane-based material had no marginal leakage. [16] The cause of these differences may be explained by several factors. Some of these factors include evaluation of permanent teeth which are different in structural characteristics with primary teeth, mesial-occlusal-distal cavity design with different C-factors, utilized etch and rinse adhesive system for methacrylate-based composite and application of different thermocycling methods.

Al-Boni et al., Joseph et al. and Casamassimo et al. compared the silorane- and methacrylate-based composite resins using classes I and II cavity restoration of permanent teeth. They reported that siloranes could display better results in gingival microleakage. [17,19]

It is noteworthy that in the primary teeth, the thickness of enamel and dentin is thinner, especially in the cementoenamel junction area where the enamel rods are oriented cervically. Dentineal quality of the primary teeth for bonding is weaker than that of the permanent teeth due to the wild dentinal tubules. Therefore, bonding is more challenging in the primary teeth, especially in class II cavity preparation, where gingival seat is close to cervical constriction of the tooth. [20]

In recent decades, the tendency toward using esthetic restoration materials (e.g., resin composites) has been increased. However, microleakage remains one of the most common problems of clinical failure, especially at the margins of the proximal box of class II cavities. [1, 2, 11] The microleakage may be caused by the poor fitting of restorative material with cavity walls, volume variation due to polymerization shrinkage, oral thermal variations, and mechanical fatigue through repetitive masticatory loading. [21, 22] Evaluation of microleakage is the most traditional method of observing the sealing efficacy of the restorative material. [12]

Current methods to evaluate microleakage involve direct visual examination, microscopic examination, scanning electron microscopic examination, air pressure, dye penetration, use of chemical and radioactive isotope tracer, neutron activation analysis, electrochemical methodologies, measuring bacteria

Table 3. Distribution of dye penetration scores and mean rank via Mann-Whitney U test

<table>
<thead>
<tr>
<th>Groups</th>
<th>n (%)</th>
<th>Dye penetration score 1 (%)</th>
<th>Dye penetration score 2 (%)</th>
<th>Dye penetration score 3 (%)</th>
<th>Mean Rank</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Clearfil)</td>
<td>30(100%)</td>
<td>22(73.3%)</td>
<td>4(13.3%)</td>
<td>2(6.7%)</td>
<td>3(6.7%)</td>
<td>28.90</td>
</tr>
<tr>
<td>II (Filtek P90)</td>
<td>30(100%)</td>
<td>18(60%)</td>
<td>8(26.7%)</td>
<td>4(13.3%)</td>
<td>0(0.0%)</td>
<td>32.10</td>
</tr>
</tbody>
</table>
penetration, artificial caries method and three-dimensional image analysis. Dye penetration is the most frequently used method and has the benefits of simple and easy manipulation. It provides easy analysis of quantitative and comparable results with no need for costly instrumentation. Nonetheless, there is no gold standard for this method. However, this method has also some limitations, such as the subjectivity of reading and high diffusibility of dyes due to their low molecular weight. Consequently, better results in a clinical situation may be expected. Thermocycling is a universally accepted method used in microleakage studies to reproduce the effects of oral thermal changes in materials.

Based on our findings, polymerization shrinkage is not a unique determinant on the extent of microleakage. However, further clinical research is needed to confirm these findings.

Conclusion
- Both of the restorative materials, irrespective of their type had microleakage.
- Microleakage in class II cavities in the primary molars, restored with silorane-based composite resin (Filtek P90) is similar to low-shrinkage methacrylate-based composite resin (Clearfil).

Acknowledgments
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Conflict of Interest: We declare no conflict of interest.

Authors Contributions
The study was designed by Sara Maleki Kambakhsh. Sara Maleki Kambakhsh and Shima Nourmohammadi defined the conceptual content of the research. The study data were collected by Shima Nourmohammadi. Statistical analysis and interpretation of data were accomplished by Saber Babazadeh and Fatemeh Pachenari. Preparation of manuscript was performed by Fatemeh Pachenari and its editing and revision was done by Sara Maleki Kambakhsh. Study supervision was performed by Sara Maleki Kambakhsh.

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