Original Article

Microleakage Evaluation of Silorane-Based Composites Versus Low Shirinkage Methacrylate-Based Composites

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Abstract

Background and Aim: Determining the best restorative material to decrease microleakage in class V restorations is of great importance in operative dentistry. The aim of this in-vitro study was to evaluate the microleakage of silorane-based composites compared to low shrinkage methacrylate-based composites in class V restorations.

Materials and Methods: In this in vitro study, class V cavities were prepared on the buccal and lingual surfaces of 24 human premolars and molars (48 cavities). The specimens were divided into four groups of 6(12 cavities) as follows: group 1 (LS System Adhesive, Primer & Bond + Filtek P90), group 2 (Kalore-GC+ Clearfil SE bond), group 3 (Clearfil SE bond + Grandio) and group4 (Clearfil SE bond + Aelite LS Posterior). All the specimens were thermocycled for 2000 cycles (5-50^{o}C).

The teeth were then immersed in 0.5% basic fuchsin dye for 24 hours at 37^{0}C, sectioned and observed under stereomicroscope. Data were analyzed using Kruskal-Wallis and Wilcoxon tests at a $p<0.05$ level of significance.

Results: There were no significant differences in microleakage among the four groups at the occlusal margin ($p>0.05$). But, there were statistically significant differences in microleakage between Silorane and Aelite at the gingival margin ($p<0.05$).

Statistically significant differences were also found in microleakage between occlusal and gingival margins (except for Kalore and Silorane) ($p<0.05$).

Conclusion: Silorane was not superior to the conventional low shrinkage methacrylate-based composites except for Aelite in terms of microleakage.

Key Words: Composite resins, Methacrylate, Microleakage

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Introduction

Although composite resins are now the material of choice for most restorations due to their esthetic properties and strong bond to tooth structure [1], their polymerization shrinkage remains a problem. This volumetric shrinkage ranges from 2% to 5% [2,3].

This shrinkage causes a contraction stress and consequent debonding at the composite-tooth interface and may lead to post-operative sensitivity, recurrent caries and microleakage [4].

Use of low shrinkage composites is one strategy to control polymerization contraction stress [5]. Silorane, a new class of ring-opening monomers is derived from the combination of Siloxanes and Oxiranes, combining the properties of both, such as biocompatibility, hydrophobicity, and low shrinkage [6,7].

Previous studies have shown a significantly improved marginal integrity on both enamel and dentin of Silorane compared to methacrylate-based composites [8,9] while others reported that Silorane was not superior to methacrylate based composites [10-13].

Others composite resins used in this study were methacrylate-based low shrinkage composites [14-16]. Aelite LS Posterior is a highly filled hybrid resin composite (88.5% by weight and 74% by volume) and its high filler content reduces its polymerization shrinkage (1.39) [14].

Grandio is a highly filled nanohybrid resin composite (87% by weight and 71.4% by volume). Nano structures are used to produce low-shrinkage composites (1.57%) [9,15].

Kaloreis a nano-hybrid resin composite that contains high molecular weight urethane dimethacrylate monomer (DX511); which has low number of C=C double bonds. The combination of high molecular weight and low number of C=C double bonds reduces its polymerization shrinkage [16, 17].

Another issue is the demand for complete integrity between the adhesive and tooth. Although long-term clinical success has been achieved with total–etch systems, the demand for simplified applicationled tothe development of self –etching adhesive systems that donot require a separate acid etch step and are based on the use of non-rinse acidic monomers that simultaneously condition and prime dentin and enamel. This approach reduced technique-sensitivity of the material and post-operative sensitivity of patients. The mentioned factors all contribute to the increasing popularity of these materials [18-20].

The aim of the current study was to compare the microleakage of different low shrinkage composites. In order to eliminate the variable of bonding type, Clearfil SE bond (two-step self-etch bonding) that serves as the "gold-standard" adhesiveinits class [21] was used to represent the methacrylate-based composite group. The aim of the current study was to compare the microleakage of Silorane-based and low-shrinkage methacrylate-based composites by means of dye penetration after thermocycling.

Materials and Methods

Twenty-four extracted intact human molars and premolars, free of cracks, caries or decalcifications were stored in 0.5% chloramine T at 4°C for 1 week and then in normal saline solution until use.

Class V cavities were prepared, with the gingival margin 1 mm below the CEJ, using a tapered fissure diamond bur (Tizkavan, Iran) with a water-cooled highspeed handpiece on the buccal and lingual surfaces of the teeth. A bur was used only to prepare five cavities, then, a new bur was used. The cavity size was approximately 3.0 mm long x 3 mm wide x 1 mm in to dentin deep. The occlusal margin of the cavity was located on enamel, while the gingival margin was located on cementum. The prepared teeth were further randomly divided into four groups of 6 teeth each (12 cavities).

Restorative Procedures: Materials used in this study and their compositions are presented in Table 1. The prepared teeth in each group were restored as follows:

Group 1(s): Low shrinkage resin composite FiltekP90 (3M ESPE, Dental Product, ST Paul, USA) with LS System Adhesive Primer and Bond (3M ESPE, Dental Product, ST Paul, USA) were used. Enamel surfaces were etched with 37% phosphoric acid (TotalEtch, Ivoclar Vivadent) for 15 seconds, rinsed for 15 seconds and gently air dried, leaving a moist surface. The Silorane Primer was applied using a microbrush with agitation for 15 seconds, gently air-dried, light-cured for 20 seconds, and the Silorane Bond was then applied followed by a gentle stream of air, and light-cured for 20 seconds. Filtek P90A3.5 shade composite was incrementally applied to the cavities and each increment was separately irradiated for 40 seconds at 900mW/cm ^{2} intensity using the LED curing unit (Guilin Woodpecker Medical Instrument Co., China).

Group 2(K): Kalore-GC composite (GC Corporation, Tokyo, Japan) and Clearfil SE bond (Kuraray Medical Inc, Okayama, Japan) were used. Enamel surfaces were etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent) for 15 seconds, rinsed for 15 seconds and gently air dried, leaving a moist surface. Primer was applied using a microbrush for 20 seconds and gently air-dried. The bonding agent was then applied and dispersed with a weak stream of air followed by polymerization for 20 seconds. Kalore-GC A3.5 shade composite was then incrementally applied to the cavities and each increment was separately irradiated for 40 seconds at 900mW/cm ^{2} intensity using the LED curing unit (Guilin Woodpecker Medical Instrument Co., China).

Group 3(G): Grandio composite (Voco Cuxhaven, Germany) and Clearfil SE bond (Kuraray Medical Inc., Okayama, Japan) were used. Enamel surfaces were etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent) for 15 seconds, rinsed for 15 seconds and gently air dried, leaving a moist surface. Primer was applied using a microbrush for 20 seconds and gently air-dried. The bonding agent was then applied and dispersed with a weak stream of air followed by polymerization for 20 seconds. Then Grandio A3.5 shade composite was incrementally applied to the cavities and each increment was separately irradiated for 40 seconds at 900 mW/cm^2 intensity using the LED curing unit (Guilin Woodpecker Medical Instrument Co., China).

Group 4(A): Aelite LS Posterior composite (BiscoInc, Schaumburg, USA) and Clearfil SE bond (Kuraray Medical Inc., Okayama, Japan) were used. Enamel surfaces were etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent) for 15 seconds, rinsed for 15 seconds and gently air dried, leaving a moist surface. Primer was applied using a microbrush for 20 seconds and gently air-dried. The bonding agent was then applied and dispersed with a weak stream of air followed by polymerization for 20 seconds. Then Aelite LS Posterior A3.5 shade composite was incrementally applied to the cavities and each increment was separately irradiated for 40 seconds at 900mW/cm ^{2} intensity using the LED curing unit (Guilin Woodpecker Medical Instrument Co., China).

The restorations were finished with fine-grit finishing diamond burs (Diatech Dental AG) and polished with sequential disks (OptiDisk, Kerr, USA). All samples were stored in distilled water at 37°C for 24 h.

The specimens were then thermocycled at 2000 cycles in baths at 5°C and 55°C, a dwell time of 30 seconds and a transfer time of 10 seconds (Malek-Teb, Iran). After thermocycling, the apices of the teeth were sealed with sticky wax, and all tooth surfaces except a 1-mm wide zone around the margins of each restoration were sealed with two coats of nail polish. The teeth were then immersed in a 0.5% basic fuchsin solution for 24 hours at 37°C. Following immersion, the teeth were washed thoroughly with distilled water, dried, embedded in acrylic auto-polymerizing resin and sectioned longitudinally in a bucco-lingual direction through the center of the restoration using a cutting machine with adiamond disc under constant water irrigation (Presi, Mecatome, T201A, France).

The degree of dye penetration at gingival and occlusal margins was then graded at 10x and 40x magnification with a stereomicroscope (Nikon, 30-DS, SMZ800, Tokyo, Japan) using the following scale:

0: No evidence of dye penetration

1: Dye penetration into half extension of the gingival or occlusal wall

2: Dye penetration into more than half extension of the gingival or occlusal wall, not including the axial wall

3:Dye penetration into the axial wall

Statistical analysis was performed using the Kruskal-Wallis test followed by Dunn'stest .The difference between the occlusal and gingival dye penetration scores in each group was analyzed by the Wilcoxon test.

Results

Data showing the extent of leakage scored for the occlusal and gingival margins of the restorations are shown in Table 2.

There were no significant differences in microleakage among four groups at the occlusal margin ($p>0.05$). But there were statistically significant differences in microleakage between Silorane and Aelite at the gingival margin. ($p<0.05$)

When comparing the microleakage between gingival and occlusal margins in each group, Grandio and Aelite yielded more dye penetration at the gingival wall than at the occlusal wall ($p<0.05$) and no significant differences were detected in other groups ($p>0.05$).

Discussion

Although composite resins have good physical and esthetic properties, their polymerization shrinkage and microleakage remain a problem.

Table 1. Materials used in this study and their composition

Material	Composition	Manufacturer	Batch #
Clearfil SE Bond	Primer: MDP, HEMA, Hydrophilic dimethacrylate, Photoinitiator, Water Bond:10-MDP, Bis-GMA,HEMA, Hydrophilic dimethacrylate, Microfiller, Photoinitiator	(Kuraray Medical Inc, Okayama, Japan)	01531A
Filtek P90	Resin matrix:3,4-Eoxycyclohexylethylcyclopolymethylsiloxane, Bis-3,4-Poxycyclohexylethylphenylmethyl silane; Filler:Silanized quartz; Yttrium fluoride;76 wt%	(3M ESPE , Dental Product ,ST Paul , USA)	195407
LS System Adhesive Primer & Bond	Primer: Phosphorylated methacrylates, Vitrebond copolymer, Bis -GMA, HEMA, Water, Ethanol, Silane-treated silica filler, Initiators, Stabilizers. Bond: Hydrophobic dimethacrylate, Phosphorylated methacrylates, TEGDMA, silane-treated silica filler, Initiators, stabilizers	(3M ESPE , Dental Product , ST Paul , USA)	20071239
Grandio	Resin matrix :Bis-GMA, TEGDMA, Filler:Fluorosilicate glass, SiO2	(Voco Cuxhaven, Germany)	1106467
Aelite LS Posterior	Resin matrix:Ethoxylated bis-GMA, Filler:glass filler, Amorphous silica	(Bisco.Inc.Schaumburg.USA)	0900001308
Kalore-GC	Resin matrix: DX-511 monomer, UDMA, Dimethacrylate co-monomers Filler: (30–35 wt% prepolymerized filler, 20–30 wt% Fluoroaluminosilicate glass, 20–33% wt% Strontium/barium glass, 1-5 wt% silicon dioxide nanofiller)	(GC Corporation Tokyo , Japan)	1004121

Table 2. Microleakage Score of different composite restorations

	Occlusal margins				Gingival margins			
	Score 0	Score1	Score2	Score3	Score0	Score1	Score2	Score3
Silorane	10(%83)	2(%17)	0(%0)	0(%0)	7(%58)	5(%42)	0(%0)	0(%0)
Grandio	10(%83)	2(%17)	0(%0)	0(%0)	5(%42)	5(%42)	2(%17)	0(%0)
Kalore-GC	9(%75)	3(%25)	0(%0)	0(%0)	7(%58)	4(%34)	1(%8)	0(%0)
Aelite Ls Posterior	9(%75)	3(%25)	0(%0)	0(%0)	2(%17)	6(%50)	4(%34)	0(%0)

In this investigation, Grandio and Aelite yielded significantly more dye penetration at the gingival margin than at the occlusal margin; which is in agreement with the previous study results that demonstrated less microleakage at the occlusal margins than at the dentin margins [22-24].

This was expected as the bond strength to enamel is usually higher than the bond strength to dentin and dentin is a less favorable bonding substrate. While enamel makes a uniform bonding substrate that consists of almost 90% inorganic material, dentin is a complex substrate with less than 50% inorganic material and high water content (21%) offering a moist surface that impairs the bonding

mechanism. Moreover, the tubular structure of dentin makes it a complex substrate [25-28].
Also, some studies reported that Grandio and Aelite composites have higher elastic modulus and polymerization contraction stress [29-32].
In Silorane and Kalore groups, no significant differences were detected between gingival margins and occlusal margins. It may be attributed to their low-shrinkage nature and the fact that at gingival margin, low polymerization contraction stress cannot overcome the bond strength.
Silorane primer has a pH of 2.7 that would provide, according to the manufacturer, a mild etching of the tooth structure and a strong and durable bond [10,24]. Moreover, Mine showed chemical bonding of Silorane primer to the hydroxyapatite crystals [33].
On the other hand, Kalore showed low polymerization shrinkage due to the presence of DX511 monomer (a monomer with high molecular weight and low number of C=C double bonds) [16,17].
The combination of low polymerization shrinkage of Kalore and the strong bond produced by Clearfil SE bond decreased gingival microleakage.
The results of this study showed no significant differences in microleakage among four groups at the occlusal margin, which is in agreement with previous studies [23,24].
Despite the differences in microleakage between the four groups at the gingival margin, statistically significant differences were only detected in microleakage between Silorane and Aelite. This finding is in accord with the results of previous studies [32,34].
Boaro evaluated the microleakage of five low shrinkage composites (Aelite, Heliomollor, Venus Diamond, Filtek Z250 and Silorane) in cylindrical cavities of the bovine incisors and reported that the microleakage of Aelite was higher than others [31], which is in concord with the current study results.
Calherios evaluated the microleakage and polymerization contraction stress of low-shrinkage composites and reported that Aelite LS had significantly higher stress than other tested composites. Moreover, the microleakage of Aelite was higher than that of other groups. This finding was consistent with our results.
According to Hooke's law, polymerization contraction stress is determined by the volumetric shrinkage and the elastic modulus of the material [14] and these properties are affected by the filler content. Although composites with higher filler content present lower volumetric shrinkage, their high elastic modulus and stiffness due to their high filler content result in higher stress levels [32].
Since the visco-elastic properties, rather than volumetric shrinkage, is considered as the most influential factor on stress development, the higher microleakage of Aelite may be explained by its higher elastic modulus and stiffness due to its high filler content. Its high stiffness offsets its low shrinkage, resulting in high contraction stress values. In fact in Aelite, addition of high filler levels in order to reduce resin volume is not an efficient approach for reducing post-gel shrinkage and polymerization stress [31,32].
However, the different polymerization mechanism (cationic ring-opening) in Silorane and the presence of DX511 monomer (a monomer with high molecular weight and low number of C=C double bonds) in Kalore result in lower polymerization contraction stress and microleakage [16,17,35].
In the current study, there were no statistically significant differences in microleakage between Silorane, Kalore and Grandio; which is in agreement with the results of previous studies reporting that Silorane was not superior to other composites in terms of microleakage [10-13].
However, Bagis et al. evaluated the microleakage of Class II composite restorations and reported that no microleakage was found in specimens restored with Silorane-based composites. The situation was significantly different for specimens restored with Grandio [9]. This finding was not in agreement with the current study results.
Hooshmand et al. evaluated the microleakage of five composites (TetricEvoCeram, Spectrum TPH, TetricCeram, Ormocer and Silorane) and reported that the degree of microleakage at the gingival margins for the Filtek Silorane was significantly lower than that of Ceram X (Ormocer) and Spectrum TPH [36]. Their results were not in accord with ours either.
Al-Boni evaluated the microleakage of Class I composite restorations (Filtek P90, Filtek Z250, Amelogen Plus) and reported that the degree of microleakage for the Filtek Silorane was significantly lower than the others [37]. In the current

study, Silorane exhibited the lowest degree of microleakage but this was only significantly different from specimens restored with Aelite.

Such different results may be explained by the differences in composite and bonding type, cavity type and microleakage scores.

Another possible explanation is the formation of oxygen inhibition layer due to the curing of Silorane primer before the application of bonding agent. This layer is formed at the primer/bond interface and can be observed in Micro-Raman Spectroscopy as an intervening zone of circa 1 um; which may act as a weak link in the bonding system [38] (but it is controversial).

Moreover, as the aim of the current study was to compare the microleakage of different low-shrinkage composites, in order to eliminate the variable of bonding type, Clearfil SE bond that serves as the “gold-standard” adhesiveinits class [21] was used to represent a methacrylate-based composite.

Clearfil SE bond as a two-step self-etch adhesive with an approximate pH of 2(39)contains the functional monomer 10-MDP, which has two hydroxyl groups that also may bind to calcium [40].

Furthermore, 10-MDP causes minimal dissolution of smear plugs and limited opening of tubules, thus reducing dentin permeability [41]. A recent study reported that MDP had the ability to adhere to hydroxyapatite tightly. Furthermore, its calcium salt hardly dissolved in water. According to the researchers, lower dye penetration observed in specimens bonded with Clearfil SE Bond might be explained by the different chemical composition of the self-etch adhesive [39].

Conclusion

Silorane was not superior to the conventional low-shrinkage methacrylate-based composites except for Aelite.

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