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Polymerization Shrinkage of Different Types of Composite Resins and Microleakage With and Without Liner in Class II Cavities

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Clinical Relevance

The use of RMGIC liner with composite resin restorations reduces microleakage. The silorane-based composite showed lower volumetric polymerization shrinkage than methacrylate-based composites.

SUMMARY

Aim: To determine the volumetric polymerization shrinkage of four different types of composite resin and to evaluate microleakage of these materials in class II (MOD) cavities with and without a resin-modified glass ionomer cement (RMGIC) liner, in vitro.

Materials and Methods: One hundred twenty-eight extracted human upper premolar teeth were used. After the teeth were divided into eight groups (n=16), standardized MOD cavities were prepared. Then the teeth were restored with different resin composites (Filtek Supreme XT, Filtek P 60, Filtek Silorane, Filtek Z 250) with and without a RMGIC liner (Vitrebond). The restorations were finished and polished after 24 hours. Following thermocycling, the teeth were immersed in 0.5% basic fuchsin for 24 hours, then midsagitally sectioned in a mesiodistal plane and examined for microleakage using a stereomicroscope. The volumetric polymerization shrinkage of materials was measured using a video imaging device (Acuvol, Bisco, Inc). Data were statistically analyzed with Kruskal-Wallis and Mann-Whitney U-tests.

Results: All teeth showed microleakage, but placement of RMGIC liner reduced microleakage. No statistically significant differences were found in microleakage between the teeth restored without RMGIC liner ($p>0.05$). Filtek Silorane showed significantly less volumetric polymerization shrinkage than the methacrylate-based composite resins ($p<0.05$).

Conclusion: The use of RMGIC liner with both silorane- and methacrylate-based composite resin restorations resulted in reduced microleakage. The volumetric polymerization

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shrinkage was least with the silorane-based composite.

INTRODUCTION

Interest in esthetic dentistry has resulted in composite resin restorations being increasingly used not only as a replacement material for failed or unesthetic amalgams but also as the first choice to restore posterior teeth.[1] Mechanical performance, wear resistance, and esthetic potentials of composite resins have significantly improved over the past few years. On the other hand, polymerization shrinkage of composite resins remains a challenge and still imposes limitations in the application of direct techniques.[2]

Polymerization shrinkage causes detachment of the enamel margins and/or can form gaps that result in marginal microleakage that allows the passage of bacteria, fluids, molecules, or ions between the cavity surface and composite resin.[3] Microleakage of posterior composite restorations is a matter of concern to the clinician, especially at the margins of the proximal box of class II cavities, as it leads to staining at the margins of restorations, recurrent caries, hypersensitivity, and pulp pathology.[4]

Packable composites are claimed to eliminate some of these shortcomings. Increased filler loading of these materials gives them a different consistency compared with hybrid composites. They are recommended for use in stress-bearing posterior regions and offer improved handling properties, such as increased sculptability and handling characteristics similar to amalgam restorations, and produce acceptable interproximal contacts. These allow them to be safely and successfully used in class II restorations.[5,6]

Recently, because of an increasing demand for a universal restorative material indicated for all types of direct restorations, including posterior teeth, a new category of resin composite was developed named nanofilled composites. Short-term (one-year) clinical studies have revealed that nanocomposites show high translucency, high polish, and polish retention similar to those of microfilled composites while maintaining physical properties and wear resistance equivalent to those of several hybrid composites[7] and exhibit sufficient compressive strength and wear resistance to justify their use in high stress-bearing areas, such as the occlusal surfaces of posterior teeth.[8]

To overcome the problem of polymerization shrinkage, extensive efforts have been invested over the years to develop low-shrinkage composite resins. As a result, dental composite research has focused on the use of ring-opening systems like oxirane-based resins cured under visible light conditions. Weinmann and others[9] described the synthesis of a new monomer system named silorane obtained from the reaction of oxirane and siloxane molecules. The novel silorane-based resin is claimed to have combined the two key advantages of the individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species.

Reduction of polymerization shrinkage can be achieved by reducing the mass of the restorative material with the use of liners. Use of glass ionomer liners under composite resins has reduced the stresses generated at the cavity walls during polymerization.[10] Resin-modified glass ionomer cements (RMGICs) might be a better material of choice for the liner because of their higher mechanical strength compared to the conventional material and their ability to set on command. They are also known to be less technique sensitive. Furthermore, RMGICs have been recommended as liners under resin composites to reduce the amount of polymerization shrinkage, potential microleakage, and secondary caries.[11-13]

The current study aimed to assess the volumetric polymerization shrinkage of four different composite resins and their microleakage in MOD cavities, with and without an RMGIC liner, *in vitro*. The tested hypothesis of the study was that placement of RMGIC liner under the composite resin restorations results in reduced microleakage, and silorane-based composite resin shows lower volumetric polymerization shrinkage than methacrylate-based composite resins.

MATERIALS AND METHODS

Selection of Teeth

One hundred twenty-eight upper premolar teeth, extracted for orthodontic purposes, were selected. The teeth were free from caries, hypoplastic defects, and cracks on visual examination. The teeth had been stored in distilled water for a maximum of three months prior to use. Using a hand scaler, calculus deposits were carefully removed and the teeth were stored in water at room temperature (23 ± 1°C) except when aspects of the experimental procedure required isolation from moisture.

Table 1: *Composite Resins Used in the Current Study*

Product	Batch Number	Ingredient	Manufacturer
Filtek Supreme XT Nanofilled Composite Resin	20080117	Inorganic fillers (59.5%), bis-GMA, UDMA, bis-EMA, TEGDMA, silica nanofillers (5-7 nm), zirconia/silica nanoclusters (0.6-1.4 μm)	3M ESPE
Filtek P60 Packable Composite Resin	20081004	Inorganic fillers (61%), bis-GMA, UDMA, bis-EMA, zirconia/silica nanofillers (0.01-3.5 μm)	3M ESPE
Filtek Z250 Hybrid Composite Resin	20090406	Inorganic fillers (60%), bis-GMA, UDMA, bis-EMA, zirconia/silica nanofillers (0.01-3.5 μm)	3M ESPE
Filtek Silorane Low Shrink Composite Resin	N105399	Inorganic fillers (55%), hydrophobic resin matrix	3M ESPE

Cavity Preparation

The teeth were divided into eight groups of 16 teeth, and standardized large MOD cavities were prepared whereby the bucco-palatal width (BPW) of the proximal box of each cavity was prepared to two-thirds of the BPW of the tooth and the occlusal isthmus was prepared to half the BPW. The cavity depth at the occlusal isthmus was also standardized to 3.5 mm from the tip of palatal cusp and 1 mm above the cementoenamel junction at the cervical aspect of the proximal boxes. The cavosurface margins were prepared at 90 degrees, and all internal line angles were rounded. The facial and lingual walls of the cavity were also prepared parallel to each other in accordance with a previously reported procedure.[11,14] Diamond fissure burs (DIATECH, Heerbrugg, Switzerland) were used in a high-speed hand piece with water coolant and changed after every five cavity preparations.

Restorative Procedures

All the teeth were restored with the same manufacturer's composite resin and its associated bonding system in accordance with the manufacturer's instructions and light cured by light-emitting diode (Radi Plus, SDI, Victoria, Australia). The cavity preparations and restorative procedures were conducted by the same dentist. The composite resins used in this study are listed in Table 1.

Group 1: Etching of enamel and dentin was performed with 35% phosphoric acid (Scotchbond, 3M ESPE, St Paul, MN, USA) according to the manufacturer's instructions. Two consecutive coats of Adper Single Bond 2 (3M ESPE) were applied using a microbrush for 15 seconds, followed by gentle air drying and then light curing for 10 seconds. Filtek Supreme XT (Shade A3B) was placed and light cured for 20 seconds.
Group 2: Teeth were restored with Filtek P60 (Shade A3) as previously described.
Group 3: Teeth were restored with Filtek Z250 (Shade A3) as previously described.
Group 4: Silorane Adhesive System primer (3M ESPE) was applied using a microbrush for 15 seconds, followed by gentle air drying and then light curing for 10 seconds. After that the Silorane Adhesive system bond (3M ESPE) was applied, followed by a gentle stream of air, and light cured for 10 seconds. Filtek Silorane (Shade A3) was placed and light cured for 20 seconds.
Group 5: Teeth were lined with a thin layer of Vitrebond (3M ESPE) on the pulpal and axial walls with approximately 1-mm thickness and light cured for 30 seconds. Then the teeth were restored with Filtek Supreme XT (Shade A3B) using the same method as for group 1.
Group 6: Teeth were restored with Filtek P60 (Shade A3) using the same method as for group 5.
Group 7: Teeth were restored with Filtek Z250 (Shade A3) using the same method as for group 5.
Group 8: Vitrebond was applied as previously described and teeth were restored with Filtek Silorane (Shade A3) using the same method as for group 4.

Eight nominally triangular increments of approximately 2-mm thickness were used to restore the teeth, three for each proximal box and two for the occlusal surface.[11,14,15] Each increment was cured for 20 seconds as per the manufacturer's instructions. The occlusal aspect of the restorations was carved to approximate the normal occlusal anatomy of an upper premolar tooth. Each tooth was restored by placing a transparent matrix (Auto matrix II, combination matrix intro-kit, Dentsply, Petrópolis, Brazil). The matrix band was held by finger pressure against the gingival margin of the cavity so that the preparations could not be overfilled at the gingival margin.[16] This also allowed the light to be directed only in an apical direction when curing the composite resin. The matrix band was removed after the restorations were completed. The restored teeth were finished with Sof-Lex Finishing discs (3M

ESPE) in a slow hand piece and 15-μm-grit finishing diamond burs (DIATECH) used in an air turbine hand piece under water coolant.

Thermocycling and Gingival Marginal Microleakage Evaluation

Root apices were sealed with a composite resin and polymerized for 20 seconds. All tooth surfaces were sealed with nail varnish, with the exception of a 1-mm band around the margins of each restoration, and the teeth replaced in water when the varnish dried. The specimens were thermocycled between two water baths maintained at 55 ± 1°C and 5 ± 1°C so that the restored teeth were submerged for 60 seconds with a 30-second transfer from water bath to water bath for the time equivalent for 1000 cycles.[17] The teeth were then immersed in 0.5% basic fuchsin dye for 24 hours, and a vertical section was made through each restored tooth midsagitally in a mesiodistal plane using a low-speed diamond blade (IsoMet, Buehler Ltd, Lake Bluff, IL, USA). Sectioned restorations were examined under a stereomicroscope (Olympus SZ 61, Olympus Corporation, Japan) at 40× magnification, and the extent of the gingival marginal microleakage was recorded. Accordingly, the degree of gingival margin microleakage was scored[18] as follows (Figure 1): 0 = no evidence of dye penetration, 1 = superficial penetration not beyond the dentinoenamel junction (DEJ), 2 = penetration beyond the DEJ but limited to two-thirds of the gingival wall length, and 3 = penetration beyond two-thirds of the gingival wall length. Two examiners scored the restorations independently, any discrepancies between them were reevaluated by both, and a consensus was reached. For each restoration, one score, by convention the worst, was used for the analyses.

Volumetric Polymerization Shrinkage Determination

Volumetric polymerization shrinkage was measured using a video imaging device (AcuVol, BİSCO, Inc, Schaumburg, IL, USA). This device has been described by Sharp and others[19] and provides data comparable to those obtained using a mercury dilatometer. Small semispherical samples of composites were manually formed and placed on the rotating pedestal of the AcuVol, in equal amounts, and left undisturbed for 10 minutes to take their final shape (n=16). After 10 minutes, they were light cured following the manufacturer's instructions. Shrinkage values were recorded continuously for 10 minutes after curing, and the final shrinkage value was recorded as percent shrinkage. Five values were taken for each material, and the mean values were calculated and used for evaluation.

Statistical Analysis

The microleakage scores and volumetric polymerization shrinkage data were statistically analyzed using a nonparametric one-way analysis of variance (Kruskal-Wallis) test followed by paired group comparisons using a Mann-Whitney U-test. Statistical significance was set in advance at the 0.05 confidence level. All data were analyzed by means of SPSS 11.5 for Windows (SPSS Inc, Chicago, IL, USA).

RESULTS

The microleakage scores for the different composite resins with and without RMGIC liner are shown in Table 2. None of the groups showed complete prevention of dye penetration. Group 7 showed the best marginal sealing. Although groups 5, 6, and 8 showed similar results ($p>0.05$), they were superior to groups 1 to 4 ($p<0.05$). No statistically significant differences were found in microleakage between the teeth restored without RMGIC liner ($p>0.05$).

When comparing each group individually, microleakage was lower in the groups in which RMGIC liner had been used. Filtek Supreme XT and Filtek Z250 with RMGIC liners had significantly less microleakage than those without liners ($p<0.05$).

The mean volumetric polymerization shrinkage values for the composite resins used in this study are shown in Table 3. The rate of shrinkage was least with Filtek Silorane and highest with Filtek P60, and these values were significantly different than those of all the other materials ($p<0.05$).

DISCUSSION

Microleakage is one of the most common problems of composite resin restorations, especially at the margins of the proximal box of class II cavities. Microleakage may result from many factors, including adaptation of resin material to the tooth surface, the adhesive system used, and polymerization shrinkage of materials used.[20,21]

Dye penetration is one of the most frequently used methods to evaluate microleakage.[21,22] In the current study, a dye penetration test was used because it is simple and relatively cheap and provides quantitative and comparable results. This method does have some limitations, however, such as

Table 2: *Gingival Microleakage Scores of Groups Evaluated*

Groups	n	Microleakage Scores				Mean ± SD
		0 (%)	1 (%)	2 (%)	3 (%)	
Group 1 (Filtek Supreme XT)	16	0 (0)	11 (68.75)	3 (18.75)	2 (12.5)	1.44 ± 0.72
Group 2 (Filtek P60)	16	1 (6.25)	8 (50)	4 (25)	3 (18.75)	1.56 ± 0.89
Group 3 (Filtek Z250)	16	1 (6.25)	9 (56.25)	5 (31.25)	1 (6.25)	1.38 ± 0.71
Group 4 (Filtek Silorane)	16	2 (12.5)	9 (56.25)	3 (18.75)	2 (12.5)	1.31 ± 0.87
Group 5 (Vitrebond + Filtek Supreme XT)	16	6 (37.5)	8 (50)	2 (12.5)	0 (0)	0.75 ± 0.68
Group 6 (Vitrebond + Filtek P60)	16	3 (18.75)	11 (68.75)	2 (12.5)	0 (0)	0.94 ± 0.57
Group 7 (Vitrebond + Filtek Z250)	16	6 (37.5)	10 (62.5)	0 (0)	0 (0)	0.63 ± 0.50
Group 8 (Vitrebond + Filtek Silorane)	16	3 (18.75)	9 (56.25)	3 (18.75)	1 (6.25)	1.13 ± 0.80

subjectivity of reading and high diffusability of dyes due to their low molecular weight.[23]

In vitro evaluation of restorative materials fails to simulate the intraoral thermal changes during eating and drinking. Thermocycling is a widely acceptable method used in microleakage studies to simulate the effects that restorations are subjected to in the mouth.[20,24,25] Some researchers, however, consider it a questionable method since the temperatures used may not be the real temperatures of hot and cold beverage tolerated by patients.[26-28]

The results of the present study highlighted that microleakage was similar between the teeth restored without RMGIC liner. In agreement with this, Hardan and others[29] and Sadeghi[30] have reported that Filtek Supreme and Filtek Z250 showed similar microleakage in class II cavities. The results of our study also agree with those reported by Fleming and others[31] and Tredwin and others,[16] who found similar marginal adaptation and microleakage using Filtek P60 and Filtek Z250 in class II cavities.

In the current study, when compared with methacrylate-based composite resins, Filtek Silorane did not significantly reduce the amount of microleakage, contrary to other studies.[32-34] In accordance with our results, Ernst and others[35] also reported similar microleakage results with silorane- and methacrylate-based composite resins.

The methods utilized in the current study during composite resin placement replicated those commonly used in clinical practice. Different microleakage scores were obtained in the current study than other reported scores, probably because of differences in experimental design.

Several methods have been developed to improve marginal sealing and reduce microleakage. The use of RMGIC liners under composite resin restorations is one of these methods because of the stress-buffering capacity of these materials to resist the debonding stress during polymerization contraction. The use of liners may also reduce the effects of C-factor (the ratio of bonded to unbonded surfaces) and lower the internal stresses within the placed restoration. However, the benefit of using RMGIC liners under composite resin restorations for reducing polymerization shrinkage and microleakage is still controversial. While some researchers[36,37] have reported that using RMGIC liners failed to reduce gap formation and marginal sealing, some have reported significant effects of RMGIC liners in reducing microleakage.[38,39] In the current study, RMGIC liner usage resulted in less gingival microleakage regardless of the composite resin used.

The polymerization reaction was accompanied by a dimensional change that resulted in shrinkage for all composite resins used in the current study. As expected, Filtek Silorane shrank less than the methacrylate-based composite resins. Cationic ring opening polymerization of the cycloaliphatic oxirane moieties is the reason for silorane-based composites' low shrinkage and low polymerization stress. The cationic cure starts with the initiation process of an acidic cation, which opens the oxirane ring and generates a new acidic center, a carbocation. After the addition of an oxirane monomer, the epoxy ring is opened to form a chain, or, in the case of two- or multifunctional monomers, a network is formed.[9]

Table 3: *Mean Shrinkage and Standard Deviation (SD) of the Restorative Materials Evaluated*

Material	Mean Shrinkage ± SD
Filtek Supreme XT	1.75^{a} ± 0.06
Filtek P60	1.97^{b} ± 0.02
Filtek Z250	1.75^{a} ± 0.04
Filtek Silorane	0.88^{c} ± 0.04

Mean values exhibiting different superscript letters were significantly different.

Despite lower volumetric polymerization shrinkage values, Filtek Silorane did not yield the lowest scores for dye penetration. If only contraction stresses determined the extent of microleakage, Filtek Silorane was expected to show the best sealing ability. This result could be related to the adhesive systems used. There are conflicting results about the effectiveness of different adhesive systems on microleakage. While some authors have reported that etch-and-rinse and self-etch adhesives produce similar results in terms of marginal adaptation and microleakage,[40,41] some of them reported higher dye penetration scores with the use of self-etch adhesives.[42-44] In the current study, the same manufacturer's composite resin and its associated bonding system was used in accordance with the manufacturer's instructions. A self-etch adhesive system (Silorane System Adhesive) and an etch-and-rinse adhesive system (Adper Single Bond 2) was used with Filtek Silorane and the methacrylate-based composite resins, respectively.

CONCLUSION

Within the limitations of this *in vitro* study, the hypothesis was accepted in that the use of RMGIC liner as the first gingival increment of class II restorations with both silorane- and methacrylate-based composite resin restorations resulted in reduced microleakage. The volumetric polymerization shrinkage was least with the silorane-based composite. However, further clinical research is needed to support these findings, as the volumetric polymerization shrinkage of the restorative materials was evaluated without cavity factor and bonding influences.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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