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Comparative Evaluation of Microleakage of Silorane-based Composite and Nanohybrid Composite With or Without Polyethylene Fiber Inserts in Class II Restorations: An In Vitro Study

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Clinical Relevance

Fiber inserts incorporated at the gingival floor of class II composite restorations resulted in a highly significant reduction of microleakage. Also, silorane composites based on a ring-opening mechanism showed reduced microleakage.

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SUMMARY

Aim: To evaluate microleakage between nanocomposite and silorane composite in class II restorations with or without a polyethylene fiber insert.

Methodology: Standardized class II cavities were prepared on extracted molars and randomly divided into 4 groups (n=20 each): group 1, Ceram X mono; group 2, Ceram X mono + Ribbond; group 3, Filtek P90; and Group 4, Filtek P90 + Ribbond. All specimens were subjected to a thermocycling regime, immersed in 2% methylene blue dye for 24 hours,

sectioned longitudinally, and examined under a stereomicroscope to assess dye penetration on a six-point scale. The score data were subjected to statistical analysis whereby Kruskal-Wallis analysis of variance was used for multiple group comparisons and the Mann-Whitney test for groupwise comparisons at a significance level of $p \leq 0.05$.

Results: A statistically significant decrease in microleakage was found when Ribbond fiber was used with nanoceramic and silorane composite. A highly significant decrease in microleakage scores was found in silorane composite when compared to nanoceramic composite.

Conclusion: Use of polyethylene fiber and silorane composite reduces microleakage in class II composite restorations with gingival margins below the cemento-enamel junction.

INTRODUCTION

Dental resin composites have become the most popular and widely used direct restorative material in today's clinical dentistry.[1,2] Although composites are now the material of choice for most restorations, the polymerization shrinkage of 2.6%-7.1% and, thus, microleakage is one of the most frequently encountered problems, especially at gingival margins placed apical to the cemento-enamel junction, as in deep class II cavities[3–5]

Microleakage has led to the development of recurrent caries, postoperative sensitivity, enamel fracture, marginal staining, and eventual failure of restorations.[6] Various studies have reported efforts to develop methods to decrease this problem by slowing down the composite polymerization rate,[7] using an incremental placement technique[8] or low modulus intermediate layer,[9] and reducing the C factor (the ratio of bonded to unbonded restoration surfaces).[10]

Ribbond fibers are bondable, reinforced, patented Leno Weave, ultrahigh strength polyethylene fibers.[11] A high modulus of elasticity and lower flexural modulus of the polyethylene fiber was reported to have a modifying effect on the interfacial stresses developed along the etched enamel-resin boundary. By embedding a polyethylene fiber into the bed of a composite before restoration, higher microtensile bond strength could be achieved in prepared cavities with a high C factor.[12] Also, it will reduce the total amount of resin matrix required to restore the cavity, and their strength will help decrease the shrinkage.[4,13]

Siloranes make up a new category of composite resin matrix based on ring-opening monomers obtained from the reaction of oxirane and siloxane molecules. The volumetric shrinkage of silorane-based composite was determined to be 0.99 vol % using Archimedes' method.[14] Reduced shrinkage in silorane is due to opening and extending the oxirane rings during polymerization, compensating for volume reduction.[1,14]

This study determined the effect of polyethylene fiber inserts and silorane composites on reducing the gingival microleakage in class II composite restorations placed apical to the cemento-enamel junction and comparing it with nanoceramic composite.

MATERIALS AND METHODS

Eighty extracted intact mandibular first and second molars were selected, cleaned with a periodontal scaler (Satelec, Gustave Eiffel, BP, France), and stored in 0.5% chloramine T solution for 1 month.

All the teeth were embedded in poly (vinyl) siloxane impression material such that it was 2 mm below the cemento-enamel junction, and standardized mesio-occlusal/disto-occlusal class II cavities were prepared using round bur No 4 and No. 245 straight fissure diamond burs (Mani Inc.,Utsunomiya, Tochigi, Japan) in a high-speed air-turbine hand piece (NSK, Tochigi-Ken, Japan) with copious water irrigation (burs were replaced after every eight preparations) to the following dimensions ($\pm$0.3 mm): 2.0-mm occlusal isthmus depth, 5.0-mm facio-lingual proximal box width occlusally and 5.5 mm gingivally, 2.5-mm pulpal-proximal box depth occlusally and 1.5 mm gingivally, and 6.0- to 8.0-mm proximal box height but always terminating 1.0 mm below the cemento-enamel junction.

The dimensions were verified with help of a UNC-15 periodontal probe. No bevels were placed at cavosurface margins.

Prepared teeth were randomly divided into four groups (n=20) as described below. A universal Tofflemire retainer (API, Schweinfurt, Germany) with matrix band (Hahnenkratt, Benzstrasse, Germany) was placed around each prepared tooth and supported externally by applying low-fusing compound (DPI Manufacturers Inc, Mumbai, India).

Group 1

Teeth were restored with Prime & Bond NT and Ceram X (Dentsply DeTrey GmbH, Germany). After application of etching gel (Dentsply Caulk, GmbH, Germany) for 15 seconds, the cavity was blot dried, leaving a moist surface. Prime & Bond NT was applied twice to thoroughly wet all the cavity surfaces for 20 seconds. The cavity was gently air dried for 5 seconds to evaporate solvent carrier followed by light curing for 10 seconds with a halogen light-curing unit (Unicorn Med., Korea). Ceram X was dispensed directly into the prepared cavity in 2-mm increments by the oblique layering method; starting in the proximal box, the first increment was placed at a 45-degree angle to the facio-gingivo-proximal line angle and cured for 40 seconds. Next, increments were placed and packed at the linguo-proximal box and finally in the occlusal portion of the box and the isthmus and cured for 40 seconds. After removal of the band, the composite was cured from all the sides again for 40 seconds.

Group 2

Teeth were restored with Prime & Bond NT, Ceram X, and Ribbond fibers (Ribbond, Inc, WA, USA). Acid etching and bonding was similarly carried out as in group 1. But before restoration with Ceram X, a <1-mm-thick amount of Ceram X was first placed on the gingival floor. Then one Ribbond fiber insert, approximately 1 mm less than the bucco-lingual dimension of the proximal box, was cut, impregnated with Prime & Bond NT, and condensed into the bed of −1mm composite resin and light cured for 40 seconds. Then Ceram X was dispensed into the remainder of the prepared cavity in 2-mm increments using the oblique layering technique as in group 1.

Group 3

Teeth were restored with P90 system adhesive self-etch primer + P90 system adhesive bond + Filtek P 90 (3M ESPE, St Paul, MN, USA). After each cavity was cleaned with a water spray and blot dried, P90 system adhesive self-etch primer was applied to the cavity surfaces for 15 seconds, followed by gentle air dispersion and light curing for 10 seconds. P90 system adhesive bond was applied to wet all the cavity surfaces, followed by gentle air dispersion and light curing for 10 seconds. Filtek P90 was dispensed directly into the prepared cavity in 2-mm increments by the oblique layering method similarly to that of Ceram X in group 1.

Group 4

Teeth were restored with P90 system adhesive self-etch primer + P90 system adhesive bond + Filtek P 90 + Ribbond Fibers. Acid etching and bonding was similarly carried out as in group 3. But before restoration with Filtek P90, one Ribbond fiber insert was placed at the gingival floor similar to that in group 2, and Filtek P90 was dispensed into the remainder of the prepared cavity in 2-mm increments using the oblique layering technique as in group 1.

A similar shade (B1) was used for all the materials. The intensity of the light-curing unit was measured as 800 mW/cm^2 using an intensity meter (Optilux radiometer, Kerr Corp, Sybron Dental Specialties, Orange, CA, USA).

All restorations were finished with a graded series of aluminum oxide discs (Sof-Lex TM, St Paul, 3M ESPE) according to manufacturer's instructions and were subjected to thermocycling according to the International Organization for Standardization (ISO) standard 11405[21] for 500 cycles at 5°C-55°C with a 30-second dwell time.

For microleakage evaluation, the apical 2 mm of each tooth was sectioned, retrograde cavity prepared, and sealed with resin-modified glass ionomer cement (GC Fuji II LC, GC Corp, Tokyo, Japan). Also, teeth were coated with two layers of nail varnish (Sunshine Cosmetics, Metoda, India) except for an area 1 mm around the gingival cavosurface margin of the restorations. Specimens were then immersed in 2% methylene blue dye buffered at pH=7 (Merck Specialties Private Ltd,, Mumbai, India) at 37°C for 24 hours, washed, and dried. All the teeth were mounted on acrylic blocks and longitudinally sectioned mesio-distally from the center of the restoration with a diamond disk (Sunshine Diamonds, Langenhagen, Germany) at a low speed and with continuous irrigation of water.

Dye penetration was evaluated at the gingival margin with a stereomicroscope (Motic Microscopes, China) at 40× magnification, and microleakage was scored according to the six-point scale used in the study by El-Mowafy and others[4] and as described in Table 1.

The median of the scores were subjected to statistical analysis using the nonparametric Kruskal-Wallis analysis of variance test and the Mann-Whitney test at a 95% significance level. Statistical analysis was done using the SPSS 11.0 program (SPSS Inc, Chicago, IL, USA).

RESULTS

Descriptive statistics, including the mean ranks and median leakage scores, are shown in Table 2. The Kruskal-Wallis test revealed highly significant dif-

Table 1: *Definition of Dye Penetration Scores*

Scores	Definition
0	No dye penetration
1	Dye penetration extending to the outer half of the gingival floor
2	Dye penetration extending to the inner half of the gingival floor
3	Dye penetration extending through the gingival floor up to one-third of the axial wall
4	Dye penetration extending through the gingival floor up to two-thirds of the axial wall
5	Dye penetration extending through the gingival floor up to full length of the axial wall

ferences in microleakage scores among the groups (p=0.000).

The Mann-Whitney U-test was used to make a pairwise comparison between the four studied groups, and it showed a significant decrease in microleakage scores when a Ribbond fiber insert was used; that is, group 2 showed a significant decrease in microleakage (p=0.020) when compared to group 1, and group 4 showed a significant decrease in microleakage (p=0.014) when compared to group 3 (Table 3).

Also, the Mann-Whitney U-test showed a highly significant decrease in microleakage scores in the silorane composite groups compared to the nanoceramic composite groups; that is, groups 3 and 4 showed a highly significant decrease in microleakage (p<0.01) when compared to groups 1 and 2 (Table 3). Referring to mean rank values (Table 1), we can also conclude that group 4 had the least microleakage and that group 1 has the maximum microleakage scores. Figure 1 shows microleakage scores in representative specimens of test groups under a stereomicroscope.

DISCUSSION

Microleakage of composite restorations occurs because of stresses placed along the tooth/restoration interface from polymerization shrinkage, temperature fluctuations in the oral environment, and mechanical fatigue through repetitive masticatory loading.[15] Previous studies reported that composite restorations showed relatively greater microleakage at gingival rather than occlusal margins.[3,4] The most likely cause for this phenomenon is polymerization contraction, which is toward the "stronger" enamel-composite joint and the light source.[4,10]

The incremental oblique layering placement of light-activated composites has been recommended to decrease overall contraction and residual stresses at the tooth/restoration interface and thus to decrease microleakage by reducing the bulk of material cured at one time.[8,13] In the present study, the oblique layering technique for incremental placement of composite described by Tjan and others[8] was used for placing the restorations.

The various methods to detect microleakage include the dye leakage method, the use of color-producing microorganisms, radioactive isotopes, the air pressure method, neutron activation analysis, electrochemical studies, scanning electron microscopy, thermal and mechanical cycling, and chemical tracers.[16] Since there is no gold standard method for

Table 2: *Descriptive Statistics of Kruskal-Wallis Test*

Groups	N	Mean Rank	Chi-Square	Degree of Freedom	*p*-Value	Significant Difference?
Group 1 (Ceram X)	20	33.40	30.765	3	0.000	Yes
Group 2 (Ceram X + Ribbond)	20	26.60				
Group 3 (Filtek P90)	20	14.50				
Group 4 (Filtek P90 + Ribbond)	20	7.50				
Total	80					

Table 3: *Mann-Whitney U-Test Exhibits Significant Difference Between Groups*

Group	Group	*U*-Value	*p*-Value (Two Tailed)	Significant Difference?
Group 1 (Ceram X)	Group 2 (Ceram X + Ribbond)	20.500	0.020	Yes
Group 1 (Ceram X)	Group 3 (Filtek P90)	0.500	0.000	Yes
Group 1 (Ceram X)	Group 4 (Filtek P90 + Ribbond)	0.000	0.000	Yes
Group 2 (Ceram X + Ribbond)	Group 3 (Filtek P90)	8.500	0.001	Yes
Group 2 (Ceram X + Ribbond)	Group 4 (Filtek P90 + Ribbond)	1.000	0.000	Yes
Group 3 (Filtek P90)	Group 4 (Filtek P90 + Ribbond)	19.000	0.014	Yes

microleakage evaluation, we used the dye leakage method because it did not require the use of complex laboratory equipment and because it is nondestructive, thus allowing the longitudinal study of restorative margins.[17] However, concerns have been raised, as there is lack of evidence supporting any correlation between clinical testing and in vitro dye penetration testing.[18]

Researchers suggested the use of a dye with a particle diameter equal to the bacterial size or somewhat smaller (around 2 μm).[19] For this reason, we used in our study a 2% solution of the methylene blue molecule (one methylene blue molecule = 1.2 $nm^2 = 120A^{0.2}$), of which the particle size is less than that of the bacterial one.[19] Also, methylene blue dye provides an excellent contrast with the surrounding environment along with a perfect and easy visualization of the prepared cavity in the digital images, which gives the evaluators a clear reference point from which to score. Moreover, as methylene blue is normally acidic (pH=3), it may demineralize enamel and dentin, generating more microleakage; hence, the solution was buffered to pH=7. Storage time for dye penetration varies from 10 seconds to 180 days. An extended penetration time might become a problem in more hydrophilic, self-etching adhesives, as they might absorb water and dye to a higher extent than conventional etch and rinse adhesives. Ernst and others[20] showed that a 30-minute dye penetration time seems to be suitable for marking marginal gaps. Nevertheless, a penetration time of 24 hours is mostly used in the literature for in-depth determination of marginal gaps.[2,20] As methylene blue is a delicate dye substance that is not stable in the presence of acidic and basic substances as well as when it is exposed to ambient light, in this study care was taken to ensure that the results were not influenced by the reaction of acidic or basic monomers that are in the adhesive systems by buffering the solution to pH=7 and penetration time of 24 hours.

For thermocycling, the temperature range of 5°C-55°C with a dwell time of 30 seconds for 500 cycles was used according to the ISO TR11405 standard,[21] and this is the estimate of the range that has been reported on the surfaces of molar teeth in the mouth of the patient.

The results showed a significant decrease in microleakage at the gingival margin when Ribbond

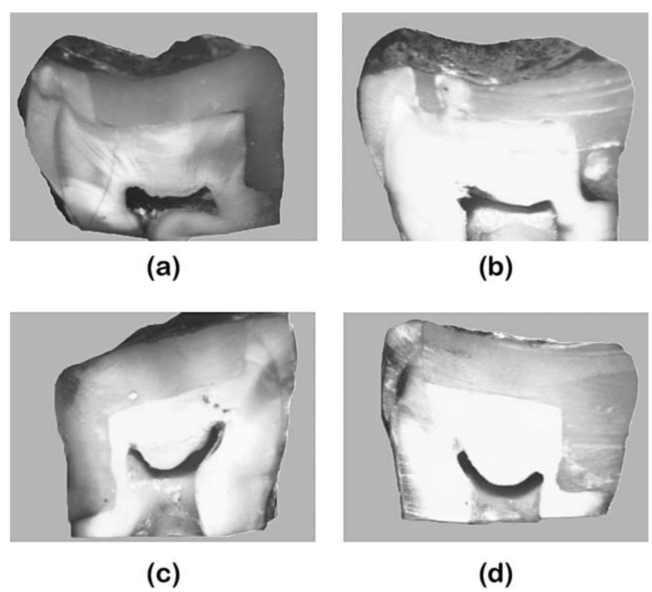

Figure 1. *(a) Representative specimen from Group 1 showing score 5 (b) Representative specimen from Group 2 showing score 3 (c) Representative specimen from Group 3 showing score 2 (d) Representative specimen from Group 4 showing score 0.*

fibers were incorporated. Placement of a fiber insert reduces gingival microleakage, as it replace part of the composite increment at this location, resulting in a decrease in overall volumetric polymerization contraction.[4,13] Also, fibers assist the initial increment of composite in resisting pull-away from the margins toward the curing light.[4,13] The fibers also have the strengthening effect of a composite margin, increasing resistance to the dimensional change or deformation that occurs during thermal and mechanical loading and hence improving marginal adaptation.[22] Studies conducted by El-Mowafy and others[4] and Ozel and Soyman [13] also showed that insertion of fiber insert reduces the gingival microleakage in class II composite restorations. In contrast, Belli and others[9] showed that there is a reduction in microleakage only at the occlusal margins and not at the gingival margins after placing the fiber inserts. One reason for such a contrasting result might be that all the restorations placed in this study were in bulk rather than incrementally placed.

The results of our study also showed a highly significant decrease in microleakage score found in cavities restored with silorane composite compared to nanoceramic composite. This might be attributed to the inherent ring-opening polymerization of silorane monomers, which can compensate for volume reduction as molecules come closer to each other, compared to radical polymerization of other composites, which is linear polymerization, manifested as a reduction in polymerization shrinkage stress at the tooth/restoration interface.[23,24] Studies conducted by Bagis,[23] Al-Boni and Raja,[24] and Yamazaki[25] also proved that microleakage with silorane is lower than that of methacrylate-based composites. These results contrast with those of Ernst,[20] who proved that microleakage of teeth restored with silorane is similar to that restored with methacrylate composites. The reason for this could be that the author had used an all-in-one (seventh generation) experimental bonding agent of silorane previously produced by the company, and in the present study, the new bonding agent produced with silorane, which is a two-step, two-component bond (sixth generation) is used, thereby giving different results.

The modulus of elasticity of the restorative material can also be considered one of the causes of marginal microleakage, thus the importance of applying an intermediary layer with a low elasticity module or a stress breaker layer.[9] This layer would then provide enough flexibility to compensate for the tension generated by polymerization shrinkage. Thus, a higher modulus of elasticity and lower flexural modulus of the polyethylene fiber might have a modifying effect on interfacial stresses and result in decreased microleakage.[9]

Although these are *in vitro* results, they are of significance because these factors cannot easily be quantitatively determined *in vivo*. Nevertheless, further clinical studies are necessary to confirm these results and evaluate their relevance to treatment outcome.

CONCLUSION

Within the limitations of this study, it can be concluded that the use of polyethylene fiber inserts and silorane composite significantly reduces microleakage in class II resin composite restorations with gingival margins below the cemento-enamel junction compared to the methacrylate-based nanoceramic composite.

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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