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Microleakage of Class I and II Composite Resin Restorations Using a Sonic-resin Placement System

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Clinical Relevance

Bonding to intact enamel surfaces (Class I preparations) as opposed to dentin (cementum) surfaces appears to show superior results regardless of the material, C-factor, or insertion technique.

SUMMARY

Objectives: To determine microleakage of posterior Class I and II restorations using the SonicFill composite resin system.

Methods and Materials: Eighty previously extracted third molars were randomly assigned to four preparation/restoration groups (n=20): Group A: Class I preparations restored with SonicFill system/bulk fill; Group B: Class II preparations restored with SonicFill system/bulk fill; Group C: Class I preparations restored with Herculite Ultra composite resin/incremental technique; and Group D: Class II preparations restored with Herculite Ultra composite resin/incremental technique. Class I preparations were approximately 3.0 mm in width buccolingually and 3.0 mm in depth. Class II preparations were approximately 3.0 mm in width buccolingually, 1.5 mm in axial depth, and 4.0 mm in gingival depth. In all groups, the enamel and dentin surfaces were conditioned with Kerr 37.5% phosphoric acid, followed by application of Optibond Solo Plus adhesive system. Following restoration, the specimens were thermocycled, immersed in methylene blue dye, and embedded in acrylic resin. Specimen blocks were sectioned in the mesiodistal direction, with marginal dye pen-

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etration (microleakage) examined using a 20× binocular microscope. Class I and II restoration microleakage was scored separately using a 0-3 ordinal ranking system. Statistical analyses were conducted using nonparametric testing at the $p < 0.05$ level of significance.

Results: Significantly less microleakage was associated with both Class I restorative groups (A and C), SonicFill bulk fill and Herculite Ultra incremental fill, compared to the Class II restorative groups (B and D), SonicFill/bulk fill and Herculite Ultra/incremental fill.

Conclusions: According to the results of this study, the materials (SonicFill vs Herculite Ultra), C-factors, and insertion techniques (bulk vs incremental) did not appear to be significant influences with regard to marginal microleakage; however, the type of preparation cavity (Class I vs Class II) and the subsequent bonding surface (enamel vs dentin [cementum]) proved to be significant factors.

INTRODUCTION

One of the purposes of a dental restoration is to create a flawless seal at the material/tooth interface (margin), which should be resistant to contamination from oral fluids.[1,2] Composite resin has been increasingly utilized for the restoration of posterior cavity preparations in educational and private practice dental settings, as innovations regarding material sciences and preparation and insertion techniques have emerged.[3-5]

Leakage or microleakage occurs in conjunction with all dental restorations and has been defined as the "clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it."[1,6-8] This potentially destructive process is associated with several limiting factors, including material component (filler particle size/shape aggregates and resin loading) and physical characteristic variables (volumetric and postpolymerization shrinkage, modulus of elasticity, and thermal expansion); methods of polymerization; cavity preparation design parameters, and configuration factor, or "C-factor." Clinical variables include material manipulation and insertion techniques, isolation constraints (usage of dental rubber dam), and adequate knowledge of adhesive and composite resin science and applicable technique.[9-16] Composite resin, used as a posterior restorative, is significantly influenced by polymerization shrinkage with amounts ranging from 1.5% to 5%.[11] Shrinkage causes debonding of the material from tooth structure, precipitating clinical and radiographic sequelae including marginal staining and micro–gap formation (approximately 10 to 20 μm). This process, in turn, permits bacterial ingress with recurrent caries, sensitivity, possible pulpal inflammation, and, finally, restoration removal and reinsertion as final outcomes.[9,11,17]

Solutions for some of these specific material and clinical dilemmas have included the introduction of "packable" and "flowable" composites—allowing for enhanced adaptability of overlying materials; the usage of different insertion techniques (incremental vs bulk); and different restoration delivery methods (thermal and/or sonic energy).[15-23] However, many of these restorative solutions have shown conflicting results with regard to the effects on material shrinkage and marginal microleakage of contaminants.[15-23]

Recently, a composite delivery system together with a proprietary composite formulation has been introduced to the market to compensate for the misgivings (physical, material, and clinical) of composite resin science technology.[23-26] This system, SonicFill, a posterior restorative system, has been developed as a "bulk fill" (up to 5.0 mm) composite resin. SonicFill technology uses sonic energy, causing viscosity changes of the composite resin formulation for reportedly initial increased flowability and increased depths of cure.[23-27]

The specific aim of the present *in vitro* research project was to test both Class I and II posterior restorations using two composite resin systems, SonicFill and Herculite Ultra, considering the effects of material qualities, insertion techniques, "C-factors," and cavity classifications (bonding surfaces) on marginal microleakage. The hypothesis of the study was that the SonicFill system would show significantly less microleakage compared to Herculite Ultra when using the same experimental protocol.

METHODS AND MATERIALS

Tooth Selection and Study Preparation

Eighty previously extracted maxillary and mandibular third molars of similar size were selected for the present study. The teeth were cleaned of calculus, soft tissue, and other debris and were stored in a 1% chloramine T solution (Fisher Chemical, Fair Lawn, NJ, USA) consisting of 12% active chlorine diluted in tap water at room temperature. This study protocol, involving human research specimens (extracted teeth), was submitted to and approved by the

University of Tennessee Health Sciences Center Institutional Review Board for "Exempt" status review prior to study commencement. All teeth were examined macroscopically and microscopically (20×) to rule out the presence of fractures/fissures, carious lesions, abrasive/erosive lesions, and restorations. Teeth that did not conform to the inclusionary criteria were discarded. The teeth were then divided into four groups of 20 (n=20) and stored in tap water immediately prior to treatment.

Cavity Preparation

Experimental groups were based upon 1) restorative system—SonicFill (Kerr/Kavo, Bismarck, Biberach, Germany) and Herculite Ultra (Kerr Corporation, Orange, CA, USA); 2) class of cavity preparation (Class I or II) and cavity C-factor; and 3) insertion technique (bulk vs incremental). Class I preparations measured approximately 3.0 mm buccolingually and 3.0 mm in depth for each molar, while Class II preparations (extending the length of the tooth, mesiodistally) measured approximately 3.0 mm wide buccolingually and 1.5 mm in axial depth. The gingival floor was measured, 4.0 mm gingivally (depth), located slightly occlusal and/or apical in proximity to the cementoenamel junction (CEJ), depending upon the proximal surface anatomy of each tooth. All internal line angles were rounded, as appropriate for composite resin preparation design. The dimensions of the cavities were verified with a periodontal probe. All preparations were cut using a #245 tungsten carbide bur (Henry Schein, Melville, NY, USA), with margins beveled using a #368 finishing bur (Henry Schein), in a water-cooled, high-speed air turbine handpiece (Henry Schein). A new bur was used for every cavity preparation. One operator performed all cavity preparations, while another investigator verified the preparation parameters prior to restoration, to ensure accuracy and continuity. The teeth were then randomly divided into four groups based upon restorative system, insertion technique, and class of cavity.

Study Groups and Restorative Procedures

Group A—SonicFill Bulk Insertion, Class I preparations (20 teeth): SonicFill composite resin, shade A3, was used to restore each Class I preparation. The enamel and dentin surfaces were conditioned using 37.5% phosphoric acid etchant gel (Kerr Corporation) for 15 seconds, then rinsed and dried with an air/water syringe for 10-15 seconds. OptiBond Solo Plus (Kerr Corporation) adhesive agent was applied to all enamel/dentin surfaces for 15 seconds (air-dried) and light polymerized for 10 seconds. SonicFill composite resin was inserted into the preparation in one bulk increment, followed by light polymerization for 20 seconds.

Group B—SonicFill System/Bulk Insertion, Class II preparation (20 teeth): SonicFill composite resin, shade A3, was used to restore each Class II preparation. The enamel and dentin surfaces/margins were conditioned using Kerr 37.5% phosphoric acid etchant gel for 15 seconds, then rinsed and dried with an air/water syringe for 10-15 seconds. OptiBond Solo Plus adhesive agent was applied to all enamel/dentin surfaces for 15 seconds (air-dried) and light polymerized for 10 seconds. SonicFill composite resin was inserted into the preparation using one bulk increment, followed by light polymerization for 20 seconds.

Group C—Herculite Ultra Composite resin/Incremental Insertion, Class I preparation (20 teeth): Herculite Ultra composite resin, shade A3, was used to restore each Class I preparation. The enamel and dentin margins were conditioned using Kerr 37.5% phosphoric acid etchant gel for 15 seconds, then rinsed and dried with an air/water syringe for 10-15 seconds. OptiBond Solo Plus adhesive agent was applied to all enamel/dentin surfaces for 15 seconds (air-dried) and light polymerized for 10 seconds. Herculite Ultra was inserted into each preparation in three incremental layers (2 = base, 1 = anatomical). Each increment of the restoration was light polymerized for 20 seconds.

Group D—Herculite Ultra Composite resin/Incremental Insertion, Class II preparation (20 teeth): Herculite Ultra composite resin, shade A3, was used to restore each Class II preparation. The enamel and dentin margins were conditioned using Kerr 37.5% phosphoric acid etchant gel for 15 seconds, then rinsed and dried with an air/water syringe for 10-15 seconds. OptiBond Solo Plus adhesive agent was applied to all enamel/dentin surfaces for 15 seconds (air-dried) and light polymerized for 10 seconds. Herculite Ultra was inserted into each preparation in four incremental layers (2 = proximal [boxes], 2 = occlusal [anatomical]). Each increment of the restoration was light polymerized for 20 seconds.

A restoration template device, as shown in Figure 1, was utilized for insertion of the Class II composite resins. The template, modeled after a device from a study conducted by Bagis and others,[28] consisted of a quadrant of plastic typodont teeth mounted in acrylic tray material surrounded by a custom-fabricated stainless-steel frame using a separate

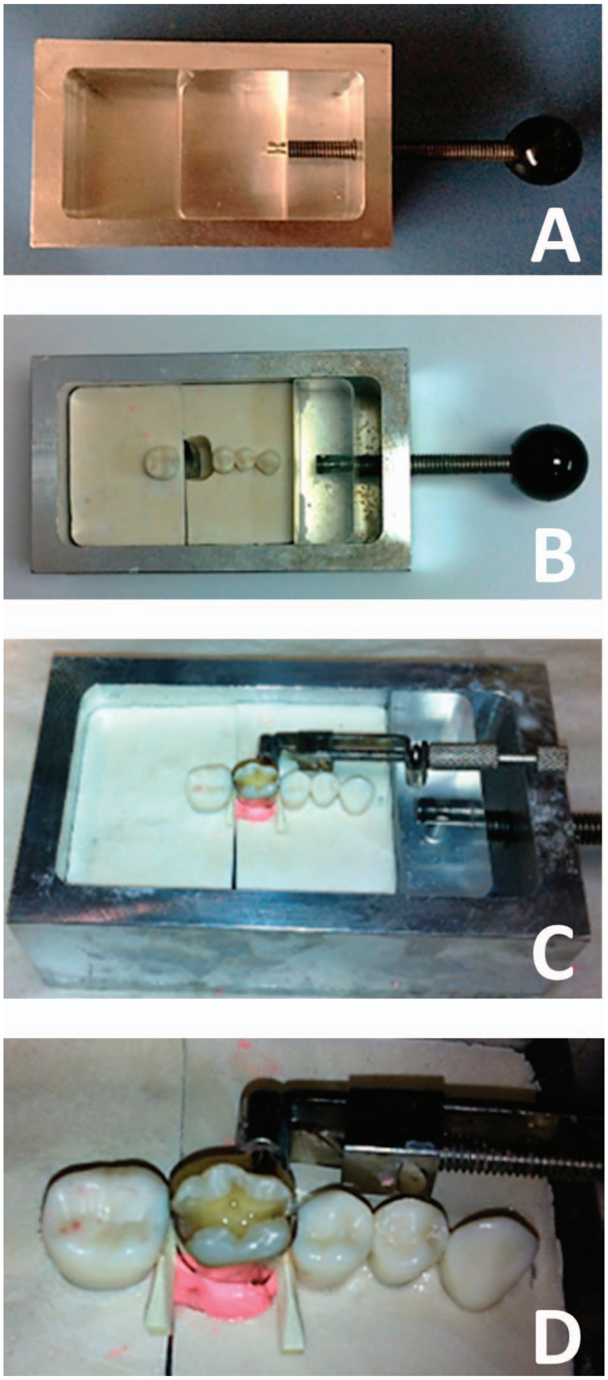

Figure 1. *Representative photographs (grouped) showing the manufactured device for insertion of the Class II composite restorations: (a)—custom-manufactured restorative device; (b)—device with plastic teeth in place and area removed for extracted tooth insertion; (c)—extracted molar with Class II preparation inserted into impression material with Tofflemire retainer and band positioned around MOD preparation; (d)—close-up photograph showing preparation ready for composite insertion, simulating a clinical patient environment.*

sliding unit with a screw/knob attached at one end of the apparatus. Each previously extracted tooth to be restored was implanted in heavy silicone-based impression material (simulating the periodontal ligament) and positioned into the acrylic mold by the sliding unit so that intimate contact was established on each proximal surface of the prepared tooth. This restoration adaptation technique was performed in order to approximate a realistic clinical situation. A Tofflemire universal metal circumferential matrix band/retainer was placed around each prepared tooth (Class II), and the respective materials were inserted according to each group's protocol and the manufacturers' instructions. One operator restored all cavity preparations, while another investigator verified the restoration parameters, to ensure accuracy and continuity.

All restorative materials were polymerized with a Schein (Henry Schein) quartz-tungsten halogen light. The light had been previously monitored with a radiometer and displayed adequate intensity ($\geq$800 mW/cm^2) levels. The composites were finished and polished using Schein (Henry Schein) finishing diamonds followed by Occlubrush (Kerr Corporation) polishing brushes. The specimens were stored in tap water at room temperature for seven days prior to leakage assessment.

Thermocycling and Assessment of Dye Penetration (Microleakage Scoring)

The specimens were subjected to artificial aging by thermocycling for 1000 cycles in separate water baths of 5°C and 55°C, with a dwell time of 60 seconds in each bath and a transfer time of three seconds. The root apices were sealed with utility wax, and the entire tooth surface was coated with two layers of commercial nail varnish to within 1.0 mm of the restoration. The specimens were immersed in a 1% aqueous solution of methylene blue dye for eight hours at room temperature, followed by thorough rinsing to remove any excess dye. The specimens were invested in clear autopolymerizing resin (Castin' Craft, Clear Plastic Casting Resin, ETI, Fields Landing, CA, USA) and labeled. A low-speed diamond saw (Buehler Isomet, Buehler Ltd, Evanston, IL, USA), cooled with water, was used to section each specimen block in a mesiodistal direction through the center of the restoration. Two sections were obtained from each block (20 blocks, or 40 readable surfaces per group), yielding dye penetration (microleakage) readings, examined at 20× magnification under a (Meiji EMT, Meiji-Labax Co, Tokyo, Japan) binocular microscope, with stan-

Table 1: *Table showing mean microleakage values of each experimental group.*

Group (Material + Class of Restoration)	Count, No.	Sum Ranks	Mean Ranks	Mean	Standard Deviation
A (SonicFill + I)	80	6920.000	86.500	0.000	0.000
B (SonicFill + II)	80	17,711.000	221.387	2.487	1.091
C (Herculite Ultra + I)	80	7747.000	96.838	0.175	0.671
D (Herculite Ultra + II)	80	18,982.000	237.275	2.775	0.795

dardized digital images obtained. Two observers scored each group blindly, and a consensus was reached if disagreement occurred. Microleakage scores (values) were determined based upon ordinal ranking (ranked 0-3) for each class of cavity preparation: 1) Class I: 0, no dye penetration; 1, dye penetration up to half of the restoration depth; 2, dye penetration greater than half of the restoration depth (to the pulpal floor); 3, dye penetration including the pulpal floor; 2) Class II: 0, no dye penetration; 1, dye penetration up to the full length of the gingival floor; 2, dye penetration up to half of the axial wall length; 3, dye penetration greater than half of the axial wall length.

Statistical Analysis

Microleakage values from all group specimens were statistically analyzed using Kruskal-Wallis and Mann-Whitney U-test nonparametric, multiple comparison tests. All data were submitted for statistical analysis at a predetermined value of $p < 0.05$ in terms of level of significance. The statistical calculations were performed using Statview 5.0 (SAS Institute, Cary, NC, USA).

RESULTS

All microleakage values are presented in Table 1. According to the Kruskal-Wallis testing, a significant difference ($p<0.0001$) was exhibited between the groups. Mann-Whitney U-test post hoc testing showed significant differences ($p<0.05$) between paired groupings (Table 2). All groups exhibited some degree of microleakage, except group A (SonicFill Bulk Insertion, Class I preparations) with a score of 0.000 ± 0.000. Group D (Herculite Ultra Composite resin/Incremental Insertion, Class II preparation) showed the greatest degree of microleakage (2.75 ± 0.795).

DISCUSSION

Composite resin has been rapidly replacing amalgam as the posterior restorative of choice for many dental patients.[4,5] However, the insertion of composite resin can be a very complex, challenging procedure for the dentist as a result of many material and clinical considerations.[5,9] This *in vitro* study utilized an objective means (dye penetration) of assessing marginal microleakage for posterior composite resin systems, utilizing different insertion techniques and cavity classifications (C-factors). Although the present study was conducted *in vitro*, careful attention was accorded to simulating a realistic clinical environment.

Specifically, this study wished to determine if the use of the SonicFill composite resin system (as compared to a universal, nanohybrid composite resin, Herculite Ultra) using an incremental-fill insertion technique had an effect on marginal microleakage of Class I and II cavity preparations. No study could be found that arrived at conclusions using different cavity preparation classes (C-factors) as a limiting variable.

The results attained in this study showed that the restoration of Class I and II cavity preparations using the SonicFill system did not prove to be a superior alternative for placement of posterior composite resins. The present study also revealed that neither the preparation configuration nor the "C-factor" played significant roles with regard to the microleakage incurred in the respective groups. The class of cavity preparation or, specifically, the bond to different tooth substrates (enamel, dentin [cementum]) was a more significant determinant of restoration microleakage. Groups A and C employing SonicFill and Herculite Ultra composite resin inserted into Class I cavity preparations revealed signif-

Table 2: *Table indicating statistical significance between paired groups.*

Group Pairings	*p*-Value	Statistical Significance ($p<005$)
A, B	<0.0001	S
A, C	0.1429	NS
A, D	<0.0001	S
B, C	<0.0001	S
B, D	0.0586	NS
C, D	<0.0001	S

Abbreviations: NS, not significant; S, significant.

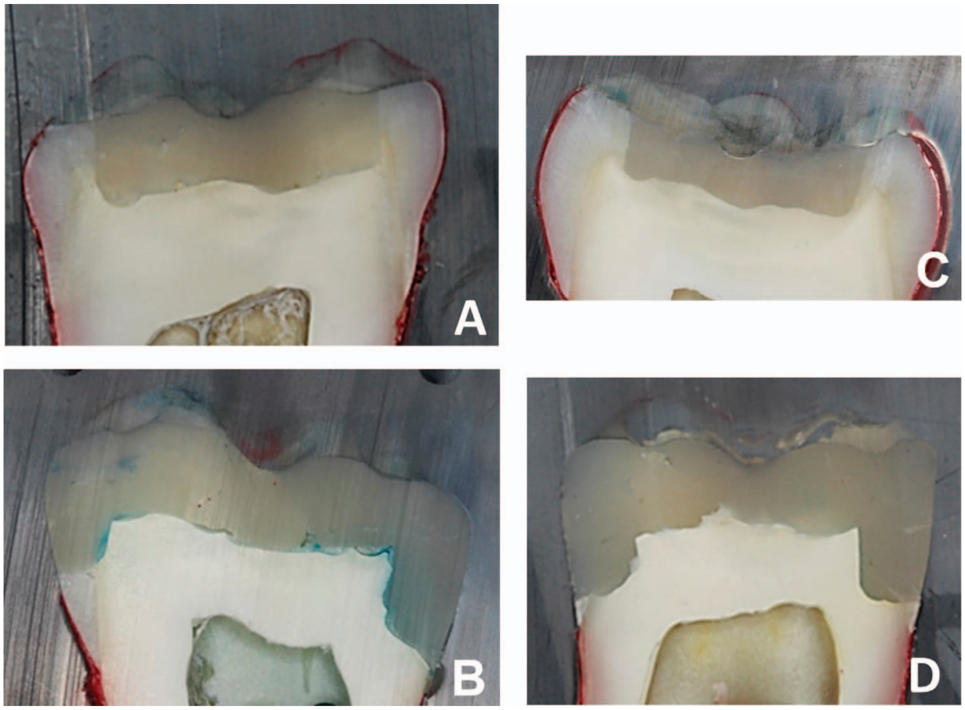

Figure 2. *Representative photographs (grouped) showing dye penetration (microleakage scores) relative to each experimental group: Group A (SonicFill™, Class I restoration) – showing no (score of "0") dye penetration (microleakage) around occlusal margins; Group B (SonicFill™, Class II restoration) – showing no (score of "0") microleakage on left (proximal) enamel surface coronal to the cementoenamel junction (CEJ) and microleakage (score of "3") on right (proximal) dentin surface apical to the CEJ; Group C (Herculite Ultra™, Class I restoration) – showing no (score of "0") microleakage around occlusal margins; Group D (Herculite Ultra™, Class II restoration) showing no (score of "0") microleakage at both proximal locations. Proximal surface preparations/restorations were located in enamel, thus revealing differences in tooth substructure (enamel vs. dentin [cementum]) adhesion.*

icantly less marginal microleakage compared to that seen in groups B and D, in which the same material systems were used, although inserted into Class II cavity preparations. This occurrence reemphasized the fact that the process of micromechanical adhesion of composite resin to enamel is a more efficacious process compared to the bond achieved by composite to dentin or cementum surface substructure.[1,29,30] Decreased levels of microleakage between the enamel surface and the adhesive/composite resin complex indicate that a quality seal has been attained; thus, a restoration with fewer marginal gaps and less subsequent clinical sequelae (stained margins, sensitivity, etc) is demonstrated.[1,2,29,30] Representative photographs (Figure 2) clearly demonstrate excellent ("0" scores) adhesion between the enamel surfaces and restorative materials (SonicFill and Herculite Ultra) for Class I restorations (groups A and C). Conversely, groups B and D (same materials, Class II restorations) clearly revealed marginal microleakage, as indicated by the dye penetration levels. Interestingly, as some of the Class II cavity preparations were cut slightly occlusal or gingival to the CEJ, dye penetration appears to originate from the proximal side where the gingival margin is located (ie, dentin [cementum]), as opposed to a corresponding enamel margin of the same restoration. In addition, the few Class II restorations in groups B and D that showed "0" scores on a single or both proximal surfaces were limited to preparations in enamel, occlusal to the CEJ (Figure 2, Group D). These occurrences add more support to the notion that superior bonds occur between enamel and the adhesive system/composite resin complex, even though the enamel margins (thinner enamel structure) are located in a proximal, gingival box for a Class II preparation.

The SonicFill restorative system utilizes sonic energy technology (changes in material viscosity) together with a composite material blend that, reportedly, creates a condition wherein the material closely adapts to the preparation margins using only one bulk increment.[23,24,26,27] Following deactivation of the sonic energy the material viscosity increases, allowing for increased depths of cure.[23,24,26,27] This system utilizes a formulation consisting of monomers (ethoxylated bisphenol A dimethacrylate, bisphenol A dimethacrylate, and triethyleneglycol), which is highly filled (barium glass and silicon dioxide) by weight (83.5%) and also includes special modifiers that react to the sonic energy, permitting a quicker "flow" and presumably better adaptability to the preparation walls.[23,24,26,27] Preliminary *in vitro* research[23,24,26] has reported polymerization shrinkage of 1.6%, increased flexural strengths, and a 5.0-mm depth of cure. These advertised claims have touted a more "user friendly," less time consuming composite resin (system) for use by the dentist.[23,24,26,27] Limited *in vitro* microleakage studies[31-34] using Class II cavity preparation/restoration criteria have shown no definitive differences when comparing the SonicFill system to other composite systems or methods of insertion, although two studies[34,35] did reveal positive results using the SonicFill, as compared to other composite resin delivery systems.

Factors such as different adhesive systems and cavity preparation designs including low configuration or "C-factors" and using different insertion techniques (incremental), polymerization sources, and the use of liners (resin modified glass ionomer and flowable composites) can decrease the unfavorable material and clinical influences associated with polymerization shrinkage and, consequently, marginal microleakage.[13,17] The preparation "C-factor" can influence the magnitude of stress on posterior composites and has been defined as the ratio of the bonded to the unbonded surfaces of a cavity preparation.[12,14] A restoration with high "C-factor" would indicate a greater potential for bond interruption due to the forces imposed from polymerization shrinkage, with subsequent formation of marginal gaps and/or voids and, consequently, microleakage.[12,14] Class I preparations have the highest "C-factors" as a result of the number of bondable surfaces; therefore, they have the greatest potential for the detrimental effects of polymerization. Class II, III, IV, and V preparations have lower "C-factors" because of the ratio of bonded to unbonded surfaces and, therefore, predispose the restoration to a lower risk for possible clinical sequelae.[12,14] Contemporary insertion of composite resin into posterior preparations usually involves multiple increments, taking into account the material shrinkage and preparation design "C-factor."[11-14] Incremental insertion of composite resin into a posterior preparation is performed to compensate for the stresses induced into the material following light polymerization. Therefore, bulk-fill composite insertion can potentially result in increased shrinkage forces, gap formation at the tooth/material interface, and, in turn, microleakage.[36] A recently conducted study tested bulk-fill (including SonicFill) vs incremental-fill composite resins, using depth of cure, hardness, and shrinkage as testing parameters, and revealed that bulk-fill composites showed greater depths of cure and decreased levels of volumetric and polymerization shrinkage.[37]

As seen by the results of the present study, although Class I cavity preparations/restorations exhibited the highest "C-factors" (five bonded surfaces to one unbonded surface = "C-factor" of 5), Class I preparations filled with both SonicFill and Herculite Ultra (groups A and C) showed significantly less microleakage compared to Class II restorations (groups B and D) filled with the same restoratives. The Class II (MOD) preparations/restorations revealed a "C-factor" of 3. Thus, the Class I restorations showed a higher "C-factor" compared to the Class II restorations. Given these facts, it appears that bonding surfaces (enamel vs dentin [cementum]), rather than cavity design "C-factors" or novel material technologies, played a major role in terms of microleakage.

While bonding to enamel has been reported with consistently predictable results,[1,38-40] challenges have been encountered with dentin surface bonding because of the complex composition and histologic nature associated with dentin. An *in vitro* study conducted by Poggio and others[41] concluded that using different restorative techniques and materials did not positively influence microleakage penetration below the CEJ, at the dentin margin—further substantiating that dentin surface substructure is not as suitable a medium for bonding as is enamel. Etching enamel is efficient in terms of the removal of the smear layer, demineralizing the inorganic enamel surface, creating microporosities for a patent, mechanical bond.[1,42,43]

The degree of dye penetration as an *in vitro* method for determining marginal microleakage of dental restorations, including a myriad of material and/or cavity preparation variables, is a commonly used evaluation device and has been repeatedly performed and reported in the dental literature, although inconclusive results have sometimes been attained.[6,8,44-46] Microleakage studies provide adequate screening methods, possibly determining clinical success and longevity of a particular material or technique, although clinical, longitudinal studies are the best projectors of restoration performance.[6,8,44-46] The results attained from *in vitro* studies cannot necessarily be extrapolated to *in vivo* clinical outcomes; however, the authors agreed that the present results demonstrated that tooth surface (enamel) morphology was the most significant factor with regard to microleakage of both posterior composite resin restoration systems.

CONCLUSION

Within the limitations of the present *in vitro* study, the hypothesis was rejected that usage of the SonicFill system for restoration of Class I and II preparation cavities resulted in significantly less microleakage. Significant microleakage was encountered with specimens in both Class II restoration groups (groups B and D). However, very little or no microleakage was associated with the Class I insertions (groups A and C).

The results showed that the bonding surface (enamel and dentin), and not necessarily material technology and/or "C-factors," was the primarily limiting factor in terms of marginal microleakage.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of Integrated Medical Research Informational System. The approval code for this study is: 479277.

Conflict of Interest

The authors 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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