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Effects of Load Cycling on the Microleakage of Beveled and Nonbeveled Margins in Class V Resin-Based Composite Restorations

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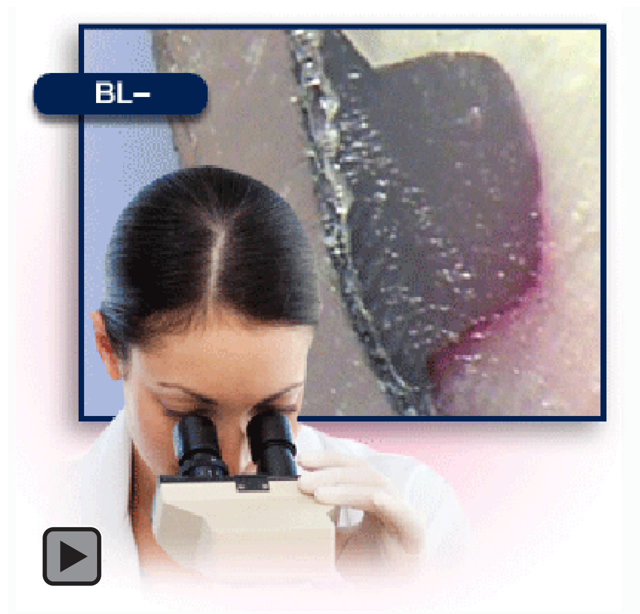
Abstract

Aim: This study evaluated the influence of mechanical loading and thermocycling on microleakage of class V resin-based composite restorations with and without enamel bevel.

Methods and Materials: Sixty class V cavity preparations measuring 3.0 mm wide (mesio-gingivally) x 2.0 mm high (occluso-gingivally) x 1.5 mm deep with the occlusal margin in enamel and the gingival margin in cementum were prepared on the buccal surfaces of human premolars using a #12 diamond round bur (Drendel & Zweiling Diamant GmbH, Lemgo, Germany) in a high-speed, water-cooled handpiece. The specimens were then divided into two groups of 30 specimens each, based on the type of enamel cavosurface margin configuration as beveled or nonbeveled (butt joint). After restoring the preparations with a flowable resin-based composite (Tetric Flow, Ivoclar Vivadent-AG, Schaan, Liechtenstein) and finishing and polishing with sequential discs (Sof-Lex Pop-on, 3M-ESPE, St. Paul, MN, USA), the teeth were stored at 37°C and 100 percent humidity. Twenty-four hours later, half of the specimens in each group (nonbeveled "N" or beveled "B") were exposed to a cycling loading for 250,000 cycles to simulate occlusal loading and assigned to two subgroups (NL+ or BL+), while the remainder of the specimens in each group were only maintained in a 100-percent-humidity environment, without any cyclical loading, until tested (NL– or BL–). The specimens were sealed with sticky wax (Kemdent, Associated Dental Products, Swindon, UK) and



nail polish. The apical foramen of each tooth was sealed with sticky wax and the rest of the tooth was covered with nail varnish, except for an area within 1.0 mm around the composite restoration. To detect marginal leakage, all of the samples were stored in a 0.5 percent basic fuchsine solution for 24 hours. The specimens were then sectioned longitudinally using a low-speed diamond blade (IsoMet, Buehler Ltd., Lake Bluff, IL, USA), machined, and evaluated under 25X magnification using a stereomicroscope (M9, Wild Heerbrugg, Switzerland). The specimens were scored on a scale from 1 to 4 on the degree of dye penetration. The qualitative data were analyzed by the Mann-Whitney U test at a 5 percent significance level ($p<0.05$). The null hypothesis of this study was

that there is no difference in microleakage between beveled and nonbeveled class V buccal preparations in premolar teeth restored with resin-based composite and subjected to simulated occlusal loading and thermocycling.

Results: In each group the gingival margin showed significantly more microleakage than the enamel margin ($p<0.05$). Load cycling did not result in an increase in microleakage in nonbeveled ($p=0.259$) or in beveled ($p=0.053$) occlusal margins. However, the gingival margins showed a statistically significant difference in microleakage after load cycling whether in cavities with enamel occlusal bevel ($p=0.004$) or in groups without a bevel. This means the enamel margin configuration of the enamel occlusal margin had no effect on decreasing microleakage in the gingival aspect of class V composite restorations. In general, the nonbeveled preparations in this study had significantly less microleakage than the bevel specimens whether they were loaded occlusally or not ($p=0.001$).

Clinical Significance: Within the limitations of this *in vitro* study, no benefit was derived from placing an enamel cavosurface bevel on the occlusal margin of a standardized class V composite restoration located at the cementoenamel junction. The most important consideration is to prevent microleakage along the gingival margin regardless of whether the occlusal enamel margin is beveled.

Keywords: class V cavity preparation, enamel bevel, flowable composite, load cycling, microleakage

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Introduction

The demand for the restoration of defects involving both the clinical crown and root surface, such as those created by cervical caries, has increased.[1] Resin-based composites are some of the materials of choice for class V restorations because of their high esthetic qualities. Clinical success with resin-based composite restorations is fundamentally dependent on effective bonding at the enamel and cervical margins under occlusal loading.[2,3]

It has been established that occlusal forces can potentially generate loading forces that are partly responsible for contributing to the failure of class V restorations.[4] Cervical preparations are subjected to both compressive and tensile stresses during occlusal loading.[5] In the case of U-shape preparations, greater stress occurs at the gingival (apical) margins than the corresponding occlusal (coronal) margins. Not only is there little standardization of the magnitude of applied loads, the frequency, the number of cycles, and the variations in the shape of preparations make comparisons of different types of failures difficult.[6] It is accepted that load cycling has a significant effect on marginal leakage.[7] It also has been reported that flowable composite resin in class V preparations can produce stresses due to resin polymerization shrinkage and that stresses also can arise from occlusal loading forces.[8]

Previously, it was thought that the cavosurface margin bevel played an important role in the reduction of marginal leakage, improved esthetics, and increased adhesion. However, when beveling is needed in a small class V conventional cavity preparation, a bevel reportedly changes the configuration of the preparation in a way that causes reduced retention.[9]

The issue of beveling the cavosurface margin of class V preparations has been under discussion since the introduction of dentin bonding agents designed to increase the adhesion of composite to dentin. Saunders et al.[10] compared marginal leakage in beveled and nonbeveled cavosurface margins of class V preparations and demonstrated that the beveled design of the cavity allowed significantly less leakage than the nonbeveled type. Owens et al.[11] evaluated the microleakage of tooth-colored restorative materials using different, second-generation dentin bonding agents at the gingival margins of class V preparations with and without bevel. They concluded that class V restorations with a gingival bevel demonstrated greater microleakage. A clinical trial[11] compared the clinical success of noncarious class V preparations on the buccal surface of canines and premolars with and without enamel bevel and restored with a microfilled resin-based composite. The results showed no significant difference in the retention rate between the two groups (beveled versus nonbeveled preparations) after two and three years. Furthermore, postoperative sensitivity, marginal discoloration, and secondary caries also were not affected by enamel beveling and the type of restorative material. However, Santini et al.[13] evaluated the marginal leakage of box-shaped class V preparations with and without a marginal bevel and did find a significant difference in the degree of microleakage between the two groups studied. In contrast, Bagheri and Ghavamnasiri[14] reported no significant difference in microleakage between the two types of enamel margins (beveled and nonbeveled) for class V cavity preparations having rounded internal line angles.

This study was designed to evaluate the effects of mechanical loading and thermocycling on the marginal leakage of class V cavity preparations with and without an enamel occlusal bevel. The null hypothesis of this study was that there is no difference in microleakage between beveled and non-beveled class V buccal preparations in premolar teeth restored with resin-based composite and subjected to simulated occlusal loading and thermocycling.

Methods and Materials

Sixty caries-free, freshly extracted human premolars were selected for this study and stored in a physiologic solution of 0.9 percent normal saline for 76 days. A standardized class V cavity, 3.0 mm wide (mesiodistally), 2.0 mm high (occluso-gingivally), and 1.5 mm deep was prepared on the buccal surface of each tooth with the occlusal margin located 1.0 mm on enamel and the gingival margin located 1.0 mm into cementum. The preparations were made using #12 diamond round burs (Drendel & Zweiling Diamant GmbH, Lemgo, Germany) in a water-cooled, high-speed handpiece. Each bur was used to make only five preparations and was then replaced. Half of the cavity preparations (n=30) were randomly assigned to Group N (nonbeveled). The remaining 30 specimens were placed in Group B (beveled), where a 0.5 mm bevel was prepared in the enamel cavosurface using a flame-shaped diamond bur (#318, KG Sorensen, Sao Paulo, Brazil). All the preparations were restored with the same flowable resin-based composite (Tetric Flow, Ivoclar Vivadent-AG, Schaan, Liechtenstein).

The total etch technique was performed prior to placement of the adhesive layer in both groups using a 35 percent phosphoric acid (Scotchbond Etchant Gel, 3M-ESPE, St. Paul, MN, USA). The acid was applied initially to the enamel margins and then extended from the superficial to deep dentin for 15 seconds. After application of the acid gel, the substrate was rinsed with an air/water spray for 30 seconds, and the excess moisture was removed with a cotton pellet applied to the dentin while the enamel was gently air dried. The total etch used consisted of one-bottle adhesive system (Excite, Ivoclar Vivadent-AG, Schaan, Liechtenstein) that was applied according to the manufacturer's directions on both enamel and dentin and thinned after 20 seconds with a gentle blast of air. The adhesive was then light activated using an Optilux500 curing unit (Demetron, Kerr Dental Corp., Orange, CA, USA) at 500 mw/cm^2 for 20 seconds. Tetric Flow was applied in two oblique increments, and each increment was light polymerized for 40 seconds.[15,16]

After restoring the preparations with a flowable resin-based composite (Tetric Flow, Ivoclar Vivadent-AG, Schaan, Liechtenstein) and finishing and polishing with sequential discs (Sof-Lex Pop-on, 3M-ESPE, St. Paul, MN, USA), the teeth were stored at 37˚C and 100 percent humidity. Twenty-four hours later, half of the specimens in each group (nonbeveled "N" or beveled "B") were exposed to a cycling loading for 250,000 cycles to simulate occlusal loading and assigned to two subgroups (NL+ or BL+), while the remainder of the specimens in each group were only maintained in a 100 percent humidity environment, without any cyclical loading, until tested (NL– or BL–) (Table 1).

The load cycling device was designed and fabricated at Mashhad University of Medical Science, Mashhad, Iran (Figure 1).

Each specimen was loaded on the occlusal surface with the direction of that loading approximately parallel to the long axis of the tooth at a frequency of 3 Hz[14] using a static ceramic ball[17] (diameter 10 mm, Hoechst CeramTec, Wunsiedel, Germany) with a 90N load value[18] (Figure 2).

Table 1. Descriptions of the specimens.

Group	Subgroups (n=15)	Description
N	NL+	Nonbeveled, load cycling
	NL–	Nonbeveled, without load cycling
B	BL+	Beveled, load cycling
	BL–	Beveled, without load cycling

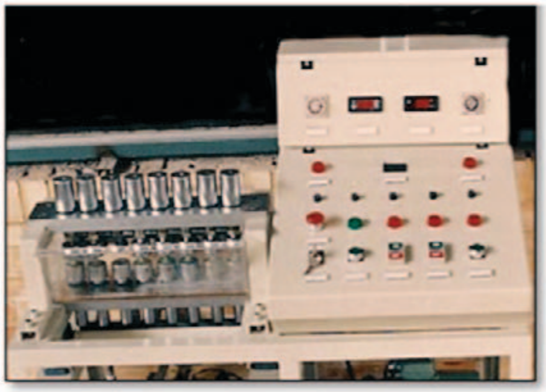

Figure 1. The Mashhad University loading machine.

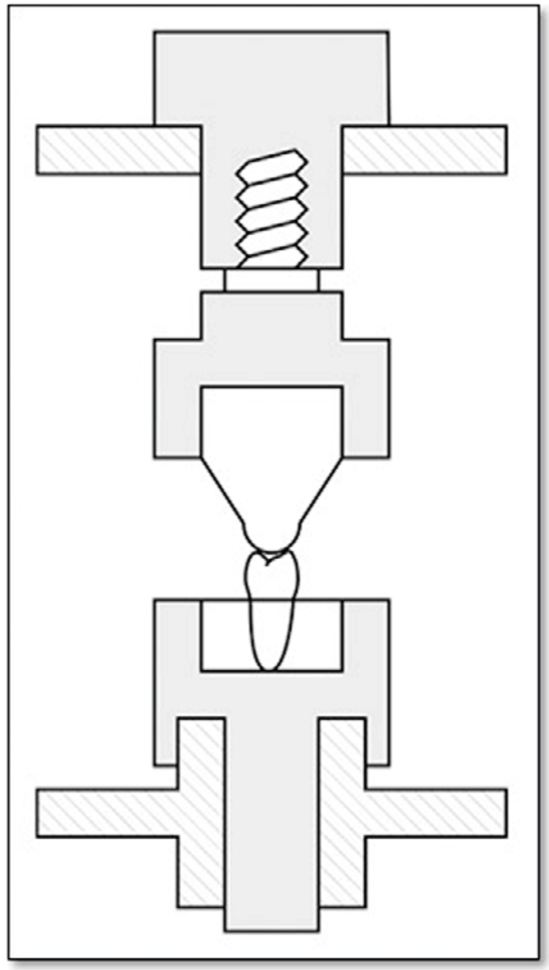

Figure 2. Schematic drawing of a tooth specimen secured in the loading machine.

The load cycling machine was configured with eight metallic molds. The root or roots of each tooth were lubricated with a thin layer of petroleum jelly and the specimens placed in a mold filled with polymethyl methacrylate autopolymerizing resin up to 1.0 mm from the CEJ. The resin secured the specimens in place during load testing and the petroleum jelly prevented bonding, so the teeth could be easily removed. The specimens were held securely in a longitudinal orientation, perpendicular to the acrylic surface, using a set square attached to the external wall of the mold to create a 90 degree angle of the vertical axis of the tooth with the surface of the acrylic resin.

During the cyclical loading, all specimens were subjected to continuous thermal cycling between 5°C and –55°C for 60 seconds by a continuous stream of water (Figure 1).[19]

After load cycling and thermocycling, the teeth were removed from the polymethyl methacrylate autopolymerizing resin in the loading machine. The apical foramen of each tooth was covered with sticky wax (Kemdent, Associated Dental Products, Swindon, UK) and the rest of the root except for 1.0 mm beyond the restoration, was covered using two layers of nail varnish.

The teeth were then immersed in a 0.5 percent basic fuchsine dye for 24 hours at room temperature. The root apices were cut 2.0 mm below the cementoenamel junction (CEJ), and then the specimens were immersed in clear epoxy resin (Araldite, Ciba-Geigy, Basel, Switzerland). After 24 hours, each tooth was sectioned longitudinally in a bucco-lingual direction through the center of each restoration with a low-speed diamond saw (IsoMet, Buehler Ltd., Lake Bluff, IL, USA) under a water coolant. The cut surfaces were examined at the occlusal and gingival margins using a stereomicroscope (M9, Wild Heerbrugg, Switzerland) by one examiner (HA) under 25X magnification.

The most extensive degree of the dye penetration at the composite/tooth interface was evaluated for both the occlusal and gingival margins using the following scoring system:

Fuchsine Dye Penetration Scoring:
0—No dye penetration
1—Dye penetration less than half of the length of the gingival or occlusal wall
2—Dye penetration up to the full length of the gingival or occlusal wall
3—Dye penetration along the axial wall

The nonparametric data were analyzed using the Kruskal-Wallis and Mann-Whitney U tests by ranks at the significant level of $p<0.05$.

Results

Score frequencies for microleakage and the mean rank with sections from the four individual teeth groups (NL+, NL–, BL+, and BL–) tested are shown in Table 2.

The parametric analysis of Kolmogrov-Smirnov did not accept the normality of the distribution of the data. Consequently, a nonparametric analysis of Kruskal-Wallis was used for comparison of the microleakage mean rank among all of the groups. This analysis revealed a statistically significant difference among the groups (p=0.000). Therefore, a Mann-Whitney U test was used for comparison of microleakage mean rank values between each of the two groups.

The occlusal and gingival margins of each group showed significant differences in microleakage

Table 2. Score frequencies and mean rank for microleakage in occlusal and gingival margins for each group tested.

Group (n=15)	Margin	Score Frequency				Mean Rank
		0	1	2	3	
BL+	Enamel	7	5	3	0	11.03
	Cementum	2	3	4	6	19.97
BL–	Enamel	10	2	3	0	8.90
	Cementum	2	3	6	4	22.10
NL+	Enamel	14	1	0	0	9.17
	Cementum	2	3	6	7	21.83
NL–	Enamel	14	0	1	0	9.57
	Cementum	2	4	7	2	21.43

Table 3. A comparison of the microleakage mean ranks for the occlusal and the gingival margins.

Group	Margins	Number	Mean Rank	Sum of Ranks	Point of Probability
NL–	Occlusal	15	9.57	143.50	0.000
	Gingival	15	21.43	321.50	
	Total	30			
NL+	Occlusal	15	9.17	137.50	0.000
	Gingival	15	21.83	327.50	
	Total	30			
BL–	Occlusal	15	8.90	133.50	0.000
	Gingival	15	22.10	331.50	
	Total	30			
BL+	Occlusal	15	11.03	165.50	0.000
	Gingival	15	19.97	299.50	
	Total	30			

Table 4. Effects of cycling loading on microleakage for all groups.

Groups*	N	Mean Rank	Significance Level
Occlusal marigin			
NL–	15	15.53	p=0.259
NL+	15	15.47	
Total	30		
Gingival margin			
NL–	15	14.53	p=0.035
NL+	15	16.47	
Total	30		
Occlusal margin			
BL–	15	14.30	p=0.053
BL+	15	16.70	
Total	30		
Gingival margin			
BL–	15	17.00	p=0.004
BL+	15	14.00	
Total	30		

* The occlusal margin was prepared in enamel and the gingival margin was placed in cementum.

Table 5. Mean rank and significance levels of microleakage at the different margin locations for all groups tested.

Margin Location	Group	Mean Rank	Significance Level
Occlusal	NL+	13.57	p=0.04
	BL+	17.43	
	NL–	11.90	p=0.004
	BL–	19.10	
Gingival	NL+	11.70	p=0.002
	BL+	19.30	
	NL–	14.83	p=0.037
	BL–	16.17	

Table 6. The comparison of beveled and nonbeveled groups.

Groups	N	Mean Rank	Sum of Ranks	Point Probability
Nonbeveled	60	53.15	3189.00	
Beveled	60	67.85	4071.00	
Total	120			.001

before (p=0.000) or after (p=0.000) load cycling (Table 3). Such outcomes indicated that in each group the gingival margin in cementum exhibited more leakage than the occlusal enamel margin. All of the cavity preparations consisted of a 90 degree gingival cavosurface margin and in all of the groups more microleakage occurred at the gingival margin than at the occlusal margin.

The cyclical loading did not cause increased microleakage at the occlusal margins in either the beveled or nonbeveled preparations (p=0.053 to p=0.249), but it did lead to increased microleakage at the gingival margins of both groups of cavity preparations (p=0.004 to p=0.035) (Table 4 and Figures 4 to 7).

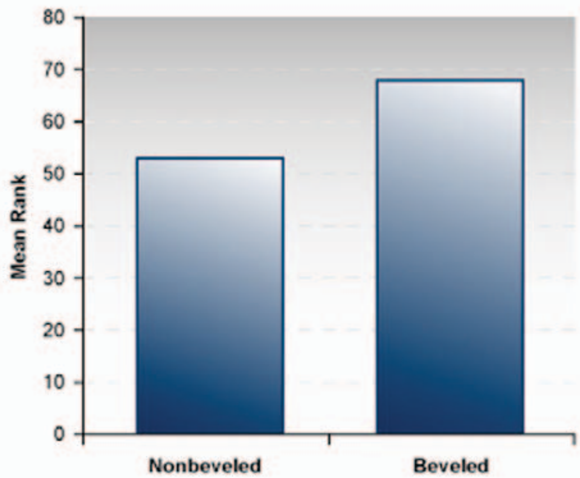

Figure 3. The mean rank values of microleakage in beveled and nonbeveled enamel preparations.

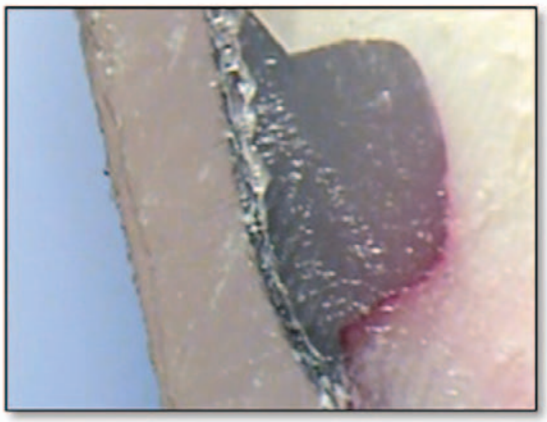

Figure 4. Stereomicroscopic view of microleakage of a specimen from the beveled and unloaded group (BL–) at 25X magnification.

Table 5 presents the effect of cavosurface configurations on microleakage in occlusal and gingival margins. Nonbeveled preparations showed significantly less microleakage whether in the occlusal margin or the gingival (p=0.002 to 0.04).

In general, nonbeveled preparations showed significantly less microleakage whether they underwent cyclical loading or not (p=0.001) (Figure 3 and Table 6).

Discussion

The stereomicroscopic examinations revealed more microleakage at the gingival margins than at the occlusal margin. Furthermore, the statistical analysis also reflected that the microleakage at the gingival margin was significantly higher than at the occlusal margin in enamel for both the

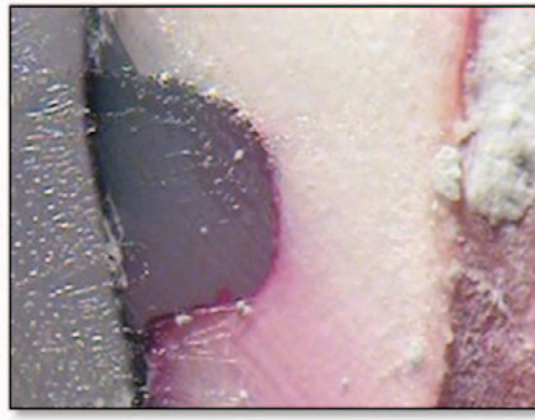

Figure 5. Stereomicroscopic view of microleakage of a specimen from the beveled and loaded group (BL+) at 25X magnification.

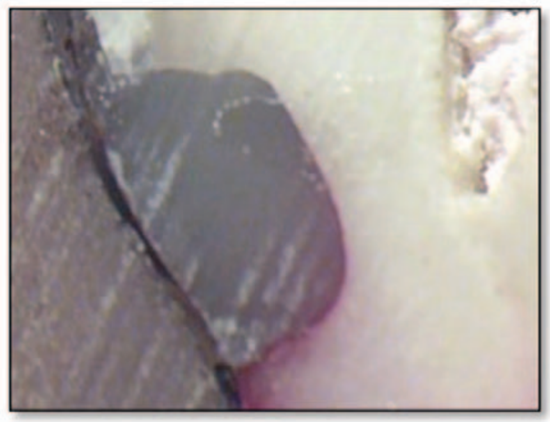

Figure 6. Stereomicroscopic view of microleakage of a specimen from the nonbeveled and unloaded group (NL–) at 25X magnification.

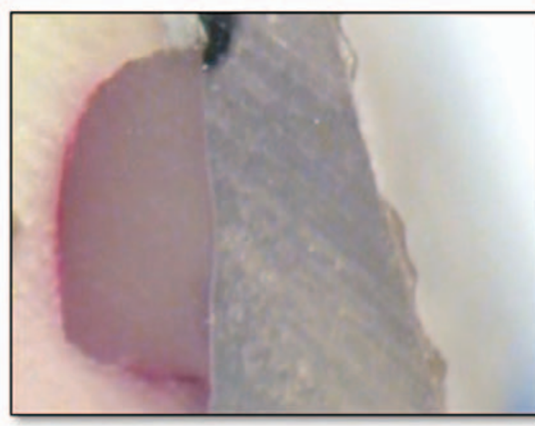

Figure 7. Stereomicroscopic view of microleakage of a specimen from the nonbeveled and loaded group (NL+) at 25X magnification.

cyclically loaded and nonloaded specimens,[4,8,20] so the null hypothesis was rejected. This finding was consistent with the results reported in several previous studies.[21–23]

The unpredictability of a dentin substrate is a serious problem when bonding restorative materials.[24] Enamel is a reliable substrate for bonding, but bonding to cementum is more challenging due to its high organic component, the variation in the degree of mineralization, and the presence of outward fluid movement.[8]

For the microleakage evaluation, the cervical margins of the restorations were positioned 1.0 mm below the CEJ in cementum due to critical adhesion in this area.[25] The tubules in the cervical region are parallel to the preparation, which impedes the formation of resin tags. Ogata et al.[26] claimed that more intertubular dentin and fewer dentin tubules are exposed, resulting in an increase of the area of hybrid layer formation. Furthermore, the exposure of fewer dentin tubules and more intertubular dentin leads to an increase in hybrid layer formation.[26]

The cavosurface bevel has been employed for many years as an accepted modification for composite restorations. The bevel exposes more enamel rods and makes them available for bonding with the acid-etch technique. The resin-enamel bond is stronger with etched transverse sections of enamel prisms than with longitudinal sections.[27]

In class V preparations, enamel margins are beveled in the belief that beveling decreases marginal leakage, increases adhesion, and improves esthetics.[9] On the other hand, enamel margin beveling on shallow class V preparations leads to a flat cavity configuration that may lead to easier displacement of the restorative material under flexural loads.

One clinical trial by Baratieri et al.[12] demonstrated beveling did not affect the retention of restorations in class V preparations after three years. Several previous in vitro studies[12–14] also reported no significant difference in microleakage between nonbeveled and beveled enamel margins in class V resin-based composite restorations. In the present study, with both nonloading and loading, the restorations with no bevel in the enamel margin showed significantly less microleakage than the group with enamel beveling.

In this study, a 90 N occlusal force was applied parallel to the load axis of the teeth[18,28] for 250,000 cycles under 100 percent humidity to simulate one year of clinical wear.[29] The present study also confirms the findings of a previous study where the applied loading force increased marginal leakage only at the gingival margins[22] with no statistically significant differences in microleakage for each type of enamel margin (beveled and nonbeveled) before and after loading. This outcome might be the result of a highly effective enamel bond established by the total etching adhesive system used.[30]

There was a significant difference in microleakage at the gingival margins between unloaded and loaded conditions in each group. Pongprueksa et al.[4] showed that use of a flowable composite in class V preparations led to increased microleakage at loaded gingival margins compared with the nonloaded gingival margins. Evidently low viscosity resin has a negative effect on marginal leakage at the gingival margin. The findings of this study confirmed the results of the study done by Pongprueksa et al.[4] Davidson and Abdalla[28] reported that cycling loading led to increased marginal leakage at the gingival margins in both the beveled and nonbeveled groups but did not affect enamel margins. In U-shaped preparations, they attributed this to the greater stress generated at the apical margins rather than at coronal margins.[4]

In the future a study should be designed to evaluate self-etch adhesive systems for restorations under loaded and unloaded conditions and compare them with total etch adhesives. In addition, a clinical trial is recommended to evaluate the longevity of class V composite restorations without beveled occlusal margins.

Conclusion

After cyclical loading from 5°C to –55°C with a 60-second dwell time, the gingival margins exhibited significantly more microleakage than the enamel margins. However, there was no correlation between cyclical loading and increased microleakage in both types of enamel cavosurface configurations (beveled versus nonbeveled).
In general, nonbeveled class V preparations in premolars showed significantly less microleakage in both the occlusal and gingival margins than either margin in beveled restorations.

Clinical Significance

Within the limitations of this *in vitro* study, no benefit was derived from placing an enamel cavosurface bevel on the occlusal margin of a standardized class V composite restoration located at the cementoenamel junction. The most important issue in such cases is to prevent microleakage along the gingival margin regardless of whether the occlusal enamel margin is beveled.

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