IDR International Dental Research

Original Article

Evaluation of marginal microleakage in composite restorations with different placement techniques

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Received: 9 June 2018
Accepted: 29 July 2018

Access Online
Quick Response Code

DOI:
10.5577/intdentres.2018.vol8.no2.4

Abstract

Aim: The purpose of this in vitro study was to evaluate the effect of different layering techniques (bulk, oblique, centripetal, split horizontal) on the marginal microleakage of Class II adhesive restorations.

Methodology: Forty-eight standardized Class II cavities were prepared on both mesial and distal sides of extracted non-carious human molar teeth. Following preparation, all specimens were randomly divided into four groups (n=12). Group 1: bulk technique; Group 2: oblique incremental technique; Group 3: centripetal incremental technique; Group 4: split horizontal incremental technique. The teeth were restored with a total-etch adhesive system and a microhybrid composite resin. After thermocycling and immersion in a 0.2% methylene blue solution for 24 hours, the restorations were sectioned, and dye penetration was evaluated under a stereomicroscope. The microleakage scores (0 to 4) obtained from the occlusal and gingival margins were analyzed with Kruskal-Wallis and Mann-Whitney U tests ($p<0,05$).

Results: Incremental placement techniques showed lower microleakage compared with bulk and lower microleakage was seen at occlusal margin compared with gingival margin. However, there were no statistically significant differences among four placement techniques and the margins ($p>0,05$).

Conclusions: Based on the results of the present study, none of the four placement techniques were found to be effective in eliminating marginal microleakage entirely in Class II restorations. All of the placement techniques showed similar results when the cavity margins were located on the enamel.

Keywords: Composite resin, incremental technique, microleakage, polymerization shrinkage.

How to cite this article: Misilli U, Yılmaz F. Evaluation of marginal microleakage in composite restorations with different placement techniques. Int Dent Res 2018;8(2):70-7.

Introduction

Currently, the increase of aesthetic demands of patients and clinicians and progressive advances in adhesive systems have stimulated a great increase in the use of resin-based composites in eliminating the loss of tooth structure caused by various circumstances (1, 2). However, despite the improvements in aesthetic appearance and the wear resistance of resin composites, the integrity of the tooth-restoration interface cannot be achieved completely because of shrinkage stresses. Consequently, microleakage remains a major drawback of resin composite restorations (3).

Efforts to reduce this problem, especially encountered at the gingival margins in Class II restorations, have focussed on factors such as cavity geometry, type of restorative material, the polymerization and the placement technique, which are known to be effective for shrinkage (4). Several methods, such as utilization of flowable cavity covering material (3, 5), layering technique and alternative light application protocols have been developed (6).

Among these methods, the incremental technique is accepted as the gold standard for the placement of resin-based composite restorations (7). When the composite resin is layered, minimal contact with the cavity walls during polymerization and a reduction in shrinkage rate with smaller composite volume are achieved. Shrinkage stress is also significantly reduced by compensating for the shrinkage of each layer with the next consecutive layer (8).

As a general approach, a horizontal incremental technique has been used in which the composite is layered and light-cured in increments of less than 2 mm. However, an oblique layering method has been developed which allows the transfer of shrinkage stresses to unbound free surfaces (9) by determining that the most important effect of the cavity geometry during polymerization is the configuration factor (10). Thereafter, different methods, such as centripetal and split horizontal incremental techniques applied in Class II cavities, were developed with the same principles (11).

Results obtained from a number of laboratory and clinical trials comparing these different incremental methods differ and no consensus has been reached on this issue. This study aimed to investigate the effectiveness of different incremental techniques, such as bulk, oblique, centripetal and split horizontal, to minimize the microleakage of gingival margins in Class II cavities. The null hypothesis was that there would be no difference in microleakage levels between Class II restorations applied using different methods, such as bulk, oblique, centripetal or split horizontal incremental techniques with the same adhesive system and composite resin.

Materials and Methods

Twenty-four extracted non-carious human molars were collected, cleaned of calculus, soft tissue and debris and stored in distilled water. Forty-eight standardized Class II cavities were prepared on both mesial and distal sides of each tooth with the following dimensions: 4-mm occlusogingival extension, 3-mm buccolingual and mesio-distal extension. The cavities were made with a no. 14 diamond bur (Dia-Tessin, Vanetti SA, Switzerland) under water coolant in a high-speed handpiece. New burs were used after every five preparations. Following preparation, all specimens were randomly divided into four groups (n=12).

Restorative Procedure

Table 1 provides details of the materials. The cavities were etched with 37% phosphoric acid for 15 seconds, thoroughly washed with water and dried. A uniform layer of a total-etch bonding system (AdperTM Single Bond 2, 3M ESPE) was applied, air-thinned and light-cured for 10 seconds (EliparTM S10, 3M ESPE, USA). All specimens were restored with a microhybrid resin Gradia Direct Posterior (GC).

Group 1 - Bulk technique: A single layer of composite was applied to the cavity and cured for 40 seconds from an occlusal direction.

Group 2 - Oblique incremental technique: The first increment of 2 mm was horizontally placed at the gingival margin and cured for 20 seconds from an occlusal direction. The second increment of 2 mm was obliquely placed contacting the buccal and axial walls and cured for 20 seconds. After the last increment was also obliquely placed, restoration was completed.

Group 3 - Centripetal incremental technique: The first layer of 0.5 mm thickness was placed up to half of the occlusogingival extension in the contact area. The second layer was placed over the previous increment to form the occlusal half of the occlusogingival extension. The resulting Class I cavity was restored in two horizontal increments of 2 mm thickness. Each increment was light-cured for 20 seconds.

Group 4 - Split horizontal incremental technique: The marginal ridge was constructed as in the centripetal technique to form a Class I cavity. In the remainder of the proximal box, each 2-mm horizontal increment was split diagonally into two portions and cured for 20 seconds. In this way, each portion of the split increment contacted only half of the gingival wall and two of the surrounding cavity walls during curing. Then, the diagonal cut was filled completely with composite and cured for 20 seconds. The same procedure was repeated for the second horizontal increment.

For finishing and polishing, abrasive discs (Sof-Lex TM XT, 3M ESPE, USA) were used in a standard 4-step (coarse to superfine) system at the occlusal and proximal surfaces.

Preparation for Microleakage Test

After the restoration was completed, specimens were stored in distilled water at 37°C for 24 hours. The specimens were then thermocycled (1000 cycles, 5°±2° to 55°±2°C, 30 seconds of dwell time, 3 seconds of transference time). After the apices of all root surfaces were occluded with composite resin, the tooth surfaces were coated with two layers of nail varnish except for 1 mm around the restoration margins. The specimens were then immersed in 0.2% methylene blue solution for 24 hours.

After the specimens were washed in running water for 30 seconds and the residual dye was removed, the teeth were sectioned through the center of the restoration with a diamond disk in a mesio-distal direction under water-cooling. Digital images of the restorations were captured by a digital camera mounted on a stereomicroscope (Olympus SZ61, Olympus Corporation, Japan) at 10× magnification.

Images were used by two previously calibrated examiners to score dye penetration along occlusal and gingival margins (Fig. 1). The examiners were blind to the techniques. The degree of penetration was determined according to the scores described in Table 2. Consensus was forced when disagreements occurred.

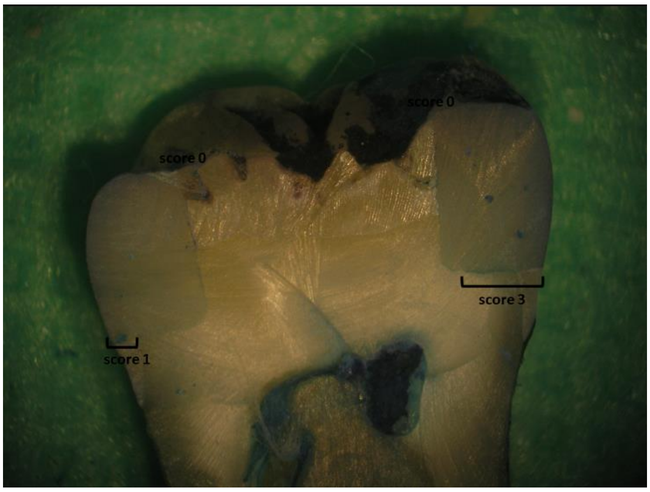

Figure 1. Level of dye penetration (An image of bulk technique group)

Statistical Analysis

Statistical analysis was performed using SPSS Statistics 21.0 (SPSS Inc., Chicago, IL, USA). The data were statistically analyzed using the Kruskal-Wallis and Mann-Whitney U tests at a significant level of 0.05.

Table 1. Manufacturers and properties of the materials utilized in the study

Products	Properties	Composition	Manufacturer&Lot No.
Etch-37 w/BAC	37% phosphoric acid, 1% BAC, semi-gel	%37 H_3PO_4, %1 BAC	BISCO Inc, USA 1500002310
Adper Single Bond 2	2-step total-etch	Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, silica nanofiller, methacrylate functional copolymer of polyacrylic and polyitaconic acids	3M ESPE, St.Paul, MN, USA N614336
Gradia Direct Posterior	Microhybrid type, Shade: A2	UDMA, dimethacrylate comonomers, F-Al-Si glass, silica, prepolymerized fillers	GC Corp., Tokyo, Japan 1503301
Elipar™ S10	2nd generation LED	430-480 nm, 1200 mW/cm²	3M ESPE, St.Paul, MN, USA 586537
Sof-Lex™ XT	Aluminium oxide coated discs	Coarse, medium, fine, superfine	3M ESPE, St.Paul, MN, USA N622131

Bis-GMA: bisphenol-A-glycidyldimethacrylate
HEMA: 2- hydroxyethyl methacrylate
UDMA: urethane dimethacrylate

Table 2. Scale of dye penetration

	Occlusal Margin	Gingival Margin
0	No dye penetration	No dye penetration
1	Dye penetration extending to half of the enamel	Dye penetration extending to 1/3 of the gingival wall
2	Dye penetration beyond half of the enamel, not into the dentin	Dye penetration extending to 2/3 of the gingival wall
3	Dye penetration into the dentin	Dye penetration into whole of the gingival wall
4	Dye penetration into the enamel and dentin toward to pulp	Dye penetration into the axial wall toward the pulp

Results

The scores of microleakage tests on occlusal and gingival margins are presented in Table 3. None of the groups showed either complete prevention of the dye penetration or the score 4, which expresses the deepest penetration on the scale.

The mean, standard deviation, and median values of microleakage levels on the occlusal and gingival margins of the specimens are shown in Table 4. It was found that the values of marginal microleakage at both occlusal (p=0,08) and gingival (p=0,34) margins were not statistically different in terms of the incremental techniques.

According to Mann-Whitney U tests, there were no statistical differences (p=0,07) between occlusal and gingival general microleakage scores (Table 5).

Table 3. Microleakage scores at occlusal and gingival margins

Groups		Score 0 n (%)	Score 1 n (%)	Score 2 n (%)	Score 3 n (%)	Score 4 n (%)	Total n (%)
Group 1	Occlusal	5 (%41,7)	3 (%25)	3 (%25)	1 (%8,3)	0 (%0)	12 (%100)
	Gingival	3 (%25)	6 (%50)	1 (%8,3)	2 (%16,7)	0 (%0)	12 (%100)
Group 2	Occlusal	6 (%50)	3 (%25)	2 (%16,7)	1 (%8,3)	0 (%0)	12 (%100)
	Gingival	5 (%41,7)	3 (%25)	1 (%8,3)	3 (%25)	0 (%0)	12 (%100)
Group 3	Occlusal	10 (%83,3)	2 (%16,7)	0 (%0)	0 (%0)	0 (%0)	12 (%100)
	Gingival	7 (%58,3)	4 (%33,3)	1 (%8,3)	0 (%0)	0 (%0)	12 (%100)
Group 4	Occlusal	9 (%75)	2 (%16,7)	0 (%0)	1 (%8,3)	0 (%0)	12 (%100)
	Gingival	5 (%41,7)	5 (%41,7)	2 (%16,7)	0 (%0)	0 (%0)	12 (%100)

Table 4. Statistical analysis of microleakage scores among all groups

	Groups	Mean±sd	Median (min-max)	Kruskal-Wallis Chi-square	p-value
Occlusal	Group 1	1,00±1,04	1,00 (0,00-3,00)	6,724	0,08
	Group 2	0,83±1,03	0,50 (0,00-3,00)		
	Group 3	0,17±0,39	0,00 (0,00-1,00)		
	Group 4	0,42±0,90	0,00 (0,00-3,00)		
Gingival	Group 1	1,17±1,03	1,00 (0,00-3,00)	3,340	0,34
	Group 2	1,17±1,27	1,00 (0,00-3,00)		
	Group 3	0,50±0,67	0,00 (0,00-2,00)		
	Group 4	0,75±0,75	1,00 (0,00-2,00)		

Table 5. Mann-Whitney U test results of microleakage scores in occlusal and gingival margins.

	n	Mean±sd	Min-max	p-value
Occlusal	48	0,60±0,92	0,00-3,00	0,07
Gingival	48	0,90±0,97	0,00-3,00	

Discussion

In this study, the goal was to determine the most effective method among the incremental techniques with microleakage levels, which is the most commonly observed effect of polymerization shrinkage stress in clinical routine. In general, none of the incremental techniques received score 4 corresponding to dye penetration into the pulp, and it was seen that in all groups except for the bulk method the number of specimens in which microleakage did not occur (score 0) was relatively higher at the occlusal margin. The present results for occlusal margins confirm the effectiveness of the enamel etching technique in improving the marginal seal and decreasing microleakage. The acid etching method is the oldest and most common method used for roughening the tooth surface and for better micromechanical adhesion. Etching with phosphoric acid creates microporosities and a roughened surface by altering tooth surface topography. Studies have shown that acid etching prior to adhesive application is effective in reducing microleakage (12). In addition, techniques for preparing tooth hard tissues, such as laser irradiation (Er:YAG laser) and aluminium oxide air abrasion have been investigated in terms of reducing microleakage and acid etching has been reported to be more successful (13). Another possible explanation for the successful behaviour of incremental techniques in occlusal margins may be the presence of spherical silica particles in the adhesive system used (14). Previous studies have shown that adding filler to adhesive systems increases the elasticity modulus and rigidity, thereby reducing the polymerization shrinkage of the adhesive and contributing to the prevention of microleakage (15,16). In another study, it was reported that the nanofillers in the adhesive systems were filtered by the collagen mesh and held on the surface of the hybrid layer, thus behaving like a stress-absorbing intermediate layer (17—19). Although it was very similar to this study, Nadig et al. (11) observed higher microleakage scores on both sides of the cavity, especially more at the gingival margin. The only difference between the preferred adhesive systems was the absence of silica nanofillers in the previous study. Accordingly, it can be concluded that the use of a filler-reinforced bonding agent results in better performance in terms of microleakage.

On the other hand, the orientation of shrinkage vectors to light was seen as one of the most important reasons for marginal gap formation (20). However, studies have demonstrated that when an adequate bonding is achieved between composite and tooth, the detrimental effects of shrinkage stress would be reduced by directing the shrinkage vectors to a center near the bonded surfaces rather than the light source (20, 21). These studies confirmed the effectiveness of adhesive systems in reducing the adverse effects of shrinkage stress. The low microleakage levels ranging from 0.17 (± 0.39) to 1.17 (± 1.27) in this study suggested that the shrinkage was directed to the walls of the cavity, thus resulting in a reduction in microleakage levels, as an adequate bonding was obtained.

In the comparison between groups for occlusal margins, the least leakage was detected in the centripetal group, but this difference was not statistically significant. This method involves creating a very thin proximal layer before filling the entire cavity to provide better adaptation of the resin composite to the cavity walls. The advantage of this procedure is that a durable composite structure is obtained because the formed proximal wall is also polymerized from the inside and the next consecutive layer which is condensed toward the gingival floor is likely to fill this gap even if a gap develops (22). Duarte and Saad compared the centripetal technique with the oblique and bulk technique and found that the centripetal method showed the lowest microleakage value, similar to this study, and that this effect was significant at the occlusal margin (1).

When the oblique and split horizontal techniques were compared in terms of values at the occlusal margin, the split horizontal method produced better results. However, this difference was not statistically significant. Usha et al. compared the oblique layering and split incremental techniques in Class V cavities, and also showed that less microleakage occurred in the split incremental method (23). The researchers have reported that the use of a diagonal cut which splits each flat increment into two triangular-shaped portions before light-curing provided relief of such stresses occurring on the cavity walls. In addition, while Hassan and Khier presented the split-increment technique for Class V cavities, they noted that the diagonal cut would benefit the marginal integrity of the restoration by preventing a competition between the strong enamel bond at the incisal margin and the weak dentin bond at the gingival margin during polymerization (24).

Santhosh et al. investigated whether the modification of the horizontal incremental method was beneficial in terms of C-factor, which is effective for polymerization shrinkage stress and therefore microleakage (25). Three different methods – the classical horizontal incremental technique (gingivo-occlusal), concave surface formation and split technique – were compared in Class I cavities with a high C-factor and no statistical difference was found between methods in terms of microleakage. Neiva et al. in their microleakage studies using different incremental methods and polymerization modifications with collimator cone and clear matrix, showed that different restorative techniques did not affect microleakage when cavity margins extend on the enamel, similar to this study (26). On the other hand, it was reported that the use of metal matrix and the use of the layering method instead of the bulk increment method were beneficial for cementum margins.

When the microleakage scores at the gingival margins were compared between the groups, the lowest leakage value was obtained in the centripetal group, although there was no statistically significant difference. Although low microleakage values were obtained in both the centripetal and split horizontal techniques, none of the methods provided the complete elimination of microleakage. Previously, researchers have reported that the advantage of the centripetal technique depends on the flowable characteristics of the composite resin used (1). The same method was followed for the formation of the proximal layer in the split horizontal incremental technique, which was introduced as a modification of the centripetal technique and it was observed that the microleakage scores at the gingival margin were limited to score 1, which indicates extending to 1/3 of the gingival margin, in both groups (27). For this reason, it can be considered that the high viscosity property of the composite resin used in this study is not sufficient to fill gaps and cannot completely prevent leakage at the gingival margin.

The bulk method was the group with the smallest number of samples, with a score 0 on both the occlusal and gingival margins. Among the groups, the bulk technique showed the highest mean values at the occlusal margin and showed higher leakage with the oblique method than the other groups at the gingival margin, but these were not statistically significant. In a similar study, it was found that the highest microleakage scores were observed in the bulk technique while the lowest scores were observed in the split horizontal technique at both occlusal and gingival margins and there was no significant difference between oblique and centripetal techniques (11).

When microleakage values were evaluated in terms of different cavity margins, the results showed that microleakage increased at the gingival margins, but this increase was not significant. In this study, gingival margins were placed approximately 1 mm coronal to the cementoenamel junction; in other words, at enamel. These higher microleakage values, which were not statistically significant at the gingival margins, can be explained by the decrease in bond strength due to the thinner enamel layer in the cervical region relative to the occlusal margin. Previous studies have reported that Class II composite restorations could be an acceptable standard when gingival margins were located at sound enamel (3, 28).

As a result of this study, the null hypothesis was accepted because there was no difference in microleakage values among the different incremental groups in which the same adhesive system and composite resin were used.

Conclusions

Within the limitations of the current in vitro study, it can be concluded that:

1. None of the incremental techniques were capable of eliminating marginal microleakage completely.
2. The incremental techniques did not significantly reduce microleakage compared with the bulk method, but there was a clear tendency for reducing microleakage in deep Class II cavities with layering techniques.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception - U.M.; Design - F.Y.; Supervision - U.M., F.Y.; Materials - U.M.; Data Collection and/or Processing - F.Y.; Analysis and/or Interpretation -U.M., F.Y.; Literature Review – U.M.; Writer – U.M., F.Y.; Critical Review - U.M., F.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: Research funded by Ondokuz Mayıs University, Samsun, Turkey (PYO.DIS.1904.15.010)

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