Effect of Polishing Direction on the Marginal Adaptation of Composite Resin Restorations

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ABSTRACT

Problem: Polishing composite resin restorations may lead to marginal defects and gap formation.
Purpose: To assess the effect of polishing direction on the marginal adaptation of composite resin restorations using two composite resins and two polishing systems.
Materials and Methods: Forty extracted human molars were sectioned along their mesio-distal axis. Buccal and lingual enamel was flattened and a triangular preparation, 0.87-mm deep and 3-mm wide, representing two 60° bevels, was performed. Specimens were randomly assigned to eight groups ($N = 20$) and restored with two composite resins: a nanofilled (Filtek Supreme Ultra, 3M ESPE, St. Paul, MN, USA) or a microhybrid (Point 4, Kerr, Orange, CA, USA) and finished with two polishing techniques: polishing discs (Sof-Lex XT, 3M ESPE) or rubber polishers (HiLuster Plus, Kerr, Bioggio, Switzerland). On each specimen, both margins were polished with the same technique, one margin from composite resin to tooth and the other from tooth to composite resin. Replicas were made for field emission scanning electron microscope observation (200×) and quantitative margin analysis was performed based on four criteria. Data were analyzed with a paired-sample *t*-test, a two-sample *t*-test, and one-way analysis of variance or their nonparametric analog.
Results: Significant differences were found in most groups between polishing directions with better marginal adaptation from composite resin to tooth than from tooth to composite resin. Differences between composite resins and polishing techniques seemed to be dependent on certain combinations of composite resin, polishing technique, and polishing direction.
Conclusion: Polishing from composite resin to tooth leads to better marginal adaptation than polishing from tooth to composite resin.

CLINICAL SIGNIFICANCE

The results obtained from this in vitro study suggest that polishing direction influences the marginal adaptation of composite resins and that polishing from composite resin to tooth structure should be clinically performed whenever possible on accessible margins to preserve marginal integrity and esthetics.

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INTRODUCTION

Since their introduction to dentistry, composite resin materials and adhesives have undergone tremendous improvements and are now widely accepted as esthetic materials to create conservative restorations maintaining sound tooth structure.

Marginal seal of composite resin restorations is essential to their longevity and esthetics. Different factors are known to affect their marginal integrity such as polymerization shrinkage,[1–3] hygroscopic expansion,[2,4–6] and difference in coefficient of thermal expansion between the tooth structure and the restorative material.[2,7]

Some authors[8–15] have also reported that finishing and polishing procedures may create marginal defects and gaps that can lead to early restoration failure. Defects at the tooth-restoration interface can result in a white margin seen immediately after polishing composite resin restorations.[12,16] Furthermore, a lack of adaptation of the composite resin at the margin may increase the risk for postoperative sensitivity, pulpal irritation, staining of margins, and recurrent caries.[10,17]

The most common reason for composite resin failure reported in the literature is recurrent caries.[18,19] It has also been stated that composite resins allow for more dental plaque adhesion than other dental materials[20–22] and can foster bacterial growth from the by-products generated after its biodegradation by salivary enzymes.[23] Consequently, sealing the margins from bacteria is of high importance in preventing caries lesions. However, when taking into account other patient-related factors such as oral hygiene and fluoride exposure from dentifrice or glass ionomer restorations, some studies[24–26] suggest that a gap may not necessarily lead to recurrent caries. Nevertheless, even in a low caries risk situation, a marginal gap allows debris accumulation and may cause marginal staining which could be considered a failure in an esthetic area. Thus, longevity and esthetics of composite resin restorations depend greatly on marginal integrity.[27]

It is therefore important to maintain the seal of the margins by applying a proper finishing and polishing protocol. Although composite resin finishing and polishing procedures are well documented, there is little information in the dental literature regarding the orientation of polishing procedures and its impact on marginal integrity. One study conducted by Maresca and colleagues[15] evaluated the direction (parallel or perpendicular) of finishing procedures in relation to gap formation, but no information is available on the specific polishing direction, either from the composite resin to the tooth structure or from the tooth structure to the composite resin. Opinion leaders frequently advocate[28,29] to finish and polish from the restorative material to the tooth structure, similarly to burnish metal restorations, in order to avoid adhesive breakdown and a white line at the margin, but to date, there is no scientific evidence in the dental literature to support that clinical recommendation.

Therefore, the purpose of this study was to assess the effect of two polishing directions: from the composite resin to the tooth structure and from the tooth structure to the composite resin, on the marginal adaptation of composite resin restorations when enamel is beveled. The outcome was evaluated based on two types of composite resin materials and two types of polishing systems.

The main null hypothesis is that there is no difference in the marginal adaptation between the two polishing directions under different conditions. Secondary null hypotheses are that there are no differences in marginal adaptation between the two polishing techniques tested and between the two types of composite resin tested under different conditions. Furthermore, there is no interaction among the three variables: composite resins, polishing techniques, and polishing directions.

MATERIALS AND METHODS

Forty sound human molars extracted less than 6 months prior to the study were collected and stored in a solution of 0.2% thymol until needed. Teeth were then

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cleaned and stored in 0.5% chloramine T solution for at least 24 hours for disinfection.

Teeth were sectioned along their mesio-distal axis using a precision saw machine (Isomet 1000, Buehler, Lake Bluff, IL, USA), resulting in 80 specimens (Figure 1). Buccal and lingual enamel was flattened using silicon carbide paper of 320 grit, 600 grit, and 1,200 grit on a polishing machine (Rotopol-V, Struers, Cleveland, OH, USA) with light pressure and water coolant. Careful attention was made to avoid dentin exposure and to ensure that all margins would be in enamel. Specimens were kept in artificial saliva (pH: 6.99) throughout the study whenever possible. The composition of artificial saliva is shown in Table 1.

Because it is clinically common to bevel enamel margins of cavity preparations on anterior teeth, the present study was designed to evaluate the marginal

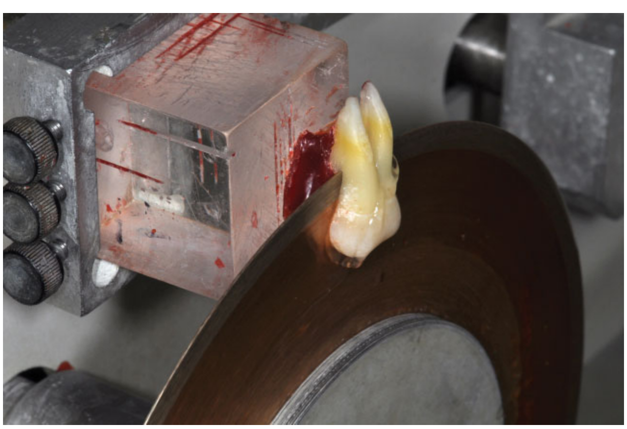


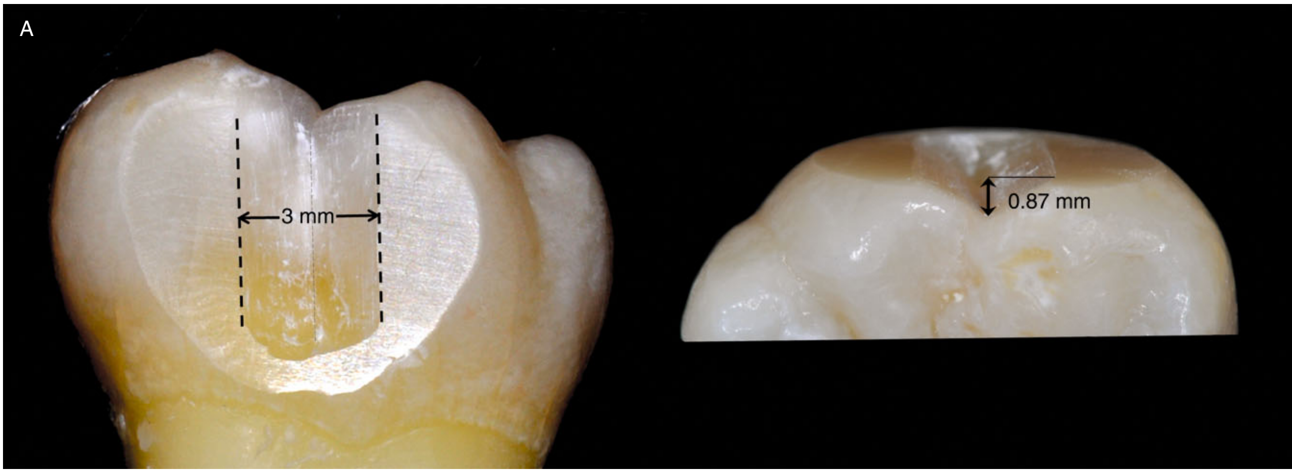
FIGURE 1. Human molar sectioned along its mesio-distal axis using a precision saw machine (Isomet 1000, Buehler, Lake Bluff, IL, USA).

TABLE 1. Artificial saliva composition

Chemical	g/10L
$CaCl_2$	0.78
$MgCl_2*6H_2O$	0.41
KH_2PO_4	5.44
KCl	22.4
HEPES buffer acid	47.7

adaptation of a composite resin to beveled enamel in general. The objective of the preparation design in this study was to create a standardized enamel bevel regardless of a specific type of cavity such as a Class III or a Class V. Therefore, a standardized preparation was made in order to create two parallel margins on each specimen, one mesial and one distal, emerging from two 60° bevels (Figure 2A). From a cross-sectional view, the preparation had a triangular shape, with the base at the margins and the tip at the deepest point of the preparation. A distance of 3 mm between the mesial and distal margins was arbitrarily chosen and, as demonstrated on Figure 2B, calculations were made to determine the required depth of 0.87 mm in order to obtain two standardized 60° bevels. In summary, the preparation outline had a width of 3 mm mesio-distally, a depth of 0.87 mm, and extended from the occlusal surface to approximately 1 to 2 mm above the cementoenamel junction occluso-gingivally. Preparations were made using a flat-end fine diamond bur with water coolant and measured with a digital caliper. The preparation design was intended to obtain two margins on a same specimen so one margin could be polished from composite resin to tooth structure and the other from tooth structure to composite resin.

The 80 specimens were randomly divided into two groups. One group was restored with a nanofilled composite resin (Filtek Supreme Ultra (FSU), 3M ESPE, St. Paul, MN, USA) (Lot number N202525) and the other with a microhybrid composite resin (Point 4 (PT4), Kerr, Orange, CA, USA) (Lot number 3312262). Figure 3 displays how specimens were distributed into treatment groups. Within each composite resin group, specimens were equally and randomly assigned to one of two polishing techniques for a total of four treatment groups: a series of Sof-Lex XT discs (3M ESPE) (SL) and a sequence of a diamond bur followed by a dark-orange Sof-Lex disc and HiLuster Plus rubber polishing cups (Kerr, Bioggio, Switzerland) (R). Within each composite resin and polishing technique group, two margins on each specimen were finished and polished with the same polishing technique, one from composite resin to tooth structure (C-T) and the other from tooth structure to composite resin (T-C)



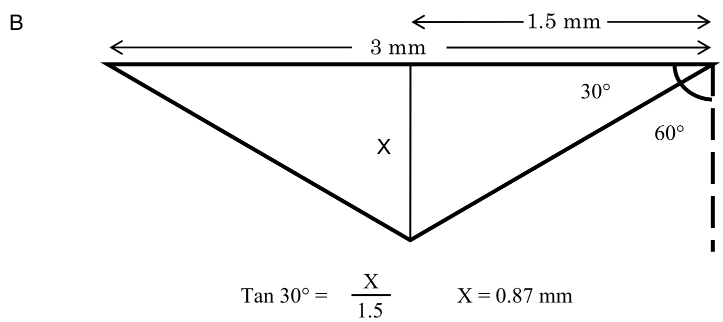


FIGURE 2. A, Standardized preparation designed to create two parallel margins on each specimen, one mesial and one distal, emerging from two 60° bevels. The preparation outline has a width of 3 mm mesio-distally, a depth of 0.87 mm, and extends from the occlusal surface to approximately 1 to 2 mm above the cementoenamel junction occluso-gingivally. B, Cross-sectional view of the preparation. Based on a width of 3 mm, calculations were made to determine the depth of 0.87 mm.

(Figures 3 and 4A). This procedure resulted in a total of 160 margins to evaluate with 20 margins in each of the eight groups.

Specimens were etched with 35% phosphoric acid gel (Ultraetch, Ultradent, South Jordan, UT, USA) for 20 seconds, rinsed, and blot dried. OptiBond FL (Kerr, Orange, CA, USA) was used for the adhesive procedure where the primer (Lot number 3448800) was applied for 30 seconds and the solvent was gently removed with air. The adhesive resin (Lot number 3525628) was applied in a thin layer and light-cured for 20 seconds using a quartz-tungsten-halogen curing light equipped with an 11-mm light guide (Optilux 500, Demetron, Kerr, Danbury, CT, USA).

According to their respective group, composite resin shade A1 was applied in one increment, adapted to minimize excess, and light-cured for 40 seconds.

The same curing light was used for all polymerization steps. The intensity of the curing light was verified periodically using the radiometer on the curing light unit to ensure that at least 600 mW/cm^2 was delivered to the material.

Restorations were finished and polished immediately after their polymerization by only one calibrated operator who finished and polished several specimens prior to the study to ensure a constant pressure and speed. The specimens were also observed under a light microscope after polishing to verify their uniformity. To further control the pressure, the speed and skills improvement throughout the study, a list of specimens placed in random group order was established using a random sequence generator in order to randomly restore, finish, and polish one specimen in each group before moving forward to the second specimen.

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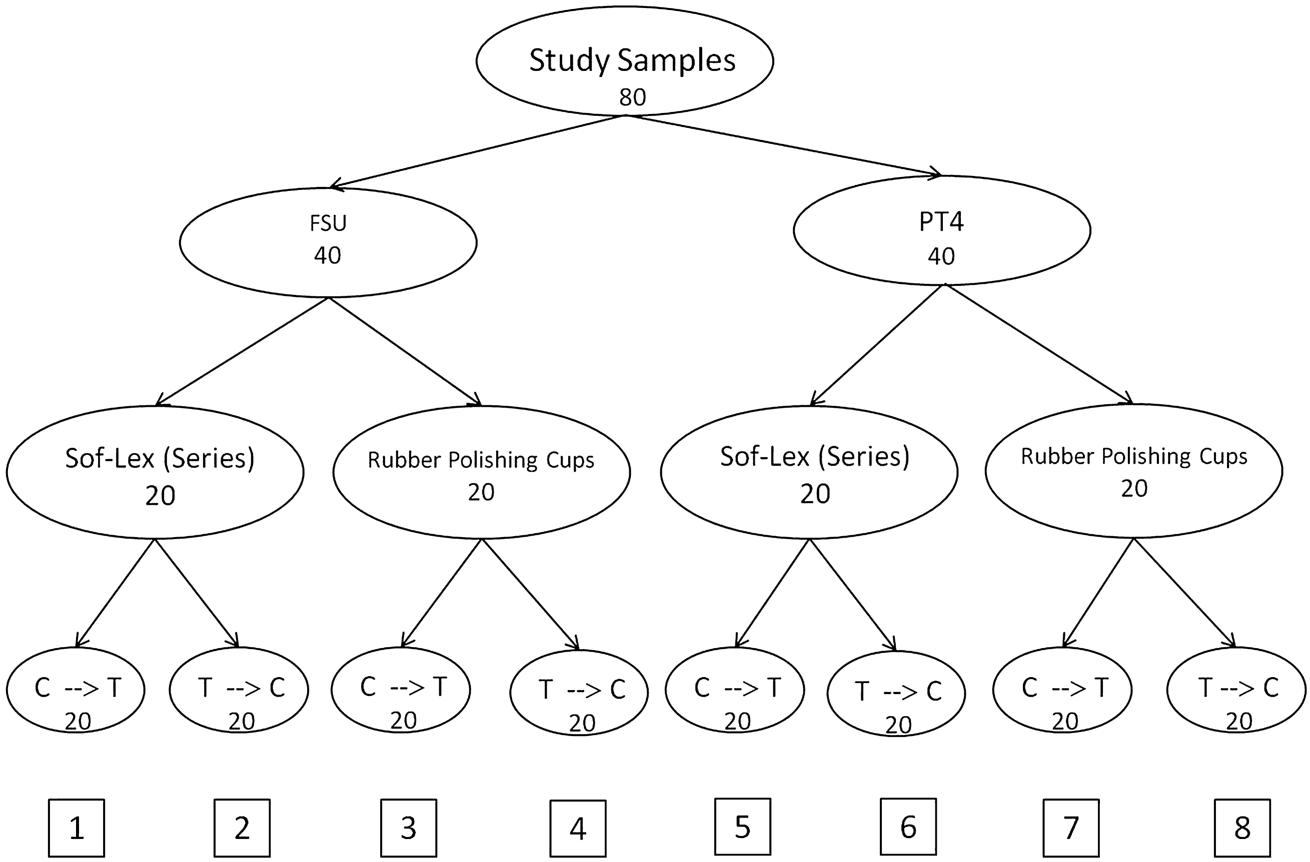

FIGURE 3. Group assignments and number of specimens. C-T = composite resin to tooth structure; FSU = Filtek Supreme Ultra; PT4 = Point 4; T-C = tooth structure to composite resin.

For the SL groups, the series of Sof-Lex discs was used sequentially from coarse to superfine grit without water (Figure 4B). For the other polishing technique (R), a diamond bur on a high-speed handpiece was used without water followed by a dark-orange Sof-Lex XT disc (3M ESPE) and by HiLuster Plus rubber polishing cups (Kerr, Bioggio, Switzerland) (Figure 4C). A blue rubber polishing cup was used first with water and a grey rubber polishing cup was used dry. Specimens were then observed under a light microscope at 20× (Zeiss, Thornwood, NY, USA) to verify the quality of the polished surface and margins.

Specimens were stored in artificial saliva for less than 4 hours before making replicas for field emission scanning electron microscope observations (FE-SEM) (Hitachi S-4800, Hitachi High Technologies America Inc., Pleasanton, CA, USA). Specimens were placed in 70% ethanol in an ultrasonic bath for 2 minutes to remove debris and contamination from the tooth-restoration interface. A first impression was made using a low-viscosity polyvinyl siloxane (Aquasil XLV Ultra Fast Set, Dentsply Caulk, Milford, DE, USA) only to ensure that no contaminant remained on the specimen surface especially at the restoration margins. A second impression using the same light viscosity material was immediately made, inspected for any imperfection, and placed in a sealed plastic container for 24 hours to allow any possible gas formation resulting from the impression material polymerization to escape. These impressions were poured with epoxy resin (Epoxicure, Buehler Ltd, Lake Bluff, IL, USA) and allowed to set undisturbed for 24 hours. Replicas were mounted on aluminum stubs using colloidal graphite paint. From the total length of the margin occluso-gingivally, only a segment of 2 mm was analyzed for the study. Therefore, a 2-mm length of the margin occluso-gingivally was outlined on the replica in the middle third of the

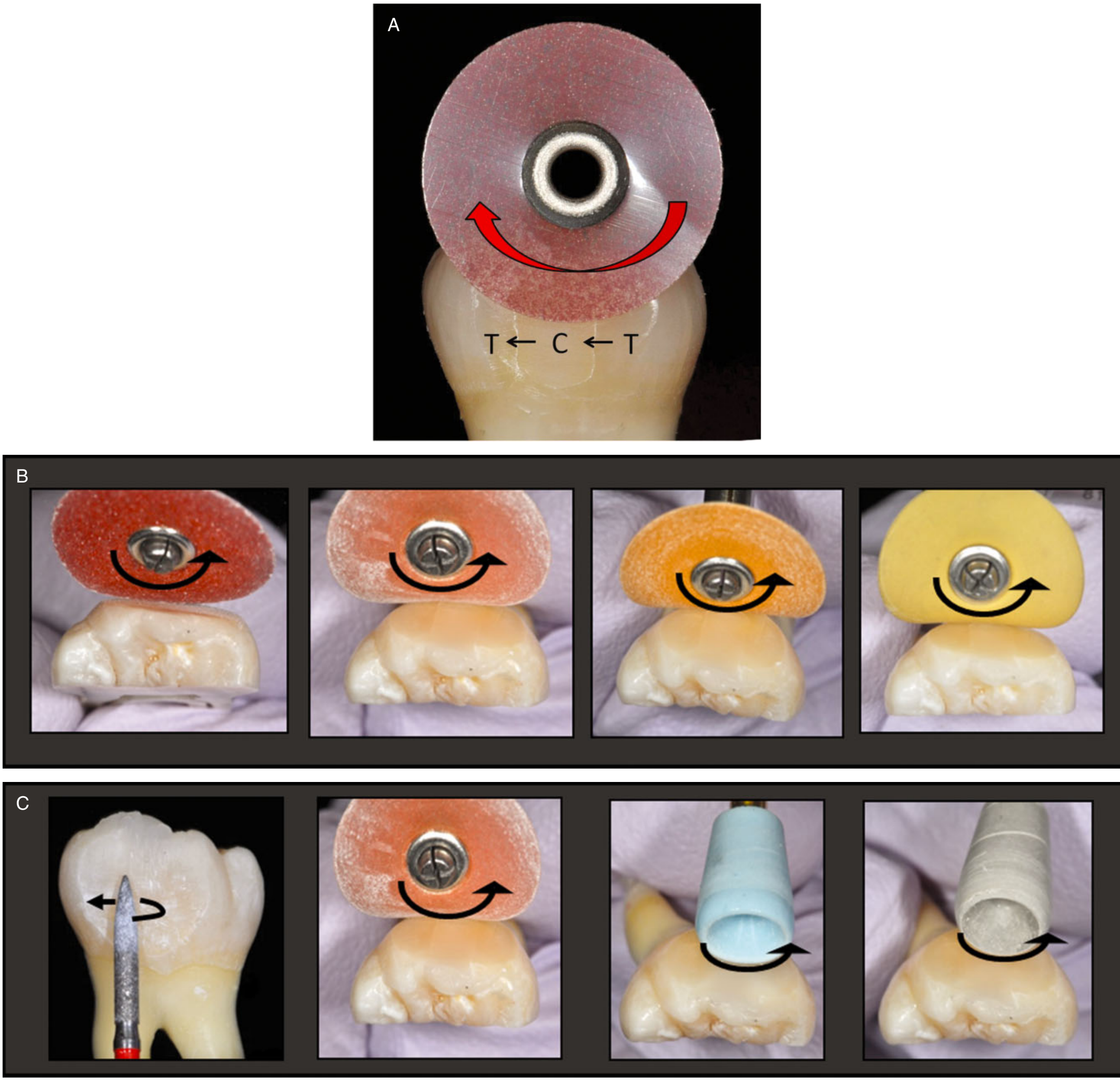

FIGURE 4. A, On each specimen, both margins were finished and polished with the same polishing technique, one from tooth (T) to composite resin C (T-C), and the other from composite resin to tooth (C-T). B, Specimen polished using the series of Sof-Lex discs. C, Specimen polished using a diamond bur on a high-speed handpiece without water followed by a dark-orange Sof-Lex XT disc and by HiLuster Plus rubber polishing cups.

restoration. Replicas were then sputter coated with gold and palladium (Emitech K550, Ashford, Kent, UK) at 10 mA for 2.5 minutes.

Replicas were observed with a FE-SEM at a magnification of 200×. For each margin, five to seven images were taken and subsequently merged together using Photoshop Elements 3.0 (Adobe Systems Inc., San Jose, CA, USA). Merged images were assigned to a random numerical code to blind the examiner during measurements.

Marginal adaptation, the outcome of this study, was evaluated with quantitative margin analysis. For each of

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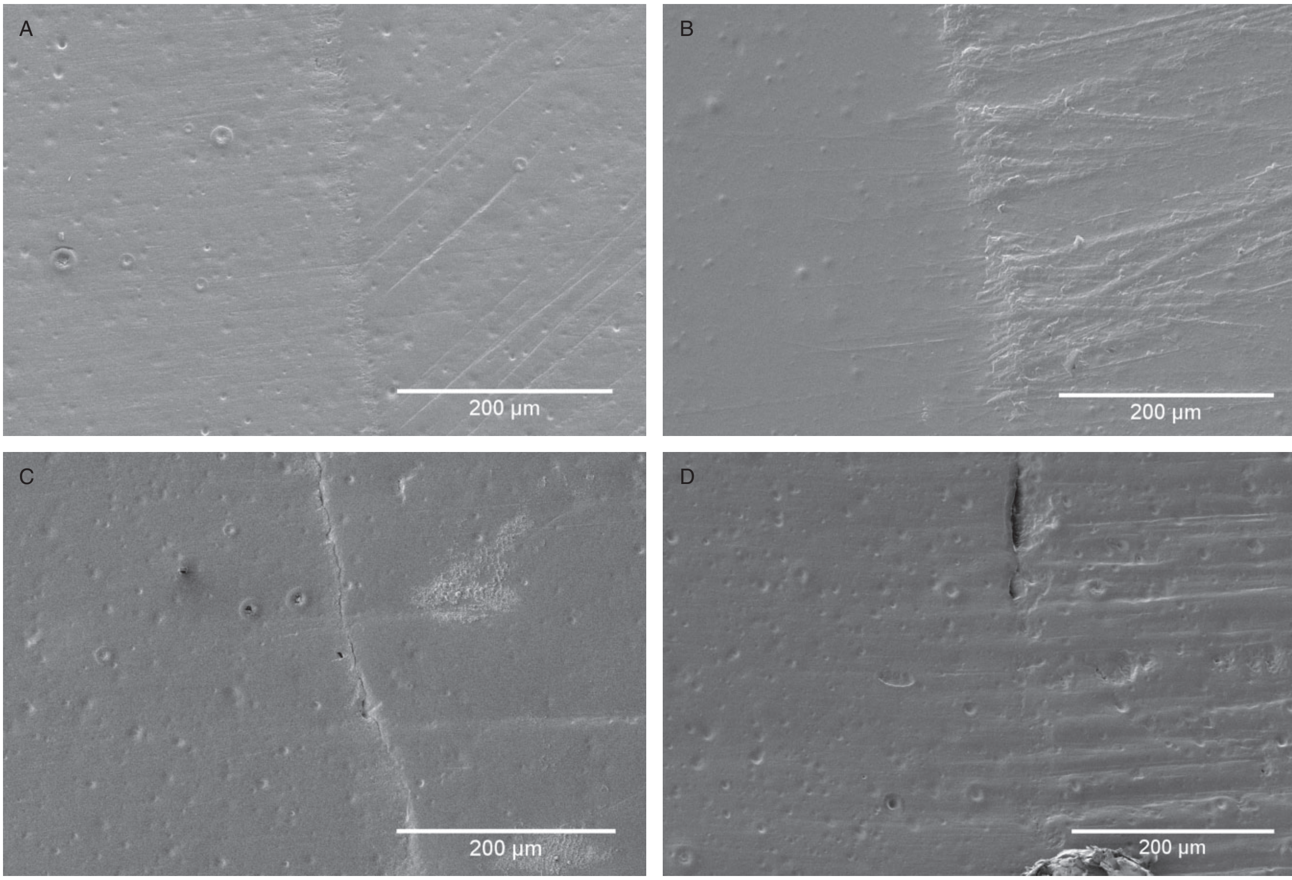

FIGURE 5. Field emission scanning electron microscope images at an original magnification of 200× representing each marginal quality criterion. A, MQ1 is represented by a continuous margin with no or slight marginal irregularities; B, MQ2 is represented by roughness at the tooth-restoration interface; C, MQ3 is represented by a hairline crack or gap of less than 2 μm; D, MQ4 is represented by a severe gap (more than 2 μm) and severe marginal irregularities.

TABLE 2. Marginal quality criteria

Marginal quality	Definition
MQ1	Margin not or hardly visible
	No or slight marginal irregularities*
	No gap
MQ2	No gap but severe marginal irregularities
MQ3	Gap visible (hairline crack up to 2 μm)
MQ4	Severe gap (more than 2 μm)
	Slight and severe marginal irregularities

*Marginal irregularities means porosity, hairline defect (no gap), roughness in the composite resin.
Source: Adapted from Blunck and Zaslansky.[30]

the mesial and distal margins of a same specimen, the length of the studied margin (approximately 2 mm) was first measured using ImageJ software (ImageJ 1.44p, Wayne Rasband, National Institutes of Health, Bethesda, MD, USA). The length of any identifiable artifact such as bubbles in epoxy resin or contamination extending beyond the margin (on the tooth structure, the composite resin, or both) was also measured and subtracted from the total length. Based on a previous study conducted by Blunck and Zaslansky[30] (Table 2 and Figure 5), each marginal defect from a same margin was ranked qualitatively using a 4-point scale (MQ1, MQ2, MQ3, and MQ4), and its length was measured. The length of all defects belonging to a same marginal quality criterion were added and expressed as a percentage of the margin length. To test for intra-observer reliability, measurements were taken twice in a 2-week interval for all specimens included in the pilot study ($N = 6$).

Statistical analysis was conducted using SAS for Windows (v9.3, SAS Institute Inc., Cary, NC, USA). First, a power analysis using six specimens per group was conducted, and the results indicated that a sample size of 20 specimens per group should have 80% power to detect a standardized effect size of 7.50% in "continuous margin" (MQ1) between polishing directions using a paired-sample t-test with a two-sided 5% significance level. Intra-observer reliability of measurements was also tested using intra-class correlation coefficient and a paired-sample t-test. For statistical purposes, MQ3 and MQ4 were combined by taking the sum of MQ3 and MQ4 and described as "gaps."

The principal variable of the study, the polishing direction, was analyzed for each marginal quality criterion using a paired-sample t-test whenever the normality of the data was respected. In the opposite case, the nonparametric Wilcoxon signed-rank test was used.

Differences between polishing techniques and composite resins were tested for each marginal quality criterion using a two-sample t-test or the nonparametric Wilcoxon rank-sum test depending on the normality of the data.

Finally, to test for a difference among the eight experimental groups, a one-way analysis of variance (ANOVA) based on ranked data, an equivalent test statistic to the nonparametric Kruskal–Wallis test, was used due to the lack of normality followed by the post hoc Bonferroni adjustment. Interactions between the three variables: polishing direction, composite resin, and polishing technique was evaluated using Mixed Model ANOVA.

A p-value of less than 0.05 was used as a criterion for statistical significance, and $0.05 \leq p < 0.10$ was used as a criterion for marginal significance.

RESULTS

Accuracy of Margin Classification

The intra-class correlation coefficients of 0.99 for MQ1, 0.99 for MQ2, 0.97 for MQ3, and 0.99 for MQ4 indicated that there was strong agreement between the two measurements made by the single observer. A paired-sample t-test revealed that no statistically significant differences between two measurements were found for MQ1, MQ2, MQ3, and MQ4 ($p > 0.05$ in each instance).

Marginal Adaptation Score

The mean % values and SDs for each marginal quality criterion (MQ1, MQ2, and MQ3 + MQ4) for all study groups are presented in Figure 6.

Polishing directions significantly influenced the quality of the marginal adaptation. The results for polishing directions are presented in Table 3. More "continuous margins" (MQ1) and less "severe marginal irregularities" (MQ2) were systematically found when the polishing procedures were conducted from C-T rather than from T-C for both types of composite resins and polishing techniques. Also, significantly fewer "gaps" (MQ3 + MQ4) were found with C-T direction for all groups ($p < 0.05$ in each instance), except for FSU/SL which was only marginally significant ($p = 0.0537$).

Polishing techniques were significantly different only for FSU polished from C-T, where discs led to more "severe marginal irregularities" (MQ2) ($p = 0.0051$, Wilcoxon rank-sum test) and to more "gaps" ($p = 0.0402$, Wilcoxon rank-sum test) than the polishing technique involving rubber polishing cups.

Some differences between the two composite resins were found. PT4 showed less "severe marginal irregularities" (0.0232, Wilcoxon rank-sum test) than FSU when polished using SL with a C-T direction, but more "gaps" than FSU when polished with R from a T-C direction ($p = 0.0381$, Wilcoxon rank-sum test).

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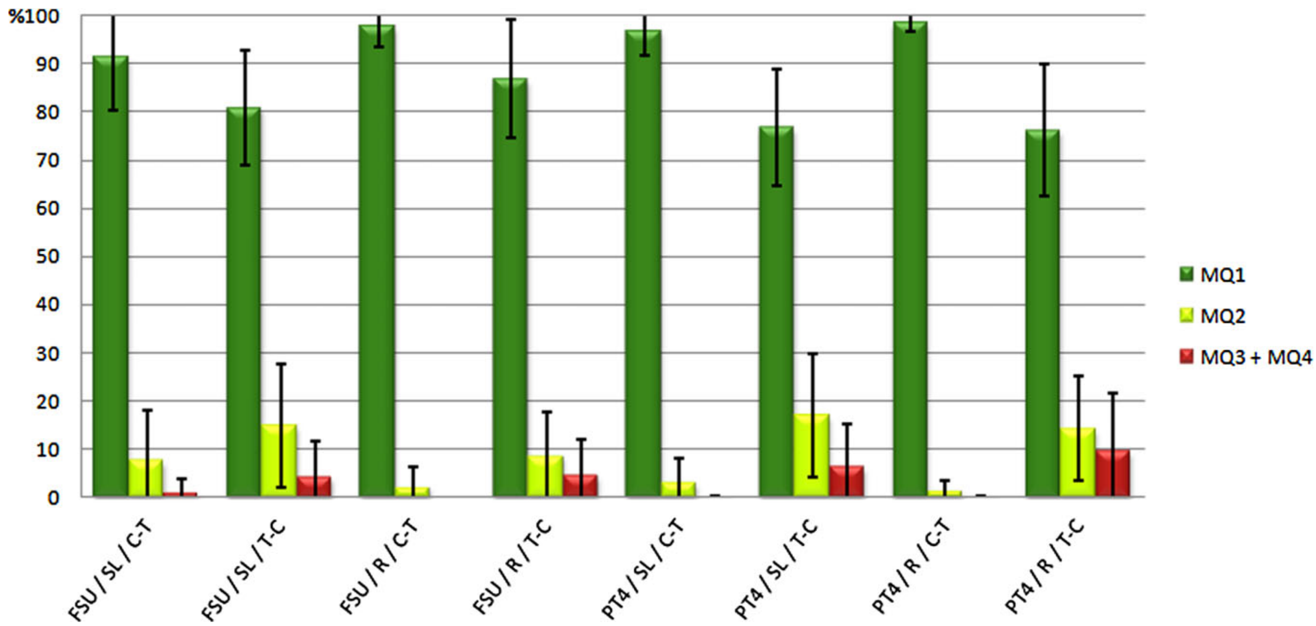

FIGURE 6. Mean % values and SD of each marginal quality criterion among the eight experimental groups. C-T = composite resin to tooth structure; FSU = Filtek Supreme Ultra; MQ1 = continuous margin; MQ2 = severe marginal irregularities; MQ3 = hairline crack up to 2 µm; MQ4 = severe gap (more than 2 µm); PT4 = Point 4; R = rubber polishing cups; SL = Sof-Lex; T-C = tooth structure to composite resin.

TABLE 3. Difference in mean % of marginal defects between polishing directions C-T and T-C under different conditions

Conditions	Mean % of continuous margin (MQ1)			Mean % of severe marginal irregularities (MQ2)			Mean % of gaps (MQ3 + MQ4)		
	C-T	T-C	*p*-value	C-T	T-C	*p*-value	C-T	T-C	*p*-value
FSU polished with SL	91.38	80.91	0.0055*	7.62	14.89	0.0388*	1.01	4.21	0.0537
FSU polished with R	97.74	86.87	0.0016*	2.26	8.66	0.0085*	0	4.48	0.0039**
PT4 polished with SL	96.96	76.74	<0.0001*	2.99	16.98	0.0002*	0.04	6.28	0.0005**
PT4 polished with R	98.51	76.26	<0.00001*	1.45	14.16	<0.0001*	0.04	9.57	<0.0001**

FSU = Filtek Supreme Ultra; C-T = composite resin to tooth structure; PT4 = Point 4; R = rubber polishing cups; SL = Sof-Lex; T-C = tooth structure to composite resin.
*Significantly different at $p < 0.05$, with a paired-sample *t*-test.
**Significantly different at $p < 0.05$, with a Wilcoxon signed-rank test.

Difference between the Eight Experimental Groups

Comparisons among the eight experimental groups are presented in Tables 4 and 5, where the groups sharing the same letter are not significantly different. For the variable "continuous margin" (MQ1), all groups polished with a C-T direction had a significantly higher MQ1 mean than the groups polished with a T-C direction. PT4/R/C-T and FSU/R/C-T groups show significantly more continuous margins than the mean of all other groups except PT4/SL/C-T. Regarding marginal "gaps," PT4/R/T-C shows significantly more gaps than the other groups except for PT4/SL/T-C and FSU/R/T-C. Moreover, except for FSU/SL/T-C, C-T direction shows significantly less gap formation than T-C direction.

Interestingly, PT4 polished with rubber polishing cups seemed to be greatly affected by the polishing direction because it showed one of the highest marginal

TABLE 4. Mean MQ1 by experimental groups

Experimental groups	*N*	Mean % of continuous margin (MQ1) (mean ranking score)	Group comparison*			
PT4/R/C-T	20	98.51 (120.53)	A			
FSU/R/C-T	20	97.74 (120.45)	A			
PT4/SL/C-T	20	96.96 (113.03)	A	B		
FSU/SL/C-T	20	91.38 (86.10)		B		
FSU/R/T-C	20	86.87 (71.78)			C	
FSU/SL/T-C	20	80.91 (50.78)			C	D
PT4/SL/T-C	20	76.74 (40.78)				D
PT4/R/T-C	20	76.26 (40.58)				D

C-T = composite resin to tooth structure; FSU = Filtek Supreme Ultra; PT4 = Point 4; R = rubber polishing cups; SL = Sof-Lex; T-C = tooth structure to composite resin.
*Means with the same letter are not significantly different using post hoc Bonferroni test ($p > 0.05$).

TABLE 5. Mean MQ3 + MQ4 by experimental groups

Experimental groups	*N*	Mean % of gaps (MQ3 + MQ4) (mean ranking score)	Group comparison*			
PT4/R/T-C	20	9.57 (123.53)	A			
PT4/SL/T-C	20	6.28 (103.40)	A	B		
FSU/R/T-C	20	4.48 (92.15)	A	B	C	
FSU/SL/T-C	20	4.21 (90.73)		B	C	
FSU/SL/C-T	20	1.01 (68.05)			C	D
PT4/SL/C-T	20	0.04 (56.38)				D
PT4/R/C-T	20	0.04 (56.28)				D
FSU/R/C-T	20	0.00 (53.50)				D

C-T = composite resin to tooth structure; FSU = Filtek Supreme Ultra; PT4 = Point 4; R = rubber polishing cups; SL = Sof-Lex; T-C = tooth structure to composite resin.
*Means with the same letter are not significantly different using post hoc Bonferroni test ($p > 0.05$).

adaptation scores of all groups for both “continuous margin” and “gaps” when polished from C-T, but also one of the lowest marginal adaptation scores when polished from T-C direction for both “continuous margins” and “gaps.”

Interactions

Results of Mixed Model ANOVA provided the evidence of nonsignificant interactions between the three variables (polishing direction, polishing technique,

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and composite resin) within each marginal quality criterion.

DISCUSSION

To maintain and improve marginal integrity and esthetics, it is essential to evaluate polishing protocols. Previous studies evaluating the effect of finishing and polishing procedures on microleakage or marginal adaptation did not investigate whether the finishing and polishing direction from composite resin to tooth structure or from tooth structure to composite resin made any difference in the quality of the margins. This present study evaluated the effect of these polishing directions on the marginal adaptation of two types of composite resins using two polishing techniques. This study refers to polishing as finishing and polishing because they are closely related and one cannot be accomplished without the other.

The results demonstrated better marginal adaptation with more "continuous margins" when polishing procedures were performed from C-T rather than from T-C which is in accordance with the common belief that polishing procedures should be conducted from composite resin to tooth structure. This could be due to the compressive strength of composite resin which is higher than its tensile strength.[2] Therefore, the direction C-T may have pushed the composite resin against the margin and protected the marginal seal, whereas the direction T-C could have pulled the composite resin away from the margin, challenging the adhesive bond. Another possible explanation is that immediate polishing may cause plastic deformation because 75% of the composite resin material is cured after 10 minutes.[2] Because polishing was performed immediately after curing the material in our study, as it is done clinically, the incomplete polymerization of the material and the heat generated during polishing procedures may have caused an increased level of plasticity which could have been an advantage for the C-T direction and a disadvantage for the T-C direction. Few studies have evaluated polishing direction. Maresca and colleagues[15] reported no significant difference between parallel or perpendicular orientation of finishing procedures. However, the perpendicular direction was performed using the same mesio-distal orientation without distinction between finishing from C-T or from T-C.

Our study detected differences in marginal adaptation between the two polishing techniques only within the C-T direction. The higher occurrence of gaps with discs could be explained by the heat generated during finishing and polishing as a result of the procedure done in a dry environment, but also by the pressure applied and by the speed of the instrument. That heat may have produced a breakdown at the tooth-restoration interface because no water was used with polishing discs, whereas water was used with one of the polishing steps in the rubber polisher group. This is in agreement with previous studies in which authors have reported the negative effect of heat on the adhesive bond at the tooth-restoration interface.[2,10,31]

PT4 showed more gaps than FSU when polished from T-C with rubber polishers, but more continuous margins when polished from C-T with Sof-Lex discs. PT4 seemed to be more affected by the polishing direction. According to Asmussen and Peutzfeld,[32] it is difficult to explain differences in mechanical and physical properties between composite resins because they vary in many characteristics such as their matrix, their filler particles (content, size, and morphology), and their particle-matrix coupling. FSU and PT4 differ in the constituents of their resin matrix and in their particles characteristics which may explain the differences observed.

Other factors can affect gap formation and gap dimension such as polymerization shrinkage and hygroscopic expansion. The C-factor, estimating the amount of stress generated at the tooth-restoration interface, is the ratio of bonded to unbonded surfaces.[1] As the C-factor increases, more stress is developed in the material during its polymerization, increasing the risk of gap formation. The triangular shape of the preparations in the present study minimized polymerization shrinkage because composite resin was bonded to no more than two surfaces as opposed to four bonded surfaces in a traditional Class I or Class V

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restoration. Even with a low C-factor, polymerization shrinkage may have created marginal defects which could have been attributed to finishing and polishing procedures. Conversely, hygroscopic expansion occurs when composite resins are placed in water or saliva which causes swelling of composite resin and may improve the marginal seal.[33] In the current study, in order to minimize the effect of hygroscopic expansion, the specimens were stored in artificial saliva no longer than 4 hours before making the impressions to produce replicas. Because of the way the specimens were polished in a random order among the groups, each specimen had equal chances to be in artificial saliva for a prolonged period of time of up to 4 hours.

Many different factors influence the marginal seal of composite resin restorations during their lifetime. It has been shown that the seal and marginal adaptation of a restoration undergo degradation with time because of masticatory forces, thermal changes, and hydrolysis.[34] Perfect marginal adaptation immediately after placement and finishing is likely to increase longevity of restorations, but it is not sufficient to prevent deterioration and degradation of the seal over time.

As stated in the introduction, caries is the main factor for replacement of composite resin restorations in the literature. However, from the clinician and patient point of view, stain accumulation in imperfect margin is a common unesthetic occurrence. Thus, obtaining good margins is primordial to maintain a high esthetic appearance of composite resin restorations.

In this study, quantitative margin analysis was chosen to evaluate the marginal adaptation in order to reduce subjectivity associated with solely qualitative measurements. Four criteria were also preferred to a pass or fail evaluation to differentiate between various sizes of marginal defects, such as marginal irregularities which may have a different clinical impact on the longevity than a marginal gap. On the other hand, too many criteria may lead to reliability issues and increase subjectivity. In the present study, the intra-observer reliability test indicated a strong agreement for all four marginal quality criteria.

This in vitro study presents some limitations. The enamel was flattened to allow a better definition of the margins for FE-SEM evaluation. This removed the aprismatic enamel and the outer layer which is often hypermineralized with high fluoride content so the result of this study cannot be extrapolated to instances where composite resin is bonded to unprepared enamel. Moreover, the design of the standardized preparation is not representative of a clinically common preparation and the depth of 0.87 mm is shallow. The preparation also facilitated the access to the margins for polishing. In clinical situations, margins are frequently difficult to access gingivally and interproximally and may not be polishable from all directions. Furthermore, only margins in enamel were assessed. It is believed that margins in dentin would likely lead to different results and therefore, the results cannot be generalized to all clinical situations. Also, there are several composite resins presenting different matrix and filler particles as well as numerous adhesive systems with different chemistry on the market. For this study, only FSU and PT4 composite resins and only OptiBond FL as an adhesive were evaluated. Results should be interpreted with caution and may not apply to other composite resins, polishing instruments, or polishing techniques.

In the present study, polishing from composite resin to tooth structure showed an advantage for marginal sealing and therefore may be translated into greater longevity and esthetics over time. Although this polishing direction is nearly impossible to accomplish interproximally and gingivally, it should be clinically performed whenever possible on accessible margins. Further studies evaluating the effect of polishing direction on the longevity of composite restorations with a similar design conducted in vivo would be relevant.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn: (1) Polishing from composite resin to tooth structure leads to better marginal adaptation than polishing from tooth

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structure to composite resin. (2) There is overall no major difference between polishing techniques, except for Sof-Lex discs which produced more gaps than HiLuster Plus rubber polishers when used from composite resin to tooth structure with FSU. (3) PT4 composite resin results in better marginal adaptation than FSU when polished from composite resin to tooth structure with Sof-Lex discs, but to more gaps than FSU when polished from tooth structure to composite resin with HiLuster Plus rubber polishers.

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