Effect of Finishing Instrumentation on the Marginal Integrity of Resin-based Composite Restorations

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ABSTRACT

Purpose: This study evaluated the effect of the use of different finishing instruments on the marginal integrity of resin composite restorations.

Materials and Methods: Bovine incisors ($N = 75$) embedded in epoxy resin had the facial enamel ground and polished to 1200-grit. A standardized cavity (3 × 3 mm, 2 mm deep) was prepared on each specimen and restored with a 2-step total-etch adhesive (Single Bond, 3M ESPE, St. Paul, MN, USA) and a hybrid resin composite (Filtek Z250, 3M ESPE) in a single increment. The restorations were mechanically polished to 1200-grit. Specimens were randomized into different groups ($N = 5$) according to finishing technique: positive control (1200-grit paper), negative control (regular-grit diamond), fine cross-cut laminated burs, straight-cut laminated burs, spiral-cut laminated burs, and finishing diamonds. The straight-cut burs, spiral-cut burs, and finishing diamonds were tested individually as fine, extra-fine, and ultra-fine, as well as sequentially as a series. A high-speed, water-cooled handpiece under standardized pressure (0.5 N) and time (40 seconds) was used for all finishing procedures. Specimens were processed for scanning electron microscope, and margin gaps were systematically measured. Data were analyzed with one-way analysis of variance and Duncan test.

Results: The negative control specimens (course diamond) presented the largest gaps, whereas the positive control specimens (mechanically polished) generated the smallest gaps. No statistically significant difference was noted between the finishing diamonds and the positive control. The negative control exhibited significantly larger gaps when compared with the other finishing instruments. Intermediate results were observed for cross-cut, straight-cut, and spiral-cut laminated burs. Fine, extra-fine and ultra-fine finishing diamonds generated smaller gaps compared with laminated burs, but the differences were not always statistically significant.

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Conclusion: Fine, extra-fine and ultra-fine finishing diamonds used to finish composite restorations generated better marginal integrity when compared with carbides and regular-grit diamonds.

CLINICAL SIGNIFICANCE
When finishing composite restorations, finishing diamond burs result in better composite margins than carbide laminated burs.

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INTRODUCTION

When placing a resin composite restoration, the primary goal of finishing instrumentation is to obtain a restoration that has proper contour, occlusion, adequate embrasure forms, and a smooth surface. In addition, perfect marginal adaptation and seal are desired. Many different rotary instruments are available for finishing resin composite restorations. However, if not carefully delivered, finishing instrumentation may lead to crevice formation and poor marginal adaptation.[1] Research shows that the degree of enamel damage induced during cavity preparation and restoration finishing can be influenced by the diamond grit size and type of bur.[2,3]

Although several studies have been performed to help determine which instruments provide the smoothest restoration surfaces,[4–8] limited quantitative information is available on marginal gaps that may occur during composite finishing. These defects potentially result in microleakage,[9] which may clinically manifest as marginal staining, postoperative sensitivity, and/or recurrent caries. Variations in finishing instrumentation techniques have been shown to affect the ability of composite restorations to resist leakage.[10] The greatest incidence of leakage was observed in restorations finished with carbide finishing burs.[11] However, Yu and colleagues also evaluated the possible influence of finishing instrumentation on microleakage, and they have shown that the best results were achieved with a 30-fluted bur followed by a short wet polishing procedure.[12] Samples finished dry with polishing disks demonstrated considerable greater microleakage.[12]

Given the variety of rotary instruments available to clinicians for the finishing of resin composite margins, it is important to systematically study these instruments in terms of their ability to generate adequate margins. Specifically, comparisons between finishing diamonds, straight-cut laminated carbides, and spiral-cut laminated carbides are not available. Therefore, this study evaluated the effect of different finishing instruments on the enamel-composite marginal integrity of resin composite restorations. A secondary aim of the study was to determine whether the direction of the finishing procedures (parallel or perpendicular to the margins) had any effect on the marginal integrity of the restorations. The null hypotheses tested were (1) that there is no difference in enamel-composite marginal integrity when cross-cut laminated carbides, straight-cut laminated carbides, spiral-cut laminated carbides, and finishing diamonds are used, and (2) that marginal gaps are not related to the orientation of the finishing instrumentation.

MATERIALS AND METHODS

Seventy-five bovine incisor crowns were obtained and stored in 0.5% chloramine T for disinfection. The specimens were embedded in epoxy resin using 1” thermosetting phenolic rings with the facial enamel surface slightly protruding from the cast. The exposed facial surfaces of the specimens were sequentially ground flat with 320, 400, and 600-grit abrasive paper under

TABLE 1. SUMMARY OF MARGINAL GAP VALUES (µM) AS A FUNCTION OF TYPE OF FINISHING TECHNIQUE (*N* = 5).

Groups	Type	Mean gap in µm (SD)*
Positive control	1200-grit polished	0.73 (0.25)[a]
Negative control	Diamond (100 µm)	16.23 (5.87)[f]
Cross-cut laminated	Fine (yellow band, 16 blades)	7.78 (2.64)[de]
Straight-cut laminated	Fine (red band, 8 blades)	6.45 (0.89)[cde]
	Extra-fine (yellow band, 16 blades)	6.28 (2.06)[cde]
	Ultra-fine (white band, 30 blades)	4.94 (1.81)[bcd]
	Fine + Extra-fine + Ultra-fine	9.15 (4.24)[e]
Spiral-cut laminated	Fine (red band, 12 blades)	6.82 (1.73)[cde]
	Extra-fine (yellow band, 20 blades)	7.82 (3.68)[de]
	Ultra-fine (white band, 30 blades)	5.34 (2.48)[bcde]
	Fine + Extra-fine + Ultra-fine	7.46 (2.48)[cde]
Finishing diamonds	Fine (red band, 30 µm)	3.73 (2.01)[abc]
	Extra-fine (yellow band, 15 µm)	3.54 (2.73)[abc]
	Ultra-fine (white band, 8 µm)	2.05 (1.86)[ab]
	Fine + Extra-fine + Ultra-fine	1.04 (0.38)[a]

*Same superscript letters indicate means that are not significantly different ($p > 0.05$).

running water (1 minute, light pressure for each cycle). Specimens were then polished with 1200-grit abrasive paper under running water and fine polished with a 5-micron diamond paste to generate a highly polished enamel surface.

A standardized Class V-like cavity measuring approximately 3 × 3 × 2 mm (mesiodistally, incisogingivally, and depth wise, respectively) was prepared in the mid-facial aspect of each specimen with a no. 271 carbide bur using a water-cooled electric high-speed handpiece. A new bur was used for each preparation. A template was used to standardize the tooth preparations, and its dimensions were verified with a digital caliper (IP 67, Mitutoyo Corporation, Kawasaki, Kanagawa, Japan). All specimens were kept in the chloramine solution.

Immediately before they were restored, the specimens were removed from the chloramine solution, rinsed with water, and gently dried with compressed air. The tooth preparation (enamel and dentin) was etched for 15 seconds, rinsed, and blot-dried. The preparations were coated with two consecutive layers of Single Bond adhesive (3M ESPE, St. Paul, MN, USA) and restored with resin composite (Filtek Z-250, shade A2, 3M ESPE). The resin composite was inserted in one increment to intentionally challenge the adhesive interface, and light-cured for 40 seconds with a light-curing unit in normal mode (Optilux 501, Kerr-Demetron, Orange, CA, USA). The preparations were slightly overfilled to allow for the finishing of the top layer of the composite. The output of the curing light unit was tested using a curing radiometer throughout the experiment (Model 100, Demetron Research Corp., Kerr, Danbury, CT, USA), which showed an intensity of 600 mW/cm^2. After curing, the specimens were stored in deionized water at 37°C for 1 week.

The specimens were randomly assigned to 15 treatment groups ($N = 5$) as shown in Table 1. Each group was finished with a different technique, including a positive control (the restoration was mechanically polished), a negative control (the restoration was roughly finished with a 100 µm grit diamond bur), and 13 groups of finishing rotary instruments (cross-cut laminated carbide, straight-cut laminated carbide, spiral-cut laminated carbide, and finishing diamond). The straight-cut, spiral-cut, and finishing diamond instruments are available in different subcategories as fine, extra-fine, and ultra-fine, so the individual effect of each instrument was tested as well as the cumulative effects of the series. All finishing instruments were used under water-spray with an electric high-speed handpiece

(NSK Ti-Max, Nl400 Brasseler USA, Savannah, GA, USA) at 30,000 rpm. The handpiece was used with light stroking action along the specimen, always using the same mesiodistal orientation. A standardized pressure of 0.5 N was applied and monitored using a custom-made apparatus consisting of a load cell, a bridge amplifier, and a data acquisition unit connected to an IBM compatible PC through a USB port. The device was used to train the operator and monitor the pressure applied while polishing the specimens. The software collected the data of the pressure values in N in a Microsoft Excel spreadsheet. A single input value was saved in the spreadsheet for every second, for the entire 40 seconds finishing cycle. A total of 40 values per sample were therefore recorded, and a summary value for each specimen was recorded as the average of the 40 values recorded for each finishing cycle (data not shown). A single operator completed all procedures after undergoing a series of training and calibration exercises to ensure that the specified pressure was maintained during the entire finishing procedure.

After the finishing procedures were completed, specimens were submerged in an ultrasonic bath for 15 minutes, to remove the debris over the margins. Vinyl polysiloxane impressions (Flexitime, Heraeus Kulzer, Armonk, NY, USA) were obtained and poured with Epo-thin, low viscosity epoxy (Buehler Ltd, Lake Bluff, IL, USA). The epoxy replicas were mounted on aluminum stubs with carbon tape and were sputter coated with gold 250 Å for 60 seconds. Specimens were observed under a scanning electron microscope (SEM; JEM 6300, Jeol USA, Peabody, MA, USA) at an accelerating voltage of 12 kV at 90° angle and working distance of 28 mm.

The enamel-composite margins were observed initially at 20× magnification for localization of all margins of the restoration, and then at 300× to examine the entire periphery (margin) of the restoration. The two largest gaps present in different axis of the restoration were selected and digitally photographed at 500×. The gaps were measured using Image J 1.34 software (National Institutes of Health, Bethesda, MD, USA). The gap measurements were averaged for each specimen. The group average was obtained by averaging the five values for each group. The correlation between the location of the gaps and the orientation of the finishing striations was qualitatively determined by the observation of all SEM images.

The data were analyzed by one-way analysis of variance and Duncan test ($p = 0.05$).

RESULTS

Composite-enamel gap mean values and SDs are presented in Table 1. The best results (smallest gaps) were obtained with the 1200-grit polished specimens (mean gap = 0.73 ± 0.25 μm). These results were not significantly different from the mean gap value obtained with the finishing diamonds. The worst result (largest gaps) was obtained with the negative control (100 μm diamond bur, mean gap = 16.23 ± 5.87 μm), which resulted in a statistically significant difference when compared with the other finishing instruments. Intermediate results were observed for the cross-cut, straight-cut, and spiral-cut laminated groups (Table 1). The SEM qualitative evaluation correlated well with the quantitative data. Representative SEM images are shown in Figures 1 through 5.

The location of the gaps did not appear to be associated with the orientation of the finishing striations. Gap formation was influenced primarily by the type of bur used, and not by the orientation of the finishing striations.

DISCUSSION

When placing direct resin composite restorations, clinicians should ensure that margins are properly finished. The primary reasons for failure of direct composite restorations are tooth or

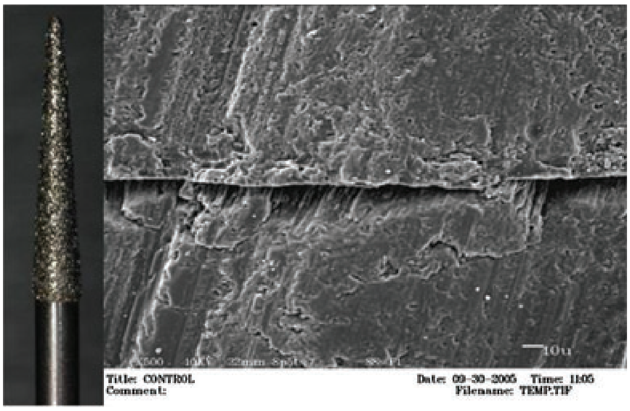

Figure 1. Representative SEM specimen (500×) showing composite-enamel margin finished with medium-grit (100 μm) diamond.

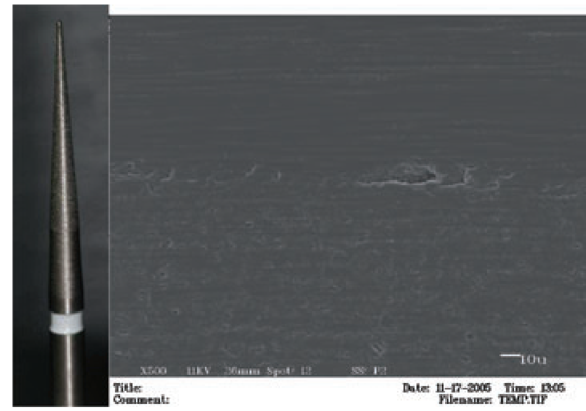

Figure 2. Representative SEM specimen (500×) showing composite-enamel margin finished with ultra-fine (8 μm) diamond.

restoration fractures and secondary caries.[13,14] Defects in the tooth-composite margin may result in microleakage and lead to marginal staining, sensitivity, and/or secondary caries.[2,15] Enamel fractures may be initiated by tooth preparation instrumentation, and extended by the contraction of the polymerizing resin composite.[16] Marginal defects can also be easily introduced during the finishing and polishing of the restoration.

Diamond and tungsten laminated carbide burs afford the opportunity to finish areas of resin composite restorations that are inaccessible to finishing discs, such as concave embrasures and occlusal surfaces. Research is controversial in recommending either diamond or carbide burs for that purpose. In this study, the effects of the various bur types recommended for resin composite finishing on the marginal integrity of the restoration were evaluated. The worst margins were observed when restorations were finished with a regular-grit (100 μm) diamond (Figure 1), which produced significantly worse margins when compared with all other groups. Conversely, the fine-grit finishing diamond burs generated the best margins of all the groups (Figure 2). These margins were not significantly different than the 1200-grit mechanically polished margins (positive control). These results are in general agreement with previous literature.[2,17] Lutz and colleagues showed that the marginal quality of restorations was significantly superior when diamond finishing burs were used.[17]

In this study, among the finishing diamonds, the use of all three instruments (cumulative use of fine, extra-fine, and ultra-fine) afforded the best results in terms of gap formation, followed by the ultra-fine, extra-fine, and fine instruments used individually. Although we did not observe a statistically significant difference between the four finishing diamond groups, a numeric reduction in the mean marginal gaps can be observed when finer diamonds are used, the best results being obtained when the entire diamond series is used sequentially. Under the conditions of this in vitro study, finishing diamonds with fine, extra-fine, and ultra-fine grit generated smaller gaps (Figure 3) compared with carbides and regular-grid diamonds, but these results should be verified with larger sample sizes to ensure that the observed differences are not a result of chance.

No statistically significant differences were noted among the cross-cut laminated, straight-cut

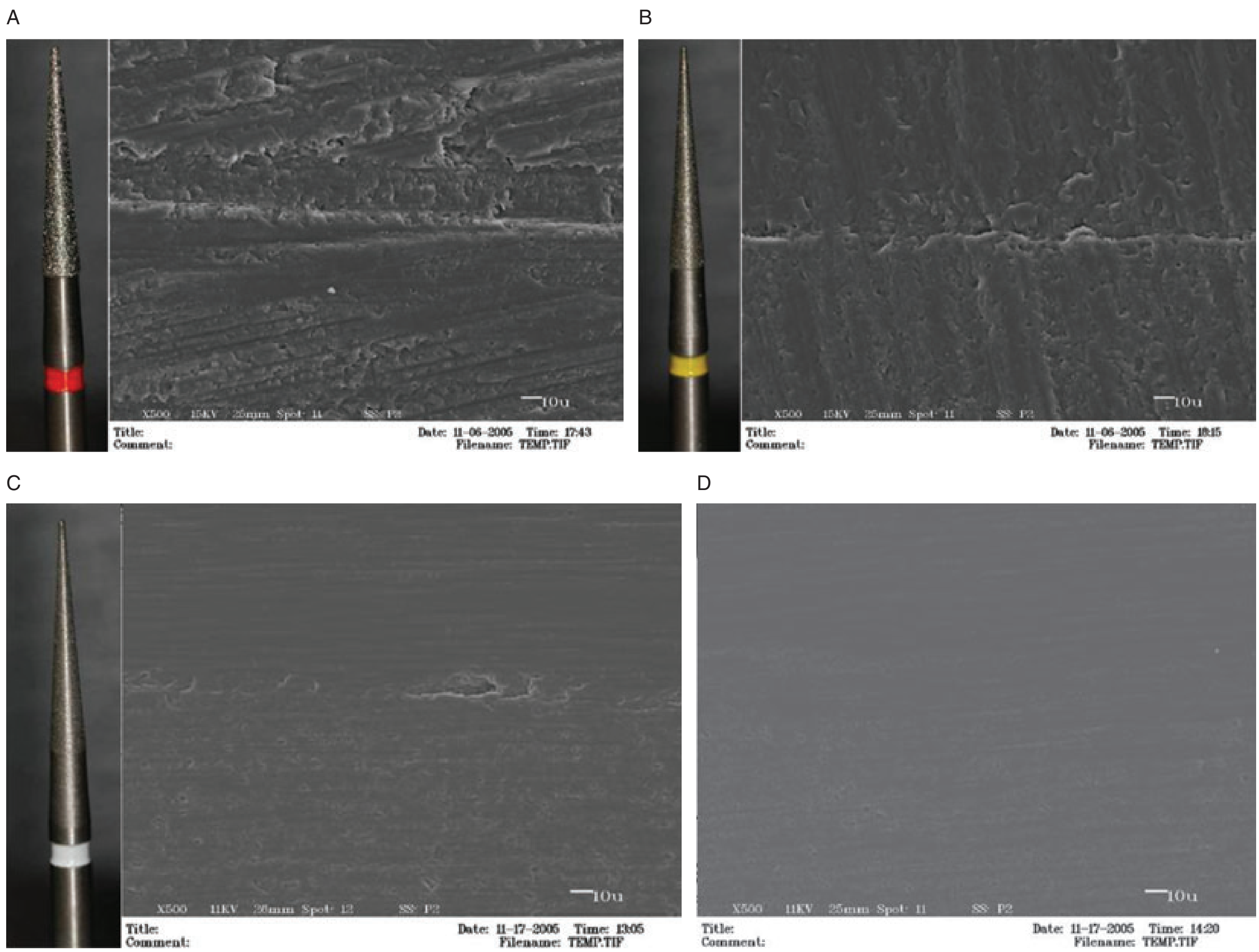

Figure 3. Representative SEM specimen (500×) showing composite-enamel margin finished with: A, *fine (30 μm) diamond finishing bur;* B, *extra-fine (15 μm) diamond finishing bur;* C, *ultra-fine (8 μm) diamond finishing bur; and* D, *diamond finishing bur series.*

laminated, and spiral-cut laminated finishing carbides. However, when comparing the straight-cut and spiral-cut groups (Figures 4 and 5), we noted that larger gaps tended to develop when all the series methods were used, leading to an interpretation that the more instrumentation in a restoration, the more likely to increase the gap, which is in contrast with the diamond group. This observation is consistent with the mean gap values, although no statistically significant differences were noted. The results of this study were comparable with previous investigations. Neme and colleagues suggested that even fine and ultra-fine instruments may negatively influence the integrity of the enamel and, to a lesser extent, restoration margins. Therefore, depending on the finishing instrument used, every additional step in a polishing sequence may increase the risk of further margin destruction.[18]

We elected to use a microhybrid composite in this study because of its universal application.

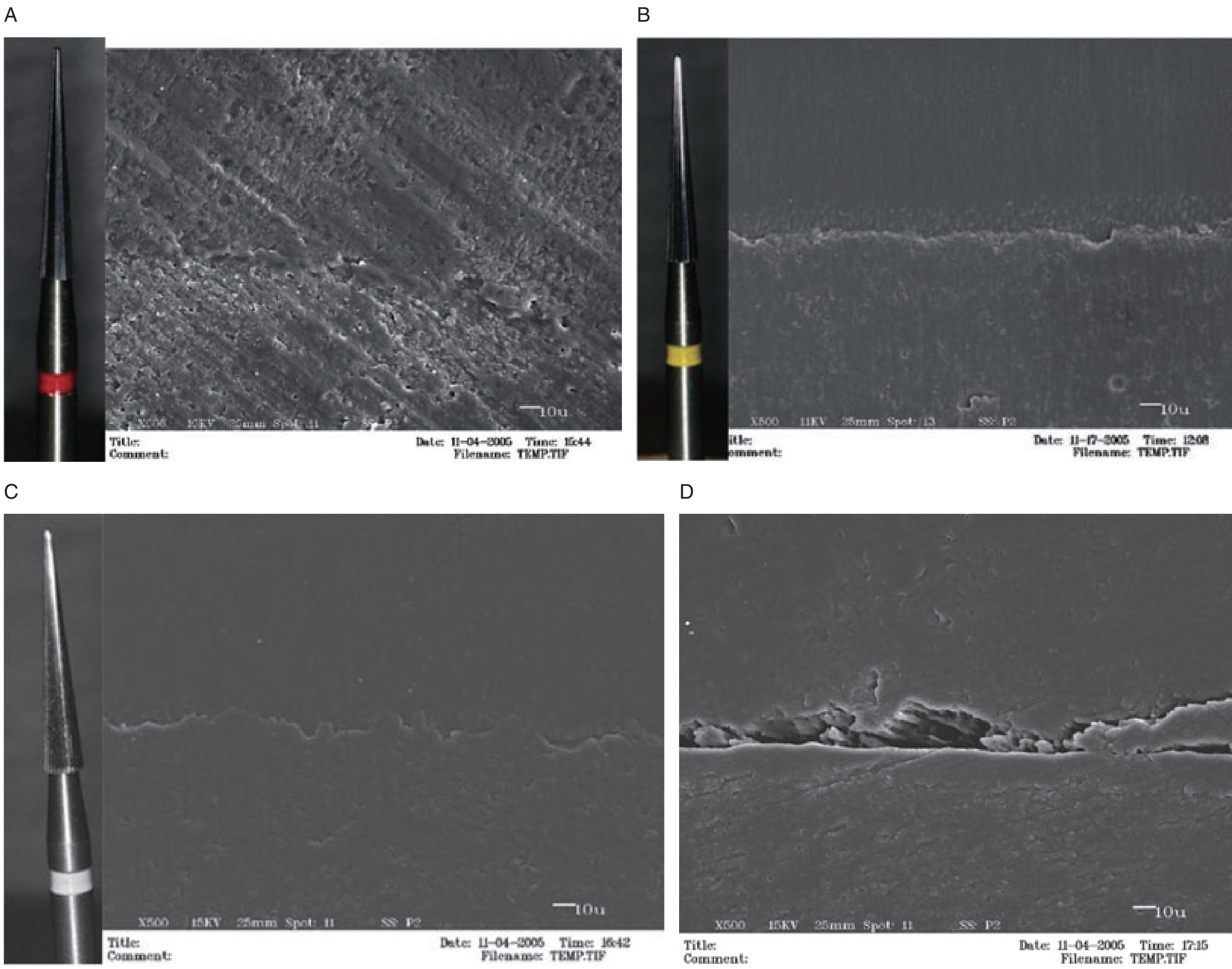

Figure 4. Representative SEM specimens (500×) showing composite-enamel margin finished with: A, *fine (8 blades) straight-cut finishing bur;* B, *extra-fine (16 blades) straight-cut finishing bur;* C, *ultra-fine (30 blades) straight-cut finishing bur; and* D, *straight-cut finishing bur series.*

There is the possibility that the results, at least in part, could be inherent to the resin system evaluated. For example, perhaps the edge strength of different composites varies. This could possibly have an influence on marginal integrity. Different results could have been found with different composites, such as microfills and nanohybrids, and more research in this area is needed. Future studies should evaluate the influence of using incremental finishing with carbide finishing burs followed by finishing diamonds as well as the influence of using finishing disks and abrasive silicone-based polishers instead of or in addition to laminated carbide and diamond burs.

CONCLUSIONS

Within the limitations of this study, it is possible to conclude that (1) finishing diamonds (fine,

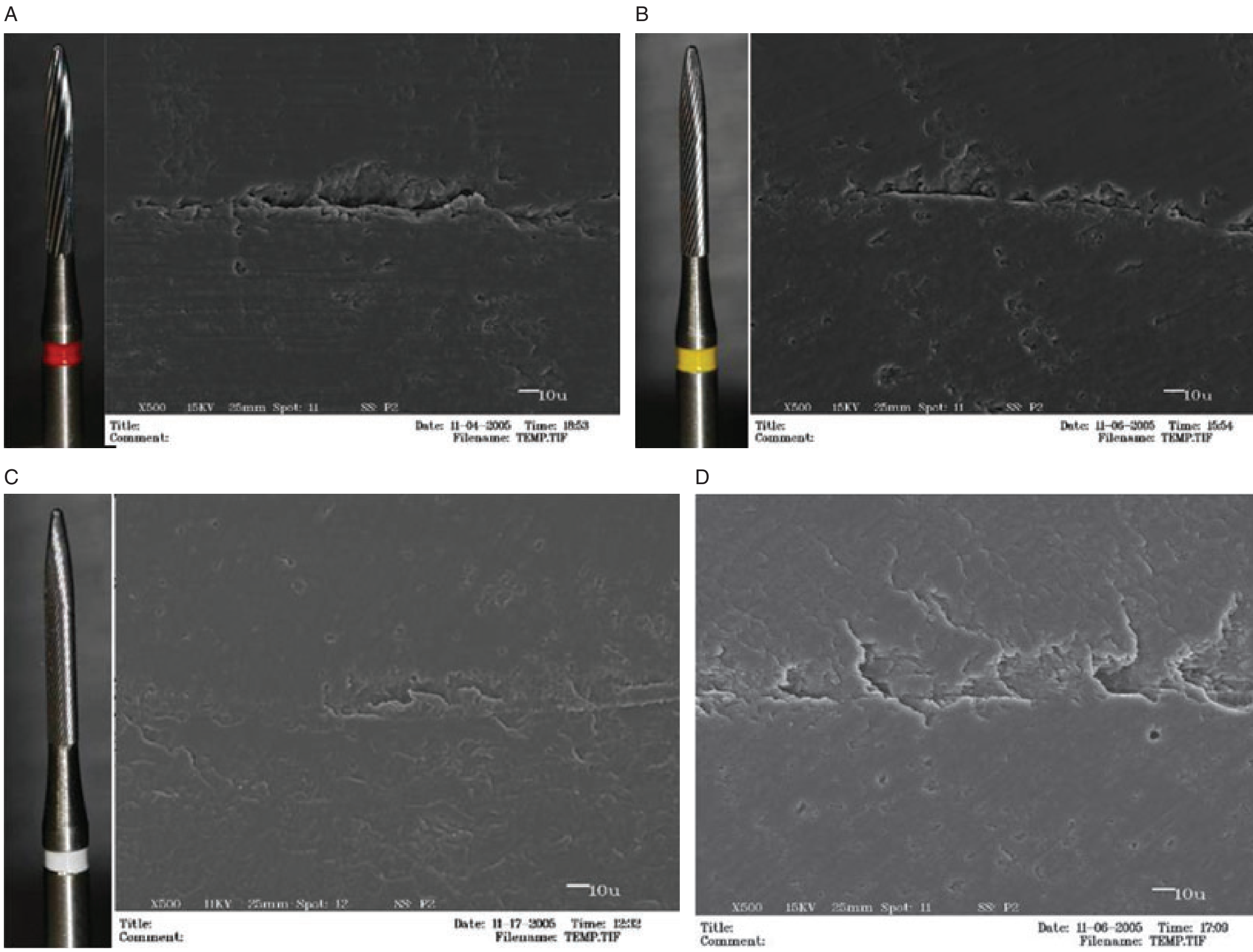

Figure 5. Representative SEM specimens (500×) showing composite-enamel margin finished with: A, *fine (12 blades) spiral-cut finishing bur;* B, *extra-fine (20 blades) spiral-cut finishing bur;* C, *ultra-fine (30 blades) spiral-cut finishing bur; and* D, *spiral-cut finishing bur series.*

extra-fine, and ultra-fine) generated the smallest marginal gaps when compared with finishing carbides and regular-grit diamonds, and (2) the location of composite marginal gaps does not appear to be associated with the orientation of the finishing striations.

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