SEM Evaluation of Surrounding Enamel after Finishing of Composite Restorations—Preliminary Results

G Iovan¹, S Stoleriu¹, S Solomon¹, A Ghiorghe¹, A V Sandu² and S Andrian¹
¹Department of Odontology, Periodontology and Fixed Prosthodontics, Faculty of Dental Medicine, “Grigore T. Popa” University of Medicine and Pharmacy, Iaşi, Romania
²Faculty of Materials Science and Engineering, “Gheorghe Asachi” Technical University of Iaşi, Romania

E-mail: stoleriu_simona@yahoo.com

Abstract. The purpose of this study was to analyze the surface characteristics of the enamel adjacent to composite resin after finishing the restoration with different diamond and tungsten carbide burs. The topography of enamel was observed by using a scanning electron microscope. Finishing with extra-ultra-fine carbide burs, and extra-fine diamond burs resulted in smooth surfaces. In few areas some superficial scratches with no clinical relevance were observed. Deep grooves were observed on the surface of enamel when fine diamond burs were used. Finishing of composite restorations with coarse burs should be avoided when there is a high risk of touching and scratching adjacent enamel during the procedure.

1. Introduction
Most composite restorations need to be finished in order to adapt to adjacent dental tissues. Finishing aims to remove excessive material from the margins and improve the contour of the restoration.

Different finishing instruments are available at the moment, among the most frequently used being the diamond and carbide burs. During finishing, both restoration and adjacent tooth may be subjected to excessive abrasion by over-instrumentation. However limited information is available regarding the iatrogenic potential of this procedure on the enamel adjacent to the restoration.

Most of the information is derived from the orthodontic data related to enamel injury after bracket removal. Despite the minor contradictions related to the variability of the tested instruments, technical protocols and research methods, most of the studies concluded that both diamond and tungsten carbide burs are fast and effective instruments for resin removal but they remove also a layer of enamel and roughen its surface[1-4].

As regarding restorations, although there are numerous studies on different methods of finishing and polishing the surface of restorations[5-7], which polishing technique is least damaging for the tooth surface is still a matter of debate. Sparse data is available[8] although for successful treatment, preserving the integrity of adjacent dental tissues should be equally important as achieving a smooth restoration.

The purpose of this study was to analyze the surface characteristics of the enamel adjacent to the composite resin after finishing the restoration with different types of burs.
2. Experimental procedures

In this study 16 extracted human molars were used. The teeth had been stored in refrigerated distilled water and used for maximum 1 month following extraction.

Buccal and lingual V class cavities were prepared using a cylindrical diamond bur with water spray and high speed. The dimensions of of the cavities were approximately 1.5mm depth, 4mm wide and 2mm high. All the margins of the cavities were prepared butt-joint in enamel and finished with fine-grit diamond bur. The cavities were cleaned with water and lightly air-dried using cotton pellets. The teeth were restore with a microhybrid composite - G-aenial Posterior (shade A3) and a self-etching one component adhesive - G-aenial™ Bond (GC Corporation, Tokyo, Japan) using a bulk-technique.

The composite resin was polymerized against a Mylar matrix. In order to minimize the extension of the material at the margins, the matrix was tightened and held by fingers beyond the margins of the cavities. Due to the normal convexities of the dental crown, composite overflows were present on the adjacent enamel in all specimens. Half of each restoration was finished using one of the tested rotary instrument, simulating the clinical procedure of removing the excessive material extending over the margins of the cavities.

The buccal restorations were finished with tungsten carbide burs and the lingual restorations were finished with diamond burs, for approximately 10s. All the preparations were performed by the same operator. 4 buccal restorations were used for testing each type of the carbide burs. 2 of the corresponding lingual restorations were used for testing a fine diamond bur and the other two restorations for testing a superfine diamond bur. The characteristics of the tested instruments are listed in table 1.

| Instrument      | Band                      | Grit/Rotation per minute | Code/Manufacturer |
|-----------------|---------------------------|--------------------------|-------------------|
| Diamond         | Fine                      | No color band            | C1OF              |
|                 | Tapered round-end         | 40µm                     | ISO 199/016       |
|                 |                            | 450,000 r.p.m.           | Top Diamco Deltadent, Italy |
|                 | Extrafine                 | Yellow                   | TR-25EF           |
|                 | Tapered round-end         | 20-30µm                  | ISO 199/016       |
|                 |                            | 300,000 r.p.m.           | MANI Inc., Japan  |
| Tungsten Carbide| Extra-fine                | Yellow                   | H 135S-014-FG     |
|                 | Straight-cut              |                          | ISO 500314166041014 |
|                 | Tapered, safe end         |                          | NTI Kahla GmbH, Germany |
|                 | Ultra-fine                | White                    | H 135UF-014-FG    |
|                 | Straight-cut              |                          | ISO 500314166031014 |
|                 | Tapered, safe end         |                          | NTI Kahla GmbH, Germany |
|                 | One-step finishing        | Blue                     | H135S-014-FG      |
|                 | Straight cross-cut        |                          | ISO 500314166072014 |
|                 | Tapered, safe end         |                          | NTI Kahla GmbH, Germany |

The prepared teeth were split in an axial mesio-distal direction. The surface of the enamel at the joint with composite in both halves of the restorations (one half resulted from using only Mylar matrices and one half after finishing with a tested bur) were observed by scanning electron microscopy using a VEGA II LSH (Tescan Czech Republic). The integrally computer-assisted microscope has a
cannon of electrons with tungsten filament, which may reach a resolution from 3nm to 30KV, and a magnification power up to 1.000,000X in the resolution mode, an accelerating voltage between 200 V and 30 kV, scanning rates between 200 ns and 10 ms per pixel.

Five of the specimens evaluated as being less abraded on adjacent enamel (one for each type of bur) were cut in an buccal-lingual direction and the section were also examined with the microscope.

Before each examination, the surface of the specimen was etched for 10s with phosphoric acid 37% and than washed with distilled water and dried. The acid etching was used in order to remove the smear layer that could change the appearance of the underneath enamel.

3. Results and discussions
In our study both diamond and carbide burs resulted in abrading the enamel surrounding the restoration, although all the tested instruments were specifically indicated by the manufacturer for finishing of composite restorations. The enamel injuries were in most cases superficial and inconsistent. As expected, the severity of the lesion was related to the efficacy of the bur to cut/abrade the substrate.

The tested diamond burs included a fine grit (40µm) and an extra-fine grit (20µm).

For the fine diamond bur, large scratches were observed on both enamel and composite resin even when 100X magnification was used (figure 1 a, b). Some of the scratches were visible with magnification loupes (3X). The fine diamond bur was included in the study because it is clinically widely used for effective removal of gross overhangs of restorations. The heavy abrasion was the result of the dimensions of the diamond grit. Obviously when using these type of burs for finishing composite restorations there is a high risk of overinstrumentation and damaging the interface with the enamel and even the surrounding enamel. Therefore such instruments should be used only for gross excess and care should be taken to avoid the contact with adjacent enamel. Once the excessive composite material is thinned, the fine burs should be changed with less aggressive instruments.

![Figure 1](image1.png)

**Figure 1.** SEM images of enamel and composite surfaces in sample finished with fine diamond burs (a. 100X, b. 500X).

Using an extra-fine diamond bur decreased the risk of severe injuries. The scratches were superficial. For 100X magnification, the specimens finished with the extrafine diamond burs did not show any significant differences between the surfaces of enamel adjacent to unpolished and polished composite. However, in terms of composite surface it was noticed a different appearance between the two halves of the restorations. On the finished surface, the glass fillers looked much larger probably because of the grinding action of the diamond bur which removed the superficial layer of resin and exposed the mineral particles (figure 2a). When higher magnification was used, fine scratches were noted on the surface of enamel adjacent to the polished composite (figure 2b).
The tested carbide burs were straight-cut with 20 blades (super-fine) and 30 blades (ultra-fine). These burs can be used in multiple-step procedure, but we decided to use them separately in order to distinguish between their iatrogenic potential.

In contrast with diamonds, carbide-finishing burs perform a cutting rather than a grinding action. Carbide finishing burs were designed to selectively cut the composite resin and conserve the enamel\textsuperscript{[9]}. However conventional carbide burs may scratch the enamel due to the shape and sharpness of their blades. Working parts with nonrounded angles may damage enamel surfaces\textsuperscript{[10]}. This applies to both burs with nonrounded flat ends and those with pointed cutting tips.

In our study when the carbide burs were used for polishing, the scratches were superficial and inconstant. Wide, deep grooves were absent.

For one sample finished with the extra-fine carbide there was a clear line of demarcation between normal enamel and the area where perikymata was flatten because of the cutting action of the bur (figure 3a). Within this area the bur “smoothed” the enamel without “scratching” it. In higher magnification very fine trails seemed to be present on the surface of enamel (figure 3b).

Polishing with the ultra-fine carbide burs resulted in enamel margins with little or no scratches at all. The surfaces of enamel adjacent to the finished composite did not show any trace of instrumentation in lower magnification (figure 4a). In higher magnification some areas with shallow irregularities could be observed on the surfaces of enamel (figure 4b).
The third tested instrument was also a carbide bur designed to be use in single-step procedure. This bur has the same shape but fewer blades with an additional cross cut which creates a roughness depth of around 1µm.

The color code (blue) and the number of blades (16) suggest a high cutting efficiency, which usually results in rough surfaces. However the surface of surrounding enamel was smooth. No significant differences could be noted between the surfaces of enamel adjacent to the areas where Mylar matrix was used and the polished surface (figure 5a). In two specimens when higher magnification was use, a clear delineation was noticed between the two areas of enamel with several trails on the surface of enamel although no deep grooves were observed.

When axial sections were assessed, a superficial loss of the adjacent enamel was observed at the margins of all the restoration after finishing (figure 6).
In our study both diamond and carbide burs resulted in cutting enamel at the joint with the composite resin. The enamel damage was superficial and inconsistent. These results are supported by a previous study which found iatrogenic abrasion of surrounding enamel during composite shaping and finishing procedures for both diamond and tungsten carbide burs [11].

The severity of the lesion was related to the type of the instrument and most important to the size of the grit or cutting blade. Best results were obtained by using extrafine diamond burs and ultrafine carbide burs. This is consistent with the results of previous studies [1,3]. In case of the cross-cut carbide bur the architecture of the blades seems to prevent the severe injury of the enamel and still being efficient in cutting the composite resin. The recommended rotation speed is low, which might contribute also to make the bur less harmful for the enamel.

Most of the data about the impact of polishing on enamel is provided by numerous studies related to resin removal after bracket debonding. In spite of the numerous studies, choosing between diamond and carbide burs have been controversial. Faria-Junior and coworkers found that polishing with an oxide disc system resulted in less enamel roughness than did the multilaminated carbide bur system [12], while Cehreli and coworkers found better results when using the 16-blade tungsten carbide bur than using ultrafine diamond bur [13]. Other studies observed that tungsten carbide drill with 30 blades during 30 s after bracket debonding resulted in higher surface variance for marks as well as deep and large scratches. This method however caused regular thickness wear, which is in accordance of our findings [14]. Similarly Vidor and coworkers found that the use of the tungsten drill (30 blades) in unidirectional movements can be recommended to remove large volumes of resin remnants although it produced grooves on the enamel surface [15]. Ryf and coworkers found that clean up with carbide burs resulted in higher variability of surface alteration [16]. Ulusoy found that 12-fluted carbide burs resulted in an irregular enamel surface in SEM evaluation, showing horizontal scars with a consistent pattern while 30-fluted burs resulted in less scarring of the enamel surface [17].

When considering adhesive removal after bracket debonding the enamel damage might be related not only to finishing procedure but also to the stress induced by the debonding of brackets and by the orthodontic treatment itself. Therefore the results of these studies cannot be extrapolated to restorative dentistry. Moreover the heterogeneity of the tested instruments, the technique used (high speed, low speed, water-spray), the time of finishing make comparison almost impossible between the results of different studies.

There are plenty of studies related to the efficacy of different finishing and polishing systems on the surface of the composite restorations as smoothness of the restoration is considered very important for the long-term success of the restoration [18]. Very few studies evaluate the impact of these procedures on adjacent dental surfaces. It was suggested that although resin remnants removal procedures cause deterioration of enamel surface, no clinical problem would be caused because the enamel surface layer contained a fluoride-rich layer of 50µm depth [19]. However the roughness of any surface exposed to oral environment would increase the retention of the bacterial biofilm. The threshold for plaque accumulation on the surface of restorative materials is considered to be 0.2µm [5,6]. The threshold for enamel is most probably different, still rough enamel at the margins of the restorations would significantly increase the risk for caries not because of the higher susceptibility of the abraded enamel but mostly because of the retention of bacterial biofilm.

Most of the studies found that finishing with both diamond and carbide burs result in enamel damage [4]. These damages can be assigned to the higher hardness of both diamond and tungsten carbide in comparison with enamel. In spite of these results the finishing burs are still widely used to remove composite resin because the advantages are significant. They are more effective than other rotary instruments and they have a versatile design allowing their access even in difficult-to-reach areas. Whether the damage produced to enamel is clinically relevant or not depends on factors related not only to the instrument, but also to the technique and patient.

Our results indicate that coarse diamond burs abrade enamel severely. On the other hand both diamond and carbide ultrafine burs seem to be acceptable solutions. Considering these preliminary results, more research is necessary in order to assess the impact of finishing procedures on the long-
term effects of these iatrogenic maneuvers. Also the dentin-composite interface should be assessed after finishing and polishing procedures since dentin is less resistant than enamel and the cervical areas of restorations are more prone to failure due to marginal defect and secondary caries.

4. Conclusions

Finishing of composite restorations with both diamond and carbide burs resulted in abrasion of adjacent enamel.

Finishing with extra-/ultra-fine carbide burs and extra-fine diamond burs resulted in smooth surfaces. SEM images showed only inconstant superficial scratches of the enamel adjacent to composite restoration.

Severe injury of enamel was observed only when fine diamond burs were used. Coarse rotary instruments should be avoided when there is a high risk of touching adjacent enamel during the finishing of composite restorations.

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