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EVALUATION OF FINISHING AND POLISHING CERVICAL RESTORATIONS THROUGH SURFACE-MATCHING SOFTWARE AND PROFILOMETRY

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ABSTRACT
The finishing and polishing of cervical restorations present intrinsic access difficulties, significantly when the restorations extend subgingivally. Problems in these maneuvers can lead to plaque accumulation, gingivitis, and caries. This work evaluated the roughness and

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the topographical aspect of cervical composite resin restorations after finishing and polishing through surface-matching software and profilometry, simulating clinical conditions. Fifteen specimens were positioned in a dental dummy to assess surface roughness and surface topography, considering three groups: G1 – rubber points (Jiffy Points / Ultradent) after finishing points F and FF (Microdont); G2 – surface sealant (Permaseal / Ultradent) after finishing points F and FF (Microdont); and G3 – polishing discs (Sof-Lex Pop-On / 3M ESPE). Profilometry assessed surface roughness parameters (Ra, Rq, Rp, Rv, and Rt). Superimposing images with surface-matching software was employed to perform a topographic surface evaluation. Roughness parameter values were compared using One-way ANOVA and post-hoc Tukey tests ($p<0.05$). G1 presented higher roughness values in all parameters analyzed except Rt, where no statistically significant difference existed. Regarding the Rp parameter, G1 showed a significant difference only concerning G3. In the other parameters (Ra, Rv, and Rz), G1 led to more important values than G2 and G3. The qualitative analysis demonstrated incomplete excesses or iatrogenic wear in regions with difficulty accessing among all groups. G3 performed better in terms of polishing. However, none of the groups reached a level of polishing considered ideal to avoid plaque accumulation. Morphological analysis demonstrated problems in difficult-to-access areas in all groups.

Keywords: Dental erosion. Polishing. Surface roughness.

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INTRODUCTION

The finishing and polishing of dental composite resin restorations require special attention since errors in these procedures can lead to plaque retention, gingival inflammation, marginal discoloration, secondary caries, iatrogenic tooth abrasion, and gingival recession (Aykent et al., 2010). Every finishing and polishing technique seeks to achieve proper restoration anatomy by removing excess composite and obtaining a smooth surface (Jefferies, 2007).

The roughness parameter most used in dentistry is the roughness average (Ra), which represents the arithmetic average of the absolute values of the profile heights over the evaluation length. Patients can distinguish differences in roughness values between 0.25 and 0.50 µm. This range encompasses natural enamel (Jones et al., 2004). Another article considers that Ra values lower than 0.2 mm are ideal for avoiding biofilm accumulation (Bollen et al., 1996).

Cervical restorations present intrinsic difficulties in the finishing and polishing process. They often apically extend beyond the enamel-cementum junction and, in some cases, have subgingival margins. Therefore, it is expected to find access difficulties (Perez, 2010). Consequently, they could be more susceptible to biofilm accumulation, which can cause carious lesions and affect periodontal tissue health (Rosin et al., 2003). Additionally, iatrogenic tooth abrasion can occur during finishing procedures (Mitchel et al., 2002).

Due to the constant development of new materials, many studies report *in vitro* comparisons of the polishing effectiveness of various finishing and polishing systems (Perez et al., 2009; Daud et al., 2018; St-Pierre et al., 2019; Lassila et al., 2020). It should be noted that almost all studies used flat specimens. Flat specimens are arguably appropriate and more manageable to standardize. However, evaluation simulating the clinical situation must be considered since dental anatomy differs substantially from regular and flat surfaces.

Just as rotary finishing and polishing instruments give different surface roughness on composite resins, they can also generate wear and grooves on the tooth surface adjacent to and over the restoration. Studies on the effect of rotary instruments on dental tissues are mainly based on orthodontic literature (Melvin et al., 2021). In cervical restorations, the critical areas for the finishing and polishing process are the gingival and the proximal margins. The gingival margin is composed mainly of dentin or root cementum. Studies that address the effects of finishing and polishing on neighboring dental tissues involve bovine

(Venturini et al., 2006) and human (Ferraris & Conti, 2014; Babina et al., 2020), which address the issue of restorations in the cervical region of the tooth. However, no simulation of the clinical situation was performed.

This study aimed to evaluate three different finishing and polishing techniques over composite resin cervical restorations and their effects on surface roughness (through profilometry), excess composite resin elimination, and iatrogenic tooth structure wear (through surface-matching software), simulating the clinical situation. It was possible to formulate a null hypothesis: the three different finishing/polishing techniques do not differ in composite resin cervical restorations' surface roughness values.

METODOLOGY

Fifteen premolars extracted for orthodontic reasons that were free from carious lesions, cracks, and fractures (assessed using a Zeiss Stemi 508 micro-stereoscope, Oberkochen, Germany) were selected from the Human Teeth Bank of the School of Dentistry at the State University of Rio de Janeiro. A pilot study was carried out to calculate the sample size. In this, two specimens from each group were analyzed by profilometry. Despite the surface's variability, each reading represented an average of at least 20 readings of each surface. Thus, an expected effect size of 0.3 and a standard deviation of 0.2 were estimated based on a pilot study. These values were input into the G*Power software (ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) together with an alpha-type error rate of 5% and a beta power of 80%. The software indicated that five samples per group would be sufficient to observe a significant effect.

SPECIMEN PREPARATION

Cavities simulating cervical lesions were prepared on each tooth's buccal surface surrounding the cementoenamel junction. They were 3 mm in height and 5 mm in width (extending to the proximal limit without invading it beyond the contact area). The occlusal margin was in the enamel, while the gingival margin was 0.5 mm below the enamel-cementum junction. The cavities were prepared by a single professional, with a standard maximum depth of approximately 2 mm, using a #2114 spherical diamond bur (Shofu, São Paulo, SP, Brazil) changed every three prepared cavities. They were restored by the same operator with two increments of an A3B color nanoparticulate composite resin (Z350 Filtek Supreme XT, 3M ESPE, Sumaré, SP, Brazil) according to the following sequence: (1) acid etching of the enamel for 30 s and acid etching of dentin and root cementum for 15 s with 35% phosphoric acid (Ultra Etch, Ultradent, South Jordan, UT, USA); (2) water jet spray for 30 s and gentle air jet drying for 10 s; (3) application of an adhesive (Adpter Single Bond 2, 3M ESPE), gentle air blast for 5 s, and light curing for 20 s with 1.200 mW/cm^2 output, (Optilight Max, Saevo, Ribeirão Preto, SP, Brazil); (4) insertion of composite resin into the cavity with a resin spatula (Millennium, Golgran, São Caetano do Sul, SP, Brazil) with a material excess extending 0.5 mm beyond all surrounding walls, verified with a digital caliper (Digital Caliper Mitutoyo 500-196-20B, Mitutoyo Sul Americana, Suzano, SP, Brazil) and light curing for 40 s each increment. The output intensity was measured after every three specimens using a light meter (Coltolux, Coltene/Whaledent, Cuyahoga Falls, OH, USA) to ensure an output of 1.200 mW/cm^2.

The teeth were scanned individually using an optical scan unit (CEREC Omnicam, Sirona Dental Systems, Bensheim, Germany). The images were processed through a software program (CEREC inLab software 4.5, Sirona Dental Systems GmbH, Bensheim, Germany) before and after finishing and polishing procedures to superimpose their images. This method enabled observing areas where excesses were incompletely removed and where wear was beyond necessary.

The teeth were divided into three groups using a computer-generated randomization table. A single previously trained and calibrated professional, different from the one who prepared and restored the cavities, performed all finishing and polishing procedures. Parameters adapted from the literature were selected for operator training and calibration (Jefferies, 2007; Lassila et al., 2020). The operator was calibrated regarding the pressure used after training on a precision scale (corresponding to a 20 g pressure) at a speed of 15.000 rpm. Considering the difficulties in accessing restorations intrinsically related to the clinical situation simulation, no finishing and polishing time restriction was imposed.

The procedures were performed individually; each tooth was inserted in an artificial dental socket to simulate clinical conditions. The tooth had its apical portion of the root removed. Then, the root was flattened and milled to create an indexing profile that would allow the removal of the tooth and its exact repositioning, if necessary. Putty addition silicone (Panasil Putty Soft, Ultradent, Indaiatuba, SP, Brazil) was inserted into the dental dummy's artificial dental socket. The tooth was positioned in the artificial dental socket, so the enamel-cementum junction coincided with the gingival level. After silicone polymerization, all finishing and polishing procedures were performed, repeating the same

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process with each sample. Before the finishing and polishing, a gingival retraction cord (Ultrapack™ #0, Ultradent, South Jordan, UT, USA) was inserted to simulate the usual clinical condition. Additionally, an instrument was used to gently retract and protect the artificial gingiva during the procedures (Gingival Retractor TI 7mm, Maximus, Contagem, MG, Brazil). When some initial damage was observed, the procedure was stopped, and the artificial gingiva was immediately replaced.

The restorations were polished using three different methods (Table 1): G1 – rubber points (RB), G2 – surface sealant (SS), and G3 – polishing discs (PD). After the finishing and polishing procedures, the specimens were scanned again. Figures 1, 2, and 3 demonstrate the finishing and polishing sequence performed in groups G1, G2, and G3.

Table 1. Finishing and polishing techniques and materials used in the study

Group	Finishing and Polishing Materials	Finishing and Polishing Techniques	Number of teeth
G1 (Rubber points)	Fine and ultra-fine diamond burs (#3205 F and FF; Microdont, São Paulo, SP, Brazil) and three-step abrasive rubber points (Jiffy Polisher; Ultradent)	Fine and ultrafine diamond burs were used with water cooling at high speed for 15 seconds each. A three-step rubber point system was used for the polishing process, without water, at low speed for 15 seconds each.	5
G2 (Surface Sealant)	Fine and ultra-fine diamond burs (#3205 F and FF; Microdont) and surface sealant (Permaseal; Ultradent, South Jordan, UT, USA)	Fine and ultrafine diamond burs were used with air and water cooling at high speed for 15 seconds each. The surface sealant was applied to the restoration's surface according to the manufacturer's instructions: 1. Etching the surface with 35% phosphoric acid (Ultra Etch; Ultradent) for 20 seconds. 2. Washing with water spray followed by air-drying. 3. Application of a thin layer of surface sealant for 5 seconds with a micro applicator. 4. A gentle blast of air from the triple syringe. 5. Light curing for 20 seconds.	5

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Figure 1. Finishing and polishing sequence of G1 (RP): (A) tooth with cervical restoration positioned on the dental dummy; (B) finishing with diamond bur 3205 F; (C) and with a 3205 FF diamond bur; (D) three-step rubber point sequence: green; (E) yellow; (F) white.

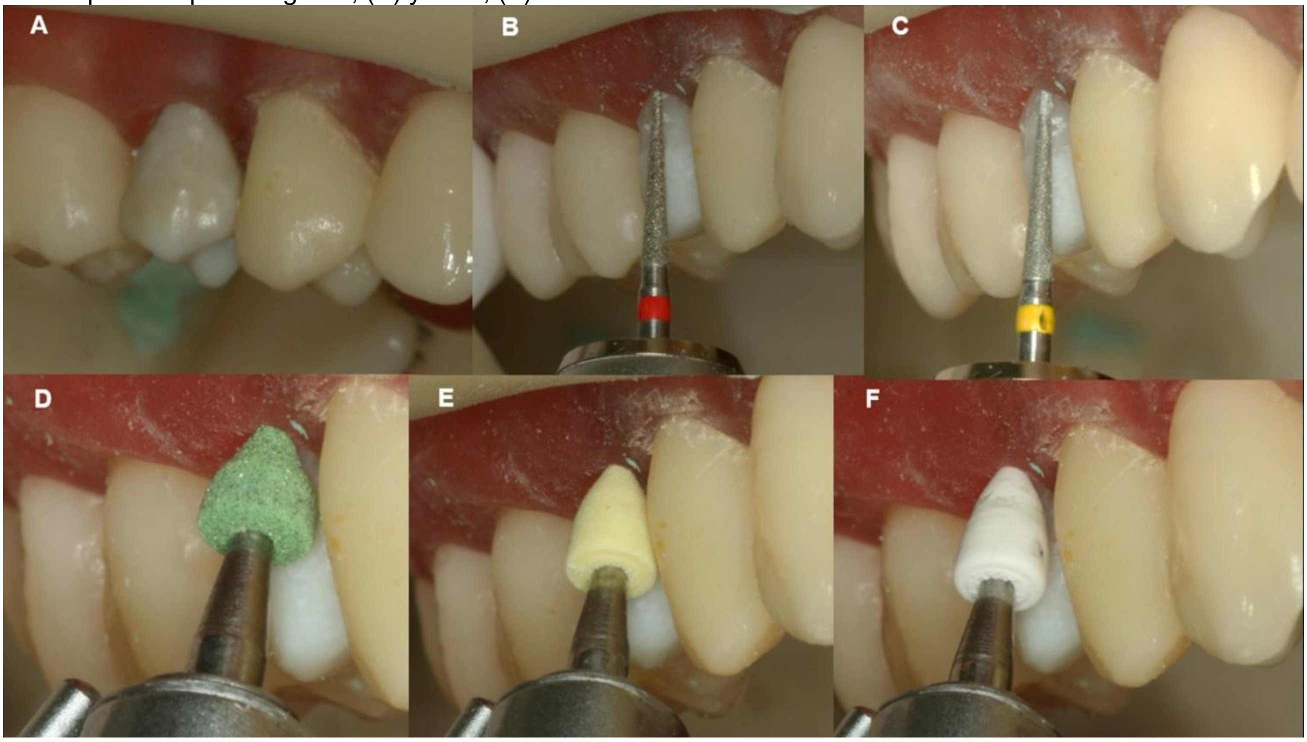

Figure 2. Finishing and polishing sequence of G2 (SS): (A) finishing with diamond bur 3205 F; (B) PermaSeal®; (C) acid etching; (D) surface sealant application; (E) photocuring.

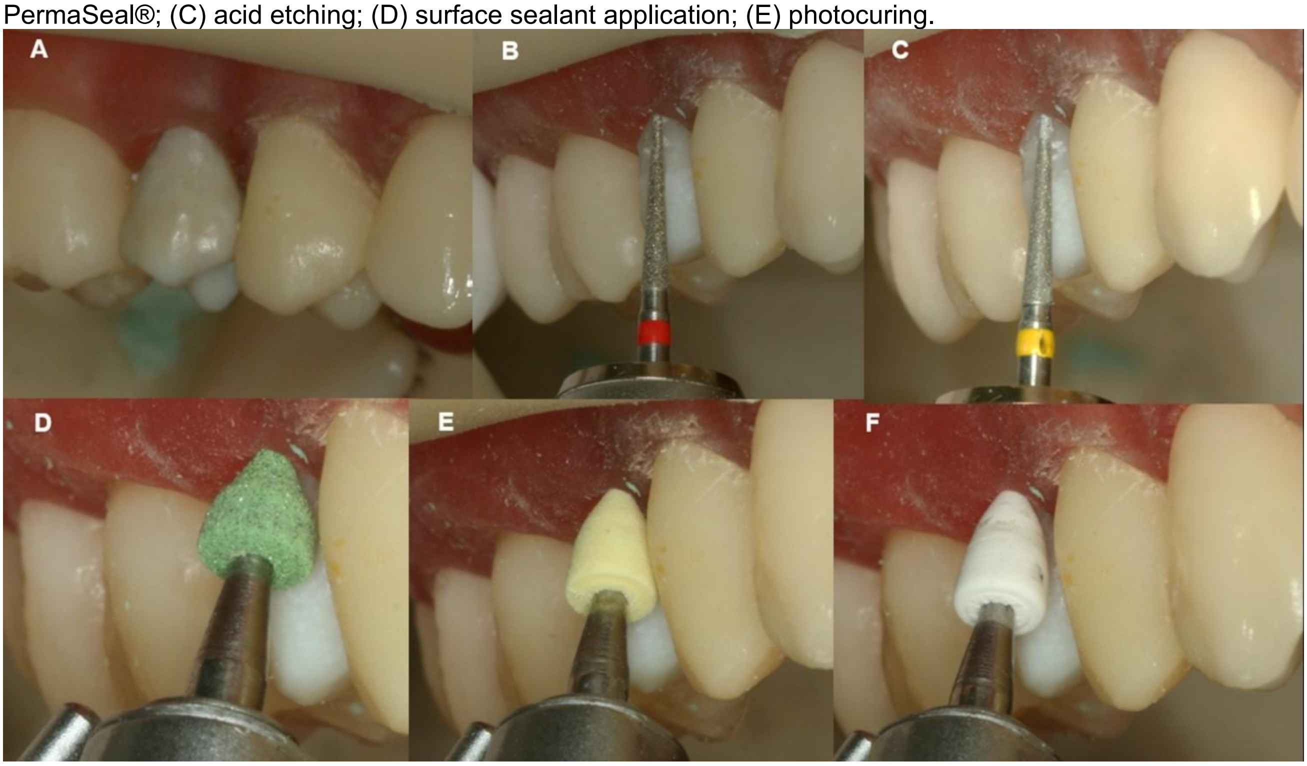

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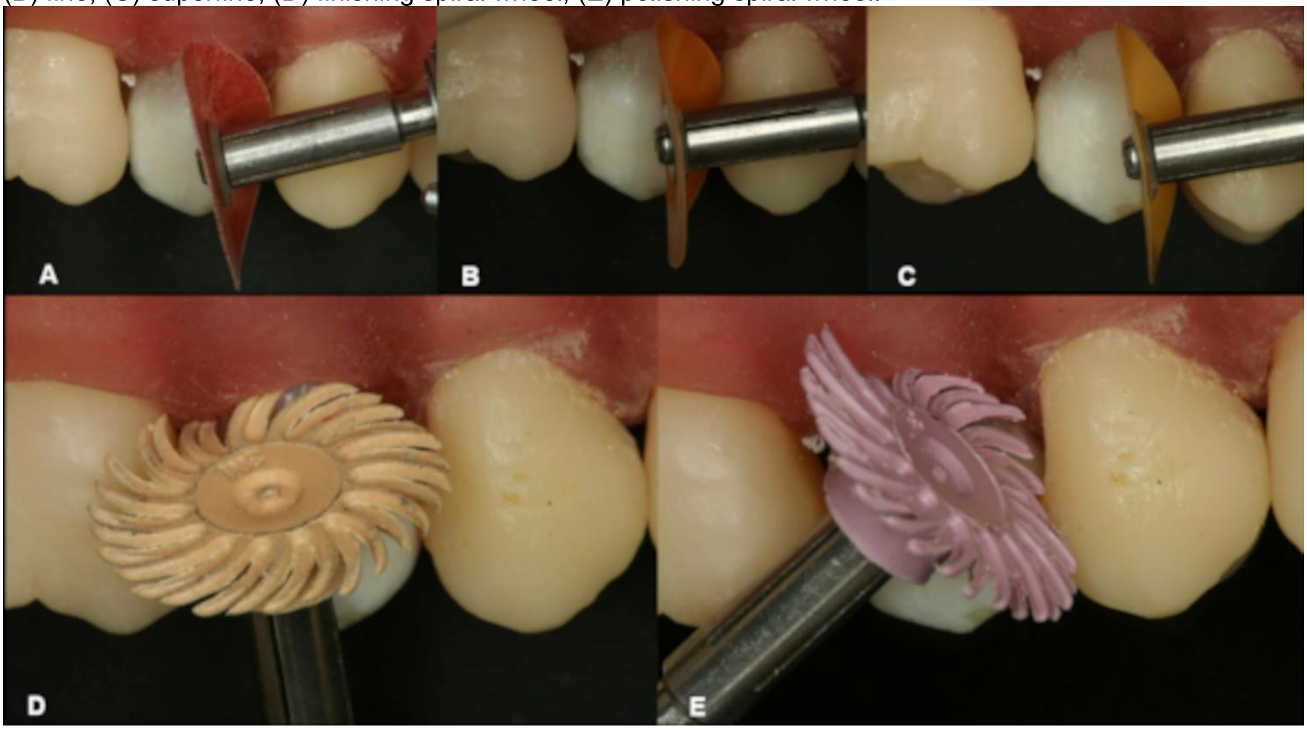
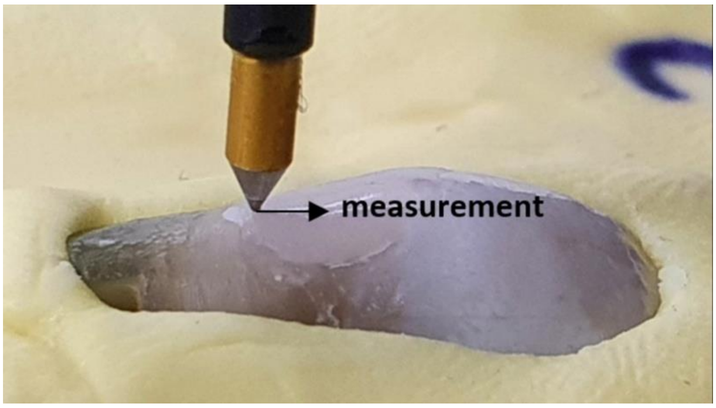
Figure 3. Finishing and polishing sequence of G3 (PD): (A) polishing discs sequence: coarse, (than medium); (B) fine; (C) superfine; (D) finishing spiral wheel; (E) polishing spiral wheel.



ROUGHNESS EVALUATION

Putty addition silicone (Panasil Putty Soft, Ultradent, South Jordan, UT, USA) was used to fill a plastic box (0,5 cm height, 2,5 cm width, and 2,5 cm wide) for a horizontal insertion of each tooth, allowing its fixation, repositioning (if necessary), and exposure of the cavity's portion in a favorable position for probe access (Figure 4).

Figure 4. The tooth is positioned in a Putty silicon indexing mold. The arrow shows the direction of the conical probe trajectory over the surface.



The measurement length of the surface topography profiles (Figure 5) to generate the tridimensional map. The number of measured profiles was 20, equivalent to a range from 1.75 to 3 mm in size in the Y direction.

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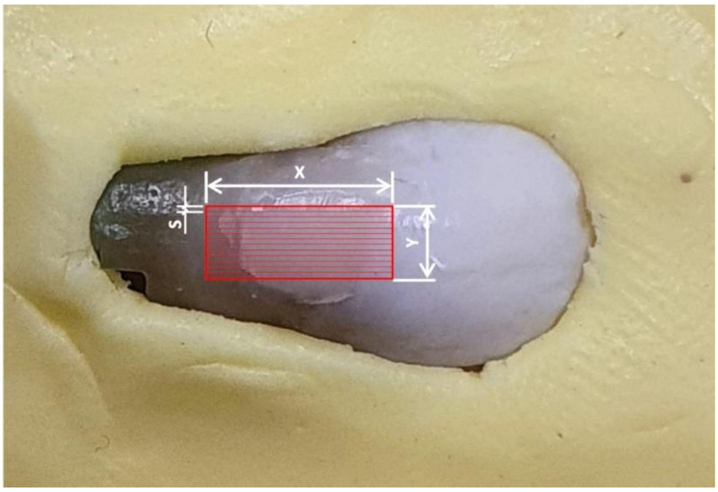
Figure 5. Measurement length of a surface topography profile: X direction varied from 5 to 7 mm, space of 0.065 mm between profiles, and Y direction range from 1.75 to 3 mm (22 to 40 measured profiles depending on Y width).



Roughness analyses were performed using the Talymap software (v.4.1.2.4434), with a sampling length (cut-off) of 0.25 mm. Considering all the measured profiles, mean roughness values were obtained for each tooth. The evaluated roughness parameters were Ra (arithmetic mean height), Rq (root mean square roughness), Rp (maximum peak height), Rv (maximum valley depth), and Rt (total height). The Ra parameter is the most used one as it is related to the heterogeneity on average; however, Rp, Rq, Rv, and Rt parameters give better information related to the abrasive condition of the surface (Gadelmawla et al., 2002). The operator of the profilometer, responsible for the roughness evaluation, was blinded to which group each specimen belonged to and was different from the previous operators involved in the other method steps.

TOPOGRAPHIC SURFACE EVALUATION THROUGH DIGITAL SCANNING

All assessments, measurements, and analyses were performed by one operator blinded to which group the specimen belonged to. For this stage, the teeth were inserted vertically in a putty-addition silicone (Panasil Putty Soft, Ultradent, South Jordan, UT, USA), which filled a plastic box (2.5 cm height, 2.5 cm width, and 2.5 cm wide) to stabilize and allow indexable repositioning of each tooth.

The STL (file format for stereolithography) models obtained from the scans were analyzed using WearCompare (Leeds Digital Dentistry, Leeds, UK), a tool developed to quantify tooth wear. A method to improve registration with best-fit algorithms was employed, registering the data points solely on preserved areas without modifications (O'Toole et al., 2019; Rodrigues et al., 2012; Gkantidis et al., 2020). A qualitative analysis was conducted

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by superimposing the images to obtain a clear view of the morphological and topographic changes after the finishing and polishing procedures. The generated images provided a colored scale analogous to the surface topography, which indicates the height changes in the different regions of the restoration.

STATISTICAL ANALYSIS

Statistical analysis was performed using IBM SPSS software v.24 (Armonk, NY, USA). After verifying the normality of the data with the Kolmogorov–Smirnov test and the homogeneity of variables with Levene's Test of Equality of Error Variances, the dependent variables (Rp, Rt, Ra, Rz, and Rv) were transformed (log10) to reach the parameters of normality. They were compared using a One-way analysis of variance. A Tukey post hoc test was performed to evaluate subgroups. The results were evaluated with a 95% confidence interval. The statistical significance level was established at $p<0.05$.

RESULTS

QUANTITATIVE RESULTS: SURFACE ROUGHNESS

Table 2 shows surface roughness parameters for each tested group and the statistical analysis data. According to ANOVA at a 95% confidence level, differences between the three groups were not significant only for Rt. Except for this parameter, G1 presented significantly higher roughness values than the other groups, in some cases than both groups (as in Ra, Rv, and Rz) or G3 (as in Rp).

Table 2. Surface roughness parameters (Ra, Rt, Rp, Rv, and Rz), expressed in mm, after finishing and polishing cervical restorations*

Roughness parameter	Ra			Rt			Rp			Rv			Rz		
Group	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
Tooth #1	1.3	0.5	0.3	13	8	5	3.1	1.4	0.8	3.0	1.0	1.0	6.2	2.4	1.7
Tooth #2	0.8	0.7	0.5	9	12	6	1.9	2.3	1.0	1.9	1.6	1.2	3.7	3.9	2.2
Tooth #3	0.8	0.9	0.4	10	13	6	2.1	2.3	0.9	2.4	1.6	1.1	4.5	3.9	1.9
Tooth #4	0.9	0.5	0.4	14	11	7	2.0	1.8	0.9	2.3	1.1	1.1	4.3	2.9	2.0
Tooth #5	1.7	0.4	0.5	29	10	12	3.2	1.4	1.2	5.0	0.9	1.5	8.2	2.3	2.7
ANOVA p-value	0.004			0.088			0.001			0.004			0.002		

Tukey pairwise comparison (95% confidence)	A B B	A A A	A A B	A B B	A B B
Mean	1.1 0.6 0.4	15 11 7	2.5 1.8 1.0	2.9 1.2 1.2	5.4 3.1 2.1
Standard deviation (SD)	0.4 0.2 0.1	8 2 3	0.6 0.4 0.2	1.2 0.3 0.2	1.8 0.8 0.4
CoV (SD/mean)	36 31 18	54 18 43	26 24 19	43 27 16	33 25 17

*Significant difference at $p < 0.05$. Different letters indicate significant difference.

QUALITATIVE RESULTS: TOPOGRAPHIC SURFACE ANALYSIS

The scanning method allowed a qualitative surface analysis, making it possible to discern the limits of the restoration, volume, and the tooth structure around it, in addition to allowing the superimposition of images before and after finishing and polishing, generating a 3D image where it is possible to visualize remaining restoration's marginal excess, and iatrogenic wear. Images generated through the scanning and the superposition before and after finishing and polishing procedures in G1, G2, and G3, respectively, are presented (Figures 6, 7, and 8). The black and white images allowed the 3D outline of the restoration and the surrounding hard tissues to be more clearly discerned. The color images were produced by superimposing the images using the surface-matching software WearCompare, highlighting areas where excessive, insufficient, or iatrogenic wear has occurred.

Figure 6. G1: blue (occlusal limit), white (cervical limit), and red arrows (iatrogenic wear); (A) greyscale images (before and after); (B) distal (initial) view, and superimposed scans; (C) frontal view of superimposed scans; (D) colored analogous scale; (E) 45º (mesial) superimposed scans.

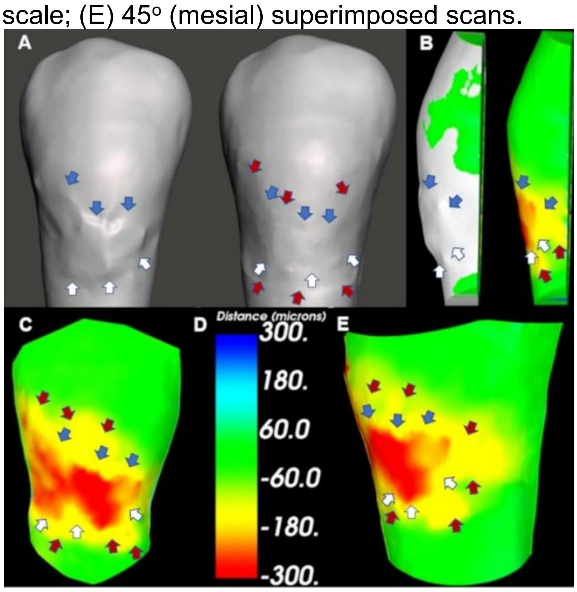

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Figure 7. G2: blue (occlusal limit), white (cervical limit), and red arrows (iatrogenic wear); (A) greyscale images (before and after); (B) distal (initial) view, and superimposed scans; (C) frontal view of superimposed scans; (D) colored analogous scale; (E) 45º (mesial) superimposed scans.

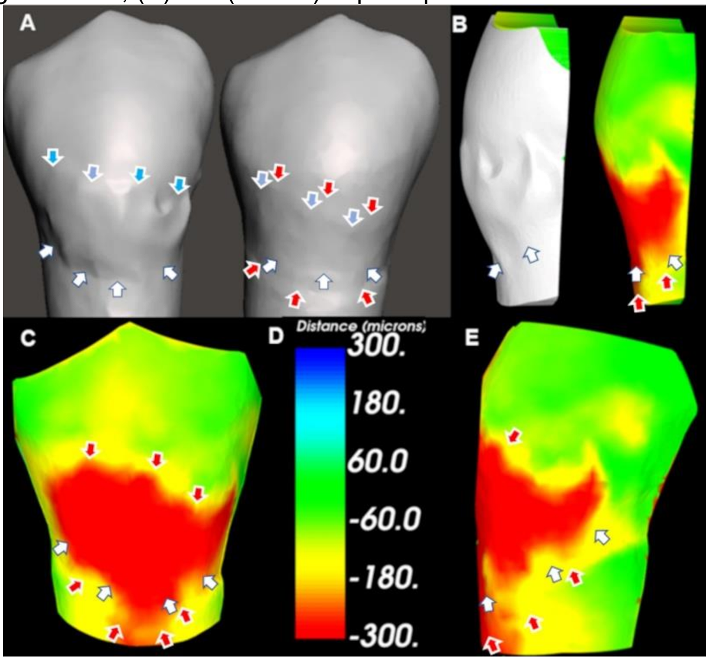
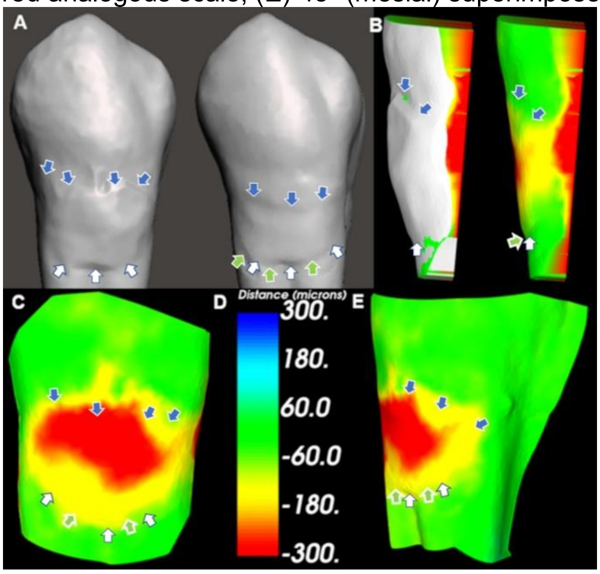


Figure 8. G3: blue (occlusal limit), white (cervical limit), red (iatrogenic wear), and green arrows (material excess); (A) greyscale images; (B) distal (initial) view, and superimposed scans; (C) frontal view of superimposed scans; (D) colored analogous scale; (E) 45º (mesial) superimposed scans.



DISCUSSION

The main objective of this work was to evaluate the effects of three different finishing and polishing procedures on the restoration of cervical lesions with the simulation of clinical conditions. Contact profilometry evaluated the surface roughness after polishing by evaluating five roughness parameters (Ra, Rt, Rp, Rv, and Rz). In parallel, a method was proposed to qualitatively evaluate the finishing and polishing through surface-matching software after digital scanning.

When analyzing surface roughness, the null hypothesis was partially rejected since only the Rt parameter did not show significant differences between the three groups. G1(RP) presented higher surface roughness values considering the other parameters. G2 and G3 did not present statistically significant differences in the parameters Ra, Rq, and Rv. G3 presented statistically significant superior results only when the Rp parameter was considered.

Ra is the most universally used parameter and is a benchmark for other existing works (Gadelmawla et al., 2002). Some studies have found that the restoration needs to present Ra (average surface roughness) values between 0.7-1.44 μm (Ferraris & Conti, 2014), 0.2 μm (Bollen et al., 1996), and 0.25-0.50 μm (Jones et al., 2004) to prevent bacterial adhesion, to obtain adequate smoothness and gloss, and a healthy relationship between the restoration and the adjacent dental tissues. In the present work, no specimen could be adequately polished if a Ra of 0.2 μm would be used by default. The higher roughness for the Ra, Rv, Rz, and Rp parameters means that the elevated rough surface of the restorations in G1 also resulted in significantly more profound valleys with a higher core volume of irregularities than those in G2 and G3.

Roughness analyses of the Ra parameter evidenced that the restoration using a surface sealant in G2 performed similarly to the discs used in G3. G2 represents a different approach to traditional surface sealant application (Gurbuz et al., 2020; Ruschel et al., 2018) since, in this work, this material was applied directly after finishing. This method seeks to obtain smoother surfaces without polishing instruments, which are difficult to access in this clinical situation. Its efficiency was tested on flat specimens with good results (Perez et al., 2009). However, the G1 and G2 groups are significantly distinct when looking at the peak-related parameter Rp. The higher roughness in both height and width directions may make the surface of the teeth restored in G2 more prone to biofilm accumulation compared to the teeth surface restored in G3.

The literature about finishing and polishing composite resins presents considerable variability in results. Some demonstrate the superiority of rubber points (St-Pierre et al., 2019), while other studies show better results from abrasive discs (Venturini et al., 2006; Babina et al., 2020).

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The qualitative evaluation of the three different groups was performed using surface-matching software (WearCompare), which was developed to analyze and quantify tooth structure loss, and any topographic change created (O'Toole et al., 2019). Studies carried out with this software were performed on uniform surfaces, where the images were captured using a non-contacting laser profilometer (O'Toole et al., 2019), a structured light model scanner (Rodriguez et al., 2012), or a high-accuracy laboratory 3D surface scanner (Gkantidis et al., 2019). In this way, it could measure changes in the surface, even at a micrometric level, allowing quantitative analysis. However, the abovementioned devices were unsuitable for irregular and convex surfaces like those analyzed in the present work. Therefore, we use an intra-oral scanner, which is suitable for qualitative analysis despite being unable to obtain data at a micrometric level (Figures 6, 7, and 8).

The data analysis obtained through the surface-matching software demonstrated problems occurring mainly in areas with more complex access, such as proximal and subgingival areas. Instruments with planar rotary motion present better performance on flat or convex surfaces (Aykdent et al., 2010). In this sense, the aspect of the surface topography is consistent with most studies involving its use. However, the biggest problem for polishing discs is accessing the regions with the most challenging access, particularly in our work, the most extreme regions of the proximal and the subgingival regions.

Through scanning, the surface topography of a G1 (RP) specimen shows iatrogenic wear, which was probably caused during the finishing procedures (red arrows) (Figure 6). The surface topography of G2 (SS) analyzed through scanning is presented in Figure 7, where the main problem is related to iatrogenic wear at the cervical margin, which was also probably occasioned in the finishing process. Another representative specimen of G3 (PD) was analyzed through scanning, where the difficulties in access led to an excess in the cervical margin (Figure 8).

Every effort was made to obtain an *in vitro* simulation of the clinical situation. In this way, it was possible to assess the finishing and polishing ability of three different methods with a different approach to that used by most articles that use flat specimens (Aykdent et al., 2010; Perez et al., 2009; Daud et al., 2018; Lassila et al., 2020). Recent studies have shown concern about preserving the surface structure without or with minimal prior sample preparation (Sorozini et al., 2018; Nečas et al., 2020). This way, surface quality assessment can be obtained directly, allowing additional data and a more realistic interpretation (Calmon et al., 2024).

Considering clinical studies, one work analyzed the iatrogenic abrasion in human teeth, but it addressed lingual surfaces of molars that present a flatter profile (Mitchel et al., 2002). Other studies focused on composite removal after bracket debonding. They are incompatible with the peculiarities found in restorations of cervical lesions (Melvin et al., 2021). The only study explicitly considering cervical restorations evaluated the effectiveness of polishing systems on Class V composite resin restorations clinically using qualitative criteria based on FDA-modified criteria and observed surface luster and staining (Jang et al., 2017). Assessment following this methodology will enable new studies correlating surface characteristics and biofilm accumulation, staining, wear, and durability of restorations.

This work has intrinsic limitations. Although every effort has been made to simulate the clinical procedure, this *in vitro* study must undoubtedly be followed by another study with an *in vivo* qualitative analysis using surface-matching software.

CONCLUSION

Based on the results of this *in vitro* study, polishing discs showed the best overall polishing performance over composite resin cervical restorations, except for the Rt parameter. Rubber points showed the highest roughness levels in all other parameters. Although surface sealants showed an intermediary performance, this group presented poorer results concerning the Rp parameter.

The qualitative topographic evaluation of the surface through matching software made it possible to observe problems like excessive or insufficient restorative material removal or iatrogenic tooth structure removal, demonstrating some of these problems, to a greater or lesser extent, in difficult-to-access regions in all specimens.

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