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Evaluation of different composite resin finishing and polishing protocols by confocal laser scan microscopy

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Aim: This study aimed to analyze the influence of finishing and polishing (F/P) protocols on resin surface through roughness (Ra) values and laser scan microscopy observations. **Methods:** Forty-eight (n=48) resin specimens were sorted into four groups (n=12), according to the type of resin used: Filtek Z250 (Z250), Filtek Z350 (Z350), Filtek One Bulk Fill (BF), Filtek P60 (P60). The specimens were sorted into six groups according to the type of F/P system used (n=2/group): Control group, Diamond bur (KG Sorensen), Soflex Pop-On Discs (3M ESPE), Soflex Spiral (3M ESPE), Dura Gloss (American Burs), and Praxis (TDV). **Results:** The highest roughness values (Ra) were attributed to BF group for all F/P systems, except for the Soft-Lex PopOn discs. The Soft-Lex PopOn, Spiral, and Praxis discs presented a better performance for the surface treatment of the tested composite resins. Regardless of the restorative material, the use of diamond bur or single-step abrasive rubber (Dura Gloss) were associated with the highest Ra values. **Conclusion:** The effect of F/P systems on Ra is material-dependent and instrument or system-dependent.

Keywords: Composite resins. Dental materials. Dental polishing.

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Introduction

Composite resins are the material of choice for esthetic restorations by adding the potential for excellent esthetic results with the preservation of healthy dental tissue[1]. However, these materials present a more sensitive technique, and refinement steps must be performed to avoid surface roughness, presence of porosity, absence of gloss and consequently color instability[2-5].

Composite restorations surface with irregularities may lead to biofilm accumulation, development of secondary caries and gingival inflammation[6,7]. For these reasons, adopting a proper finishing and polishing (F/P) protocol is crucial in dental practice. Finishing consists at removing excess of restorative material to obtain the expected anatomy and occlusal adjustments, whereas polishing refers to the reduction of surface irregularities caused by finishing instruments[8]. These procedures have a considerable influence on surface quality, esthetics, and longevity of resin composites[7,9-11].

Due to the heterogeneity of composite resins compositions and a variety of F/P systems available on the market[2,9], satisfactory polishing results is difficult to achieve. Previous studies showed that one-step polishing systems can be superior, or comparable to multi-step techniques, depending on the finishing protocol used before polishing procedure, and on the type of composite resin employed[9,12,13].

The surface properties of polished resin composites are commonly evaluated based on roughness values[8,9,12-14]. Analysis of the Ra of a resin is a critical parameter to determine the properties of this dental material. This evaluation can be performed using a variety of methods including laser scan microscopy as an effective analytical technique for quantitative characterization of surface changes[15,16]. However, few studies have been carried out comparing different composites resins and F/P protocols through laser scan microscopy analysis.

In view of the vast number of F/P systems offered on market, the aim of the present study was to evaluate, through laser scanning confocal microscopy, the surface roughness of micro-hybrid, nano-hybrid and nanoparticulate resins, submitted to different F/P protocols.

MATERIALS AND METHODS

This present was study was carried out with four composites (Filtek Z250; Filtek Z350; Filtek One; Filtek P60 / 3M ESPE) with different types of load. Resins and their particularities are described in Table 1.

Table 1. Description of resins properties used in this research.

Material/ Manufacturer	Lot	Type	Shade	Inorganic load (type)	Inorganic load (size)
Filtek Z250/3M-ESPE/USA	1725800273	Microhybrid	A3	Silica Zirconia/Silica	20nm 0.1 – 10 μm

Continue

Continuation

Filtek Z350/3M- ESPE/USA	1810100515	Nanoparticle	A3B	Silica Zirconia Zirconia/Silica	20nm 4 a 11nm 4 a 11nm/20nm
Filtek One Bulk Fill/ 3M-ESPE/USA	1814300172	Nanohybrid	A3	Silica Zirconia Zirconia/Silica Ytterbium Trifluoride	20nm 4 a 11nm 4 a 11nm/20nm 100nm
Filtek P60/3M-ESPE/USA	1818700369	Microhybrid	A3	Zirconia/Silica	0.01 a 3.5 microns

Forty-eight specimens of composite resin were obtained (n=12), with circular cross-section and flat surface, 2mm X 6mm (high x diameter), with the aid of a cylindrical aluminum matrix. The resin was placed into the matrix in two increments of 1mm each, except for Filtek One resin (3M ESPE, Seefeld, BY, Germany), which allows photopolymerization in a single increment. Prior to the insertion of the first increment, a polyester strip (Maquira, Maringá, PR, Brazil) was positioned under the cylindrical matrix. The photopolymerization of the first increment was performed for 20 seconds, with a Radii-E LED device (SDI, Bayswater, WA, Australia), whose light intensity from the device was measured using a radiometer Hilux-LED (SDI, Bayswater, WA, Australia) and maintained between 1.000 to 1.800 Mw/cm^2.

The second increment was covered with a second strip of polyester and pressed by a glass plate before being polymerized. With this, a greater uniformity of the surface between the specimens was achieved.

In each group, two specimens were drawn and separated to compose the control subgroup (resin in direct contact with the polyester matrix, without any polishing finishing process). The other specimens were fixed in glass plates with cyanoacrylate (Superbonder Loctite-Henkel, Düsseldorf, NW, Germany), on its lower face, to stabilize the specimens to start the finishing and polishing process. After 24h of storage in distilled water, the finishing and polishing protocols were carried out.

The finishing and polishing methods were performed by a single operator. Initially, all specimens, except the control group, were submitted to finishing, under the action of the extra fine granulation diamond bur # 3195FF (KG Sorensen, Cotia, SP, Brazil), in high rotation, for 5 seconds, under constant refrigeration. Then, they were randomly sorted into subgroups according to the type of polishing system used, totaling 2 specimens for each subgroup, as described in Table 2. All polishing instruments were used dry.

All specimens were again stored immersed in distilled water, in closed and properly identified containers, at room temperature, and remained closed for 48 hs until the moment of their analysis[17].

Table 2. Finishing and polishing instruments and protocols

INSTRUMENT (MANUFACTORER)	PROTOCOLS
Diamond tip (KG/Sorensen)	The diamond bur of extra fine granulation # 3195FF, in high rotation, was used on the specimens, for 5 seconds, under constant refrigeration.
Soflex Pop-on XT (3MESPE)	The discs were used sequentially, from the largest to the smallest granulation, which were applied for 15s each, with washing through water / air spray for 10s between each disc.
Soflex Spiral (3MESPE)	After finishing with the most granulated disc in the Soflex Pop-on XT System, pre-polishing was performed with the disc based on aluminum oxide (beige) applied for 15s in counterclockwise rotation, washing with water / air spray for 10s, drying, and polishing with the diamond disc (pink) at the same time.
Abrasive Rubbers (American Burs)	Sequential application with abrasive rubbers, most granulated (initial finishing and smoothing), medium (polishing and scratch removal) and fine (final gloss) was performed for 15s each, interspersed by washing with water / air spray for 10s.
Praxis system (TDV)	Discs were used in the 4 granulations successively, from the thickest to the finest, 20s of each disc, interspersed by washing with water / air jets for 10s and drying.

The average Ra was measured by a confocal laser microscope - Confocal Microscope ZEISS LSM 700 (Zeiss, Jena, TH, Germany). The images were obtained in the 50x objective, through a laser presenting a wavelength of 405nm, with a power of 0.5mw. The central region of the sample was chosen, and the images were acquired, each 120 µm x 120 µm in size[18]. The images were analyzed using the ZEN X64 software, version 1.1.0 (Zeiss, Jena, TH, Germany). This software allowed the image to be divided into 6 parts, so that it was possible to obtain the average surface roughness value for each image cut.

The verification of normality was performed by the Shapiro-Wilk test and the verification of the hypothesis of equality of variances was through the Levene F test. In the case of a significant difference by the F test (ANOVA), Tamhane multiple comparisons tests were performed, and when the difference was significant by the Kruskal-Wallis test, multiple comparisons tests were performed. The choice of the F test (ANOVA) occurred in situations where the data had a normal distribution in each category and the Kruskal-Wallis test in the case of rejection of the hypothesis of normality. For the comparison between the resins in each type of protocol or between the protocols in each type of resin, the F tests (ANOVA) or Kruskal-Wallis test were used.

RESULTS

Table 3 presents the results of surface roughness considering the F/P protocol and type of resin. It is observed that roughness averages varied from 0.11 µm (Control - Z350) to 2.09 (diamond bur - BF).

Table 3. Mean, standard deviation, median and the 25th and 75th percentiles of roughness considering the F/P protocol and type of resin.

F/P Protocol	Resin				p value
	BF	Z250	P60	Z350	
	Mean ± DP Median (P25; P75)	Mean ± DP Median (P25; P75)	Mean ± DP Median (P25; P75)	Mean ± DP Median (P25; P75)	
Control	0,52 ± 0,52 (ad) 0,22 (0,09; 0,98)	0,16 ± 0,06 (ae) 0,16 (0,10; 0,23)	0,19 ± 0,13 (a) 0,13 (0,08; 0,22)	0,11 ± 0,02 (a) 0,10 (0,09; 0,13)	$p^{(1)} = 0,155$
Diamond bur	2,09 ± 1,09 (A, bc) 2,13 (1,01; 3,16)	0,73 ± 0,40 (B, b) 0,66 (0,46; 0,93)	0,88 ± 0,30 (B, b) 0,96 (0,62; 1,10)	1,23 ± 0,23 (A, b) 1,23 (1,14; 1,39)	$p^{(1)} < 0,001$*
Pop On	0,17 ± 0,06 (a) 0,16 (0,12; 0,22)	0,20 ± 0,04 (c) 0,19 (0,17; 0,22)	0,25 ± 0,10 (ac) 0,25 (0,16; 0,36)	0,22 ± 0,06 (c) 0,21 (0,19; 0,24)	$p^{(1)} = 0,136$
Spiral	0,30 ± 0,15 (A, ad) 0,30 (0,15; 0,44)	0,15 ± 0,02 (B, a) 0,14 (0,13; 0,16)	0,25 ± 0,07 (A, ac) 0,23 (0,19; 0,31)	0,17 ± 0,05 (B, d) 0,16 (0,14; 0,19)	$p^{(1)} = 0,001$*
Abrasive rubber	1,35 ± 0,14 (A, c) 1,29 (1,28; 1,44)	1,28 ± 0,37 (A, d) 1,20 (0,95; 1,70)	0,74 ± 0,13 (B, b) 0,73 (0,64; 0,79	0,38 ± 0,10 (B, e) 0,41 (0,36; 0,44)	$p^{(2)} < 0,001$*
Praxis system	0,31 ± 0,11 (A, d) 0,27 (0,24; 0,33)	0,18 ± 0,04 (B, ce) 0,17 (0,15; 0,22)	0,25 ± 0,06 (AC, c) 0,24 (0,20; 0,30)	0,24 ± 0,04 (C, c) 0,24 (0,20; 0,27)	$p^{(1)} < 0,001$*
p value	$p^{(1)} < 0,001$*	$p^{(1)} < 0,001$*	$p^{(1)} < 0,001$*	$p^{(1)} < 0,001$*	

(1) Through the Kruskal Wallis test with comparisons of that test
(2) Through the F test (ANOVA) with Tamhane comparisons
Obs. If the capital letters in parentheses are all distinct, there is a significant difference between the corresponding resins
Obs. If the lower-case letters in parentheses are all distinct, there is a significant difference between the corresponding protocols.

When comparing the behavior within composite resins in each F/P protocol, it was observed that, except for the Control and Pop On groups, the roughness averages were significantly higher when Bulk-Fill (BF) resin was used. Through the multiple comparisons tests, significant differences were verified in the Diamond Tip Group between BF x Z250 and BF x P60 resins; in the Spiral Group between BF x Z250 and BF x Z350 and P60 x Z250 resins; in the group Abrasive rubber between BF x P60 x Z350 resins and in the Praxis System group between Z250 and Z350 x BF and P60.

For each type of the resins, significant differences (p<0.001) between the protocols were verified. In BF, P60 and Z350 resin, the averages were correspondingly higher when the diamond tip protocol was used, followed by the abrasive rubber protocol. The results showed lower Ra values for Pop On and Praxis for all resins. For the BF and P60 resins, diamond pits and abrasive rubbers groups, were similar to each other and differed from the other systems.

Figure 1 shows the average surface roughness (Ra) values for each resin, after finishing and polishing procedures.

Regarding confocal laser scan microscopy analysis, all control groups showed higher surface smoothness due presenting less variety of color when compared to other groups (Figures 2A, 2G, 2M, 2S). This finding is associated with the low values of surface roughness of all control groups tested (Figure 1). The other images obtained by microscopy showed different behavior according to resin and protocol used. Diamond bur and abrasive rubber finishing protocols showed, the roughner surface in all resin groups observed.

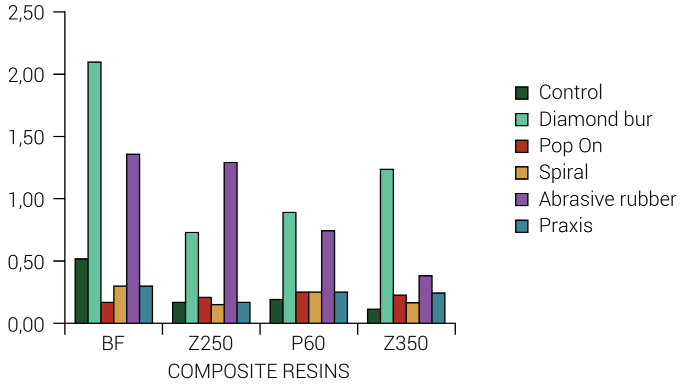

Figure 1. Average hardness (μm) according to resin and F/P protocol used.

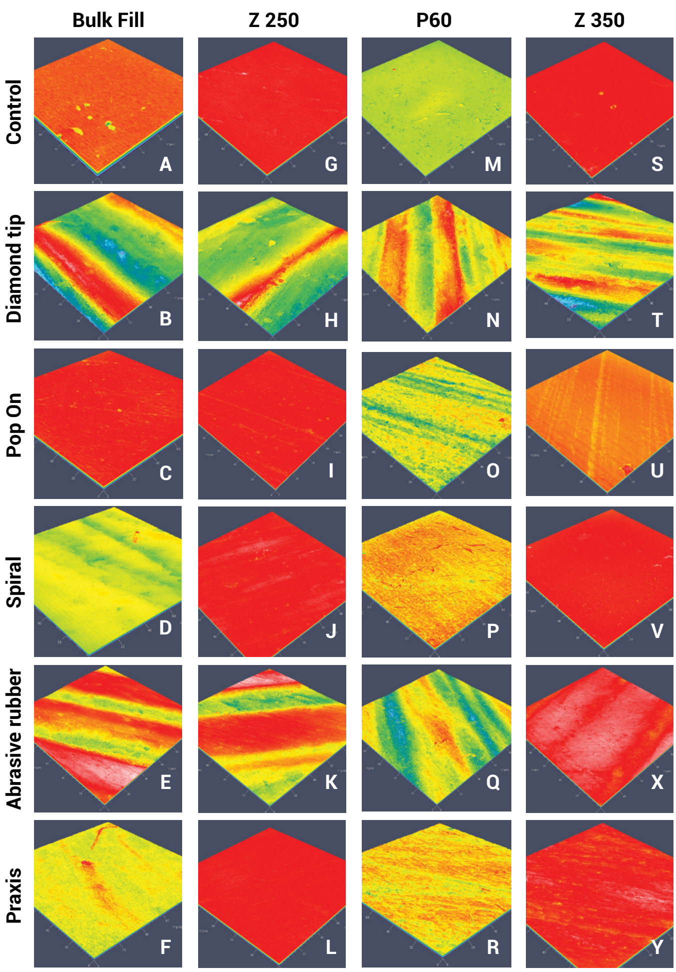

Figure 2. Microscope confocal analysis according to resin and protocol used. **BF: Control** (A); **Diamond Tip** (B); **Pop On** (C); **Spiral** (D); **Abrasive Rubber** (E); **Praxis** (F); **Z250: Control** (G); **Diamond Tip** (H); **Pop On** (I); **Spiral** (J); **Abrasive Rubber** (K); **Praxis** (L); **P60: Control** (M); **Diamond Tip** (N); **Pop On** (O); **Spiral** (P); **Abrasive Rubber** (Q); **Praxis** (R); **Z350: Control** (S); **Diamond Tip** (T); **Pop On** (U); **Spiral** (V); **Abrasive Rubber** (X); **Praxis** (Y)

DISCUSSION

Several parameters are described for the analysis of dental materials surface, with the average Ra being the most used due to the greater quality control[10]. The Ra value is calculated by the arithmetic mean between the peaks and valleys recorded in a defined surface, with the rougher surface having the highest Ra value[16,18]. In this study, the specimens received the finishing and polishing procedures after 24 hours of photopolymerization, which is ideal, since approximately 75% of the light curing occurs during the first 10 minutes but is completed after a period of 24 hours. If the finishing procedure is carried out before the final polymerization, plastic deformation of the composite may occur[19].

There are several F/P systems available on the market, with different compositions, types of abrasives and shapes. However, to achieve the desired effectiveness, it is necessary that abrasive particles have greater hardness compared to the filler particles present in the resin[20]. Otherwise, the inability to remove load particles can result in removing the resin matrix, causing greater final roughness[20]. This fact may be associated with the Ra results obtained for diamond bur and abrasive rubber, which scored the highest roughness values when compared to other groups. In addition, other extrinsic factors related to the polishing instrument, such as the geometry of the instrument and the way they are used, can also provide a higher Ra[16,21-25].

It is noted in literature the importance of the superficial smoothness of composite resin restorations after the finishing and polishing procedure. This procedure can prevent plaque accumulation, color change, secondary caries, and gingival inflammation[7,23]. In our study, the contraindication of Bulk-Fill resins restorations without a proper polishing step is perceived, since the use of only a diamond bur or a single-step abrasive rubber resulted in higher Ra values (Fig.2B, 2E).

All samples, except for the control group, were finished with diamond burs, prior to polishing. This procedure, which simulates the protocol performed at the clinic, left irregularities in the composite surface with several depressions, which is demonstrated in the image of the topographic analysis of the samples (Fig.2), as well as in the Ra means presented (Fig.1). Diamond burs have high cutting efficiency, so they are used in the initial finishing step, removing excess and irregularities from the restoration. However, diamond burs are not enough to eliminate finishing roughness because of its highest values of roughness compared to polishing steps[9].

In contrast, the control groups showed the lowest values of surface roughness for all resins tested, corroborating with other studies that also used the polyester matrix strip as a control group[26,27] (Fig.2A, 2G, 2M, 2S). However, this smooth surface can rarely be maintained in a clinical situation due to the need for finishing to restore the contour, occlusal adjustment, and removal of excess material in marginal areas, resulting in greater roughness of the restoration surface[9]. Another importance of the use of polyester strips in the control group is in the control of formation of the oxygen inhibition layer.

The polish ability of a composite resin is mainly affected by the size of the filler particle, with a smoother surface being achieved in composites with smaller fillers. Some studies have compared nanoparticulate composite with other types of composite resins and have observed that these resins showed better polishing characteristics, making it possible to make them smoother after this procedure[8,19]. However, in the present study, Filtek Z350 resin, representative of the nanoparticles, presented a lower index of Ra only when the Soflex Spiral (3M ESPE) was applied (Fig.1)

Gonçalves et al.[27], found in their work that nanofilled e and hybrid resins did not show statistically significant differences on Ra, showing that surface smoothness is not inherent only in the composition of the composite, but also in the F/P systems used. Among the systems tested in the present study, the lowest Ra values, regardless the resin, were the PopOn and Spiral systems. Previous studies concluded that nano-tech-based composites showed higher Ra values of after F/P procedures[8,19]. This fact can be corroborated in our study, since the Bulk-Fill resin obtained the highest Ra values in all protocols, except for the PopOn system (Fig.1).

The search for an ideal polishing system has resulted in some technological advances, the development of single step systems is an example, in which, ideally, a single instrument is used to obtain high gloss and minimal roughness. However, the influence of the time used during polishing and the surface roughness is proven in the literature. According with a previous literature finding, the sequential use of the four Soft-Lex discs resulted in a longer application period, consequently obtaining fewer roughness surfaces[21]. The present findings corroborate with this information, since all protocols that used two or more polishing instruments, such as Soft-Lex discs, for example, had a greater final smoothness when compared to single-step polishers, such as abrasive rubber.

This research demonstrated an excellent effectiveness of the polishing systems Sof-lex PopOn, Soflex Espiral and Praxis, which are the base of aluminum oxide. Such evidence is correlated to the ability to cut load particles and the resin matrix equally, causing homogeneous wear and, consequently, a smoother surface[22,23,28]. Associated with these characteristics, these systems stand out even more because they have a sequence of decreasing granulations in their discs. Nevertheless, disc systems, such as Soflex PopOn and the Praxis system, have an anatomical limitation, which makes their clinical use difficult on certain surfaces, especially the occlusal surface of posterior teeth. In areas that could not be reached by the aluminum oxide discs, the carbide burs can promote satisfactory surface smoothness for the nanocomposite restorative materials[28].

Several factors must be analyzed to verify the maximum effectiveness of a specific polishing system, not only the ability to maintain a smooth, but also a brightness surface, for example. However, it is noted in the literature that there is no consensus on which polishing technique provides an ideal smoothness and gloss for resinous composites[4,10]. Although the analysis with confocal laser scan microscopy allows a high level of accuracy for the data, the present study has the limitations inherent to an in vitro study, thus raising the need for further investigation, preferably randomized clinical trials that can complement the evidence raised here and help guide clinical practices.

In conclusion, the Ra is dependent on the type of F/P protocol used, as Soft-Lex PopOn, Espiral, and Praxis disks showed better performance for the surface treatment of the tested composite resins. Regardless of the restorative material, the isolated use of diamond bur or single-step abrasive rubber generated higher mean roughness values. Ra is also dependent on the type of resins employed, as the highest roughness values were attributed to the nano-hybrid Filtek One resin for all finishing and polishing systems, except for Soft-Lex PopOn discs.

DATA AVAILABILITY

Datasets related to this article will be available upon request to the corresponding author.

Conflict of Interest

The authors declare no conflict of interest.

Author Contribution

Substantial contributions to the conception or design of the work: SOUZA, KMR; SILVA, RVM; SILVA, CHV, GUIMARAES, RP.

Acquisition, analysis, or interpretation of data for the work: SOUZA, KMR; SILVA, RVM; DIAS, MF, LINS-FILHO, PC; SILVA, CHV, GUIMARAES, RP.

Drafting the work or revising it critically for important intellectual content: DIAS MF, LINS-FILHO, PC; GUIMARAES, RP; SILVA, CHV

Final approval of the version to be published; GUIMARAES, RP; SILVA, CHV

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: SOUZA, KMR; SILVA, RVM; DIAS, MF, LINS-FILHO; SILVA, CHV, GUIMARAES, RP.

All authors actively participated in the discussion of the manuscript's findings, and have revised and approved the final version of the manuscript.

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