

Research Article

Effect of Three Polishing Systems on Surface Properties of Resin Composites with Different Filler Particles

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Abstract

Objective: To evaluate the effect of rubber points and spiral-shaped wheels of three polishing systems on the surface properties (surface roughness and gloss) of four universal resin composites loaded with different filler particle systems.

Methods: Disk-shaped specimens of four resin composites loaded with different filler particles systems (n = 5 for each group): nanofilled (Z350 - Z3), suprananofilled (Estelite Omega - EO), submicron-hybrid (Brilliant Everglow - EG) and hybrid (Vitra - VI) were built up to standardized surface roughness and submitted to three polishing systems, all of them with tip and spiral-shaped wheels: Jota (JO), Ultradent (UD) and American Burrs (AB). Surface roughness (Sa parameter) was evaluated under 3D-laser confocal microscopy and gloss (gloss unit - GU) by using a glossmeter. Data were analyzed with two-way ANOVA and Tukey HSD test.

Results: Surface roughness ranged from 0.33 to 0.53 μm for rubber points and from 0.22 to 0.55 μm for spiral-shaped wheels. Regarding gloss, the ranges were 33.9 to 64.4 GU for rubber points and 29.7 to 61.5 GU for spiral-shaped wheels.

Conclusion: In general, JO and AM produced lower surface roughness and higher gloss than UD and EO and Z3, resin composites with smaller filler particles, presented better gloss than VI and EG.

Keywords: Resin Composite; Filler Particle Characteristics; Finishing, Surface Roughness; Gloss

Introduction

Thanks to welcomed characteristics such as an on-demand polymerization reaction that allow to rebuild the teeth anatomy with details, the natural-like appearance (color, translucency and gloss) similar to the dental hard tissues and the capability to adhere to the cavity walls, resin composite has been widely used to restore posterior and anterior teeth [1]. Among other aspects, the features of the filler particles, i.e., size, shape, hardness and vol.% play a crucial role on the surface aspect developed by a resin composite after polishing [2]. Based on the size of their filler particles, resin composites can be classified into hybrid (0.5-3 μm), microhybrid (0.4-1 μm), microfilled (0.04-0.4 μm) and nanofilled (0.1-100 nm) [3]. More recently, however, a manufacturer has proposed the term suprananofilled to name a material with spherical filler particles in a range of 100 to 300 nm, 200 nm mean size. According to this manufacturer, this filler particle system enables excellent gloss retention and wear resistance to the composite [4]. Theoretically, the smaller the size of the filler particles, the glossier and less rough can be a resin composite surface [5]. However, contrarily to this thought, previous studies have shown that resin composites with greater filler particles may present similar results to nanofilled and microfilled materials in terms of roughness, gloss and color [6,7]. Thus, evaluating the behavior of different resin composites regarding surface properties remain as a tool for predicting the success of resin composite restorations [2,8,9].

Beside the influence of the filler particle system, the use of a suitable finishing and polishing system is also mandatory for a resin composite to achieve favorable aesthetic results [10]. Several polishing systems with different abrasive particle such as synthetic diamonds, aluminum oxide and silicon oxide are available in the market. Moreover, most of them are fabricated in different forms such as rubber points, discs, and, more recently, spiral-shaped wheels [11]. However, there is no consensus about which of them are more efficient for finishing a resin composite restoration because multiple factors including the shape of the tips, the hardness of the abrasive particles and the time and the finishing protocol applied by the operator may impact the final result [7]. Due to these aspects, clinicians are constantly searching for polishing systems capable of producing resin composite surfaces with improved roughness and gloss [12-14]. In this context, it still seems relevant to evaluate the combination of different polishing systems and resin composite in order to produce useful results for the daily dental clinic. Therefore, the aim of the present study was to evaluate the effect of three polishing systems with abrasive rubber points and spiral-shaped wheels on the surface properties (surface roughness and gloss) of four universal resin composites loaded with different filler particle systems. The null hypothesis tested was that would be no difference in surface roughness and gloss produced by the polishing systems irrespective of the resin composite.

Material and Methods

Three polishing systems with rubber points and spiral-shaped wheels (Table 1) and four resin composites loaded with different filler particle systems (Table 2) were evaluated in the present study.

Polishing System	Rubber points Abrasive Color - grain	Spiral-shaped Wheels Abrasive Color - grain
Jota - JO	Jota Professional Diamond Green - medium Gray - gray	Jota Swivel Diamond Brown - medium Gray - fine
Ultradent - UD	Jiffy Silicon carbide Yellow - medium White - fine	Jiffy Natural Diamond Yellow - medium White - fine
American Burrs - AB	Ultra-Gloss Silicon carbide Pink - medium Blue - fine	Twisst-Gloss Diamond Brown - medium Green - fine

Table 1: Polishing systems tested in the study.

Resin Composite	Organic Matrix	Filler System
Vitra - VI	UDMA TEGDMA	52-60 vol% Silica/Zirconia (200 nm)
Brilliant	Bis-GMA	56 vol%
Everglow	Bis-EMA	Silica glass
EG	TEGDMA	Zirconia oxide (20 nm - 1 µm)
Estelite Omega - EO	Bis-GMA 2-hydroxy propoxy,TEGDMA	71 (vol%) Silica/Zirconia (100-300 nm) (mean: 200 nm)
Z350 - Z3	Bis-GMA Bis-EMA UDMA TEGDMA	55.5-63.3 vol% Silica (20 nm) zirconia (4-11 nm) zirconia/silica nanoclusters (0.6- 10 µm)

Table 2: Resin composite tested in the study.

Specimen Preparation

Thirty disc-shaped specimens (8.0 mm Ø and 2 mm height) for each resin composite were built up using a stainless-steel split-mold. The mold was filled with the composite, covered with a polyester strip, pressed with a 0.7 mm thickness glass slide and light-activated using a LED curing unit with an irradiance of 800 mW/cm² for 40 s. For each resin composite, the specimens were randomly divided into six groups (n=5) according to the polishing system [5].

Polishing Procedures

The polishing procedure was performed by a single operator using an electric handpiece at 8,000 rpm. All the polishers were applied in a circular motion for 30 s to simulate a clinical protocol and to avoid the risk of grooving the specimen surfaces (water irrigation was used when recommended by the manufacturer). One polisher was used for each 5 specimens. Before surface roughness and gloss measurements, the specimens were cleaned in distilled water for 5 min using an ultrasound bath and dried using oil-free compressed air [6].

Surface Roughness Evaluation

Roughness was measured using a 3D-laser confocal microscope - 3DLCM (LEXT OLS4001, Olympus, USA) [15]. For each specimen, an area of 409.6 µm² (640 × 640 µm) was scanned with a lens MPLAPONLEXT 20 using a XYZ fast scan scanning mode under a 1X zoom. The 3D topography of each specimen was reconstructed by the software and the surface roughness was obtained through the Sa parameter (average absolute deviation of the surface) using the following equation:

$$Ra = \frac{1}{L} \int_0^L |f(x)| dx,$$

where L is the length of the section and f(x) is the displacement function.

Gloss Evaluation

A small-area glossmeter was used to measure gloss. Five specimens for each resin composite were positioned in the aperture of the glossmeter by using a custom-made jig that maintained the same position of the specimens for repeated measures. Gloss unit (GU) was measured in triplicate for each specimen using an area of 4 mm² (2 × 2 mm) and 60° geometry for both light source and detector. The average of the three measurements was used as representative value for each specimen [6].

Statistical Analysis

The obtained data were analyzed using Prism 9 software (GraphPad Inc., Boston, USA). Initially, the normal distribution of errors and the homogeneity of variances were checked by Shapiro-Wilk's test and Levene's test. Based on these preliminary analyses, each variable (surface roughness and gloss) was separately analyzed using two-way ANOVA and Tukey's HSD post hoc test. All analyses were performed at a significance level of $\alpha = 0.05$.

Results

Regarding the rubber points, two-way ANOVA detected no statistical significance for polishing system ($p = 0.0748$) and resin composite ($p = 0.1095$) independent factors.

Contrarily, the interaction resin composite × polishing system was found to be significant ($p = 0.0311$). For Spiral-shaped wheels, two-way ANOVA detected statistical significance for resin composite, with Z3 presenting the lowest surface roughness ($p < 0.05$). The independent factor polishing system was also found to be significant, with JO and AB presenting similar and lowest surface roughness than UD ($p < 0.05$). Table 3 shows the mean and standard deviations of surface roughness for all groups. For rubber points (A), it can be noted that VI polished with JO presented highest roughness than the other groups ($p < 0.05$). All resin composites presented highest surface roughness when polished with UD spiral-shaped wheels (B) ($p < 0.05$).

Groups	Rubber Points			Spiral-Shaped Wheels		
	JO	UD	AB	JO	UD	AB
VI	0.33 (0.05) ^a	0.54 (0.01) ^b	0.39 (0.04) ^a	0.31 (0.07) ^a	0.55 (0.05) ^b	0.41 (0.03) ^a
EG	0.44 (0.10) ^a	0.46 (0.05) ^a	0.37 (0.03) ^a	0.42 (0.02) ^a	0.54 (0.05) ^b	0.38 (0.02) ^a
EO	0.35 (0.09) ^a	0.33 (0.06) ^a	0.40 (0.02) ^a	0.29 (0.11) ^a	0.53 (0.06) ^b	0.32 (0.04) ^a
Z3	0.46 (0.16) ^a	0.45 (0.02) ^a	0.38 (0.01) ^a	0.23 (0.05) ^a	0.43 (0.03) ^b	0.22 (0.01) ^a

Table 3: Mean surface roughness (standard deviation) for all tested groups. In rows, for each polisher shape, different uppercase letters show significant statistical difference (Tuley's HSD, $p < 0.05$).

Fig. 1 shows images of representative surfaces of topography for each resin composite after polishing with rubber points. It can be noted that surfaces polished with JO and AB present a more regular surface than those submitted to UD. Similar aspects can be observed in surfaces polished with spiral-shaped wheels (Fig. 2).

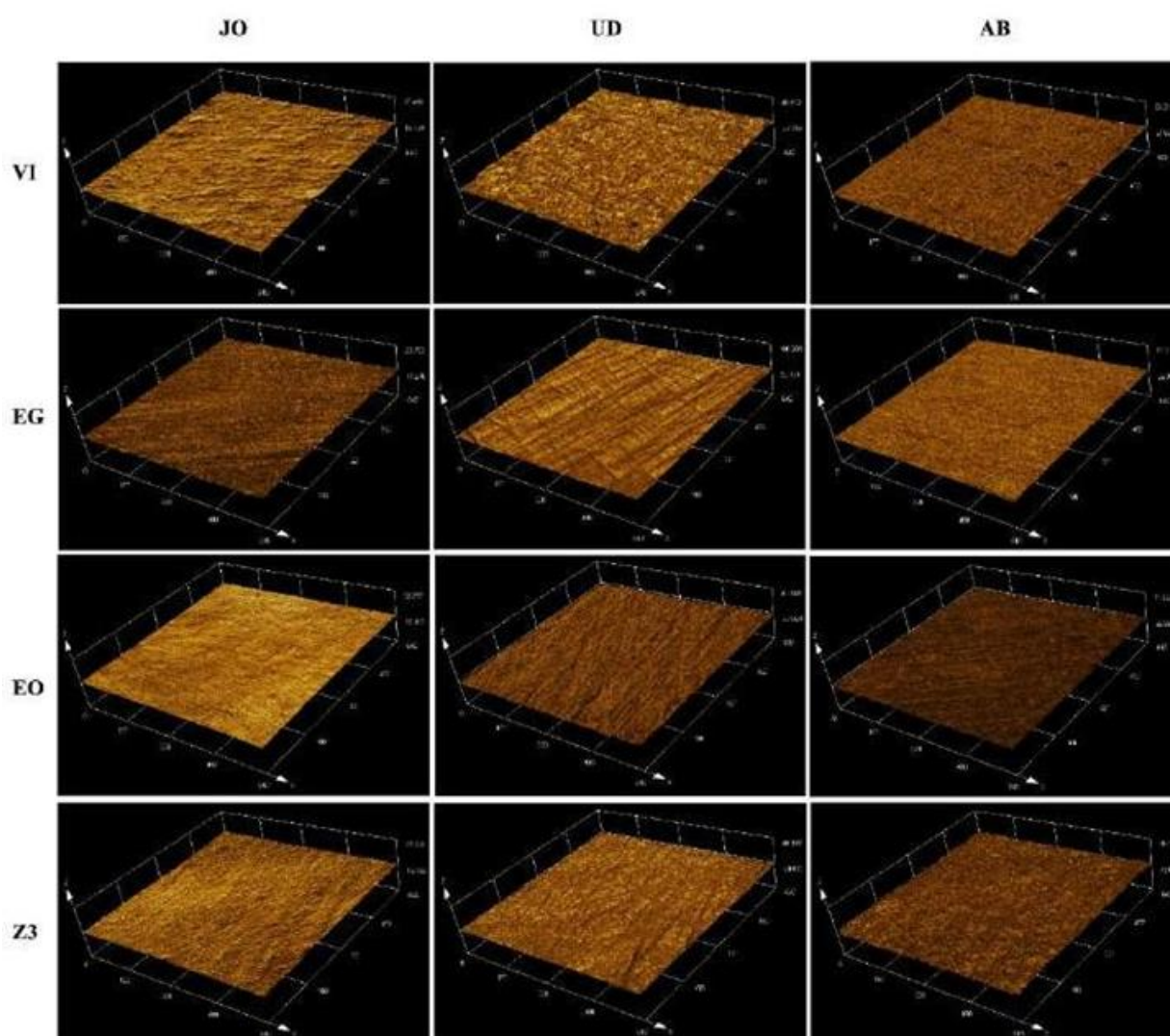


Figure 1: Representative 3DCLM images of the surface topography of each resin composite after polishing with rubber points.

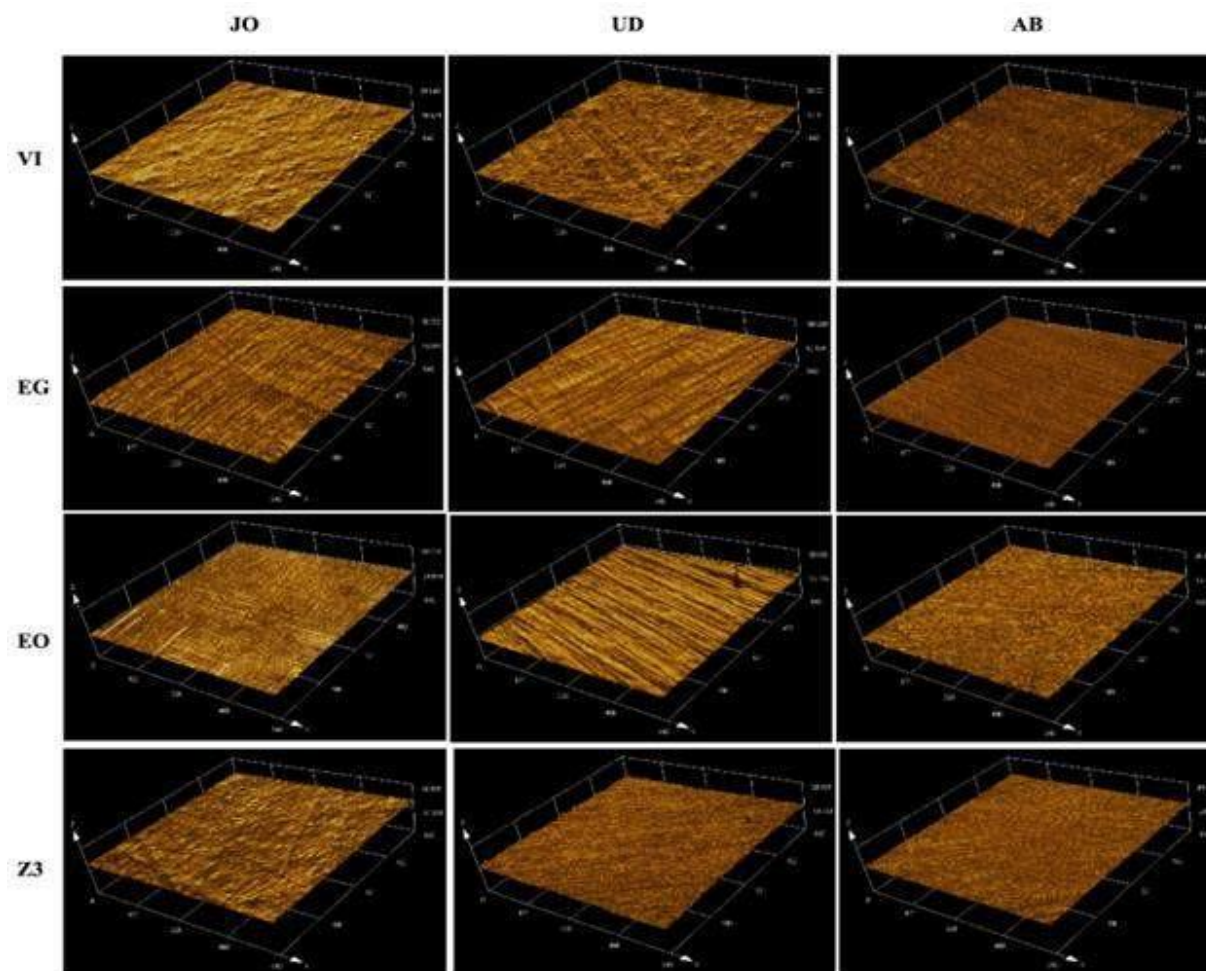


Figure 2: Representative 3DCLM images of the surface topography of each resin composite after polishing with spiral-shaped wheels.

Irrespective of the shape of the polisher (rubber point or spiral-shaped wheels), two-way ANOVA showed statistical significance for both independent factors ($p < 0.05$). For rubber points, the highest gloss was presented by JO ($p < 0.05$) and UD and AB were not statistically different from each other ($p > 0.05$). With respect to spiral-shaped wheels, JO and AB presented statistically similar and better gloss than UD ($p < 0.05$). For both polishers (rubber point or spiral-shaped wheels), EO and Z3 presented the highest gloss, while VI and EG presented similar and lowest gloss ($p > 0.05$). Table 4 shows the mean and standard deviations of gloss for all groups.

Groups	Rubber Points			Spiral-Shaped Wheels		
	JO	UD	AB	JO	UD	AB
VI	62.4 (5.9) ^a	41.2 (2.1) ^b	45.8 (6.5) ^b	36.1 (2.6) ^a	29.7 (5.9) ^a	34.3 (2.5) ^a
EG	49.3 (17.4) ^a	33.9 (7.5) ^b	42.8 (2.8) ^{a,b}	34.7 (1.5) ^a	30.8 (2.5) ^a	40.2 (2.2) ^a
EO	64.5 (4.6) ^a	46.1 (3.6) ^b	51.5 (12.1) ^{a,b}	58.0 (2.7) ^a	56.2 (10.6) ^a	57.8 (4.7) ^a
Z3	59.2 (3.6) ^a	47.7 (3.7) ^a	50.3 (2.5) ^a	61.5 (4.0) ^a	45.3 (8.5) ^b	57.8 (3.6) ^a

Table 4: Mean gloss (standard deviation) for all tested groups. In rows, for each polisher shape, different uppercase letters show significant statistical difference (Tuley's HSD, $p < 0.05$).

Discussion

In the present study, it was investigated how polishing systems with different shapes and type of abrasive would affect the surface roughness and the gloss of resin composites loaded with different filler particles. Clinically talking, these surface

properties are key for achieving aesthetic restorations and influence the service life of resin composite restorations [16]. The rationale for this was to produce useful data for guiding clinicians in their daily choices in terms of resin composite polishing systems. Roughness exerts an important role on bacterial colonization over stiff surfaces in the oral environment [17]. In addition, the rougher a surface, the higher its influence on gloss of resin composites and this is an aesthetic concern [18-20].

In the current study, surface roughness ranged from 0.33 to 0.53 μm for rubber points and from 0.22 to 0.55 μm for spiral-shaped wheels, values that agree with those showed by previous studies [14,21]. All resin composites polished with the spiral-shaped wheels of UD presented higher roughness than those submitted to JO and AB (Table 3). Moreover, VI polished with UD also presented the worst roughness (Table 3). These results led to the rejection of the null hypothesis of the current study. It is well-known that the characteristics of a polisher, such as the hardness of the imbedding matrix and the shape and size of its abrasive particles may interfere with the surface roughness produced in a resin composite [22]. The spiral-shaped wheels of the three polishing systems used here present diamond particles in their composition (Table 1). According to Takanashi, et al., the abrasive particle size must be small enough to prevent scratches on the resin composite surface [23]. Thus, although the manufacturers do not release the exact composition of their materials, one can suppose that the higher roughness produced by UD was influenced by the size of its diamond particles [23]. The aspects seen in Fig. 2, where the topography of VI, EG and EO show more irregular surfaces with striking grooves may support this thought.

It is noteworthy that all values of roughness obtained in the present study were above 0.2 μm , the surface roughness threshold reported to facilitate the adhesion and colonization of biofilm on resin composite surfaces [24]. However, it is important to point out that instead of traces of roughness (Ra parameter), as used in most previous studies [1,14,21], in the present study the Sa parameter, which expresses the average of the absolute values of Z(x,y) in the measured area and is a more precise parameter, was used. In addition, according to Dennis, et al., since additional intraoral factors such as the morphological features of bacterial cells may influence the effects of roughness on bacterial adhesion and biofilm accumulation, simple correlation between surface roughness and biofilm formation remains debatable [22,25].

Gloss is the result of the interaction between the light and the morphology of a surface. Clinically, this surface property plays a crucial role in aesthetic restorations because differences in gloss between the restoration and the surrounding enamel can be easily detected by the human eye [7]. The values of gloss, from 33.9 to 64.4 GU for rubber points and from 29.7 to 61.5 GU for spiral-shaped wheels, agree with earlier studies and are in the range or closer to the threshold for clinical acceptance (40-50 GU) [14,26,27].

Irrespective of the shape of the polisher, EO and Z3 presented higher gloss than VI and EG (Table 4). Since EO and Z3 have smaller filler particles in their composition (Table 2), this finding may be supported by previous studies showing that resin composites with smaller filler particles develop higher gloss when polished with different polishing systems [6,28]. After polishing with spiral-shaped wheels, VI and EG presented lower gloss than EO and ZE. From Table 3, it can be noted that these two resin composites presented higher values of roughness than EO and Z3. Since previous studies have shown negative correlation between surface roughness and gloss, it is reasonable to claim that in the present study the higher roughness of VI and EG had negatively influenced the gloss developed by these resin composites after polishing with spiral-shaped wheels [14,29].

Conclusion

Within the limitations of the present study, it can be concluded that irrespective of the shape of the polishers, JO and AB produced lower surface roughness and higher gloss than UD. Also, EO and Z3, resin composites with smaller filler particles, presented better gloss than VI and EG.

Conflict of Interests

The authors have no conflict of interest to declare.

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