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Influence of Finishing and Polishing Techniques and Abrasion on Transmittance and Roughness of Composite Resins

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Clinical Relevance

Clinicians can choose any of the finishing and polishing systems tested without compromising the light transmittance of the final restoration.

SUMMARY

The aim of this study was to evaluate the influence of finishing and polishing systems and toothbrush abrasion on transmittance (T) and surface roughness (Ra) of three composite resins (Filtek Z350 XT, Tetric N-Ceram, and IPS Empress Direct). Eighteen resin disks (10 mm diameter × 2 mm thick) finished by polyester strips had initial surface smoothness recorded, representing phase 1 (P1). Specimens were divided into three groups (n=6) according to the finishing/polishing instrument used (One-Gloss, TopGloss, and Sof-Lex) to compose phase 2 samples (P2). Then specimens were subjected to 514 cycles of toothbrush simulation using a toothpaste slurry, with a constant load applied to soft bristles, and were then washed (phase 3=P3). After each phase, the specimens were examined by an optical profiler and spectrophotometer to measure Ra and T. Data were analyzed by analysis of variance, Tukey and Pearson tests. T values were statistically influenced by composite resin (p=0.000) and phase of measurement (p=0.000) factors, while the finishing/polishing system used (p=0.741) did not affect T. On the other hand, Ra values were

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statistically affected by the factor finishing/polishing system (p=0.000), but not by composite resin (p=0.100) and phase of measurement (p=0.451). Tetric N-Ceram and Empress Direct presented higher values of roughness when polished by OneGloss, while TopGloss and Sof-Lex showed a lower roughness. It can be concluded that composite resins transmitted more light after dental abrasion. Transmittance of composite resins was not modified by the distinct roughness created by finishing/polishing instruments.

INTRODUCTION

The surface quality of restorations is considered a key factor for clinical success. A smooth surface increases the lifetime of composite resin restorations, optimizing their esthetic appearance and reducing plaque accumulation and surface pigmentation.[1] In this context, the finishing and polishing techniques used are important steps to guarantee long-lasting restorations.[2,3]

The literature shows numerous reports evidencing a wide range of finishing and polishing instruments available for clinicians, such as multilaminated drills, diamond-impregnated rotary instruments, rubber or silicone disks and wheels, and carbide- and aluminum oxide–based abrasive disks.[4] There is no consensus in the literature about which instrument is the most suitable for each type of composite resin; the restorations are classified by filler particles[5] as microfilled, microhybrid, or nanohybrid.[6]

In addition to surface smoothness, esthetic and chromatic characteristics of dental restorations may also be influenced by illumination conditions and optical properties of the restorative material, such as transmittance, light scattering, fluorescence, and opalescence.[7-9] Transmittance, for example, refers to the transmission of light through a body and may occur with different levels of absorption and scattering within the material.[10] The transmittance of the human tooth is higher at the incisal edge, especially in young patients with relatively intact enamel. Thus, the restoration of young teeth is difficult to achieve because of the original optical properties. The filler content of a composite resin is an important factor affecting the transmittance of the final restoration. In addition, the amount, size, and shape of the filler particles directly affect the light scattering ability of the composite resin.[11]

Both surface texture and optical properties are affected by degradation between the organic matrix and the filler, wear of the filler particles, and weakening of the adhesion between the organic matrix and inorganic filler.[12] The literature[13,14] proves that the action of toothbrushes and the use of abrasive toothpastes result in significant wear of the restoration, with consequent increased surface roughness. Even when excellent finishing and polishing procedures are carried out and the restoration surface is very smooth, it is important to remember that the wear rate of restorative materials submitted to tooth brushing is not similar to that of dental enamel.[15] There are several previous works[14,16,17] showing the effect of tooth brushing on the surface roughness of restorative materials, but there are no reports concerning the effect of surface roughness on light transmittance and the final esthetic quality of composite resin restorations.

From a clinical standpoint, it is important to understand whether the changes caused by brushing can affect the optical properties and the roughness of different composite resins polished by different finishing and polishing systems. Hence, the aim of this study was to evaluate the transmittance and surface roughness of three different composite resins as a function of the type of finishing/polishing system used and the phase of measurement of these properties (before or after polishing and brushing).

METHODS AND MATERIALS

Eighteen disk-shaped specimens (10 mm diameter × 2 mm thick) of each composite resin (Table 1) were prepared using a polypropylene matrix. The composite resin was inserted in one single portion, covered with a polyester strip, and photoactivated (Radii-Cal, SDI, Bayswater, Australia; intensity of 800 mW/cm^2) for 40 seconds. The surface smoothness promoted by a polyester strip represented phase 1 (P1). All specimens were stored in distilled water at 37°C for 24 hours.

A 10 × 4 mm square area was delimited on disk surfaces. The disks of each composite resin were subdivided (n=6) according to the type of finishing and polishing system used (Table 2): OneGloss (Shofu Inc, Kyoto, Japan), TopGloss (EDENTA, St. Gallen, Switzerland), and Sof-Lex (3M ESPE, St Paul, MN, USA). The polished specimens were stored in distilled water at 37°C for seven days, representing phase 2 (P2).

Toothbrush simulation was carried out using a tooth brushing machine (MSE-ELQUIP, São Carlos, SP, Brazil) equipped with 10 toothbrushes with soft

Table 1: *Materials Used in the Study*				
Composite/Lot No.	**Manufacturer**	**Type**	**Shape**	**Filler Content**
Filtek® Supreme XT/N367731)	3M ESPE, St Paul, MN, USA	Nanofilled	Translucent (CT)	Nonagglomerated/nonaggregated, 75 nm silica nanofiller
				Agglomerate silica nanocluster (0.6-1.4 μm)
				72.5% by weight
Tetric® N-Ceram/R27050	Ivoclar Vivadent AG, Schaan, Liechtenstein	Nanohybrid	Translucent (T)	Barium glass, ytterbium trifluoride, mixed oxide, and copolymers (0.04-3 μm)
				80%-81% by weight
IPS Empress® Direct/R47920	Ivoclar Vivadent AG, Schaan, Liechtenstein	Nanohybrid	Translucent (Trans 30)	Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide, and copolymers (0.04-3 μm)
				75%-79% by weight

nylon bristles (Oral B 30, Procter & Gamble, São Paulo, SP, Brazil) (Figure 1B) and a toothpaste slurry in a proportion of 1:2 by weight (90 g of Colgate Máxima Proteção Anti-Cáries® [Colgate-Palmolive, Osasco, SP, Brazil] + 180 mL of distilled water). Taking into account that an individual brushes his teeth twice a day for one minute each time, the machine was calibrated to perform 257 cycles per minute for two minutes, comprising a total of 514 cycles. One cycle corresponded to the full movement (back and forth) of the toothbrush. A constant load of 200*g* was applied to the active tips of the brushes' bristles. Brushes were replaced after each 514 cycles, and the samples were randomly brushed. After brushing, specimens were abundantly washed in running tap water, representing phase 3 (P3).

After each of the three phases, specimens were examined in an optical profilometer (Proscan 2100, Scantron, Venture Way, Tauton, UK) and with a spectrophotometer (CM-3700d, Konica Minolta, Aichi Prefecture, Japan) for determination of the surface roughness (Ra) and total transmittance (T), respectively.

Measurement of Surface Roughness

Surface roughness measurements were performed with an optical profilometer (2100, Scantron, Venture Way). Scanning areas were limited to 1 mm^2 in the center of each specimen with the use of a S11/03 sensor. At the X axis, 1000 steps of 0.001 mm were used, while at the Y axis, five steps were used, with a pitch of 0.2 mm. The mean values for Ra were obtained from each experimental group using specific software (Proscan Application software, version 2.0.17).

Measurement of Light Transmittance

The transmittance is given by the ratio (%) of intensity of the incident light and the light transmitted by the specimen for each wavelength. After storage in water, specimens were evaluated by the spectrophotometer Cintra 10 UV-Visible Spectrometer (GBC, Braeside, VIC, Australia). Measurements were made every 5 nm in the wavelength range from 400 to 700 nm, corresponding to the visible light spectrum of the human eye. For each specimen, three readings were recorded at different places and the obtained values were averaged. The numerical values (percentage) of transmittance in each wave-

Table 2: *Composition and Application Time of Finishing and Polishing Systems Used in this Study*			
Finishing and Polishing Material/Lot No.	**Manufacturer**	**Material Time**	**Application Time, s**
OneGloss (OG)/281091	Shofu Inc, Kyoto, Japan	Aluminum oxide one-step finisher and polisher	15
TopGloss (TG)/Y09.001	EDENTA Ag, AU, SG, Switzerland	Diamond-impregnated micropolisher	15
Sof-Lex (SL)/1227200585	3M ESPE, St Paul, MN, USA	Aluminum oxide–coated disks (coarse, medium, fine, superfine)	15 for each disk

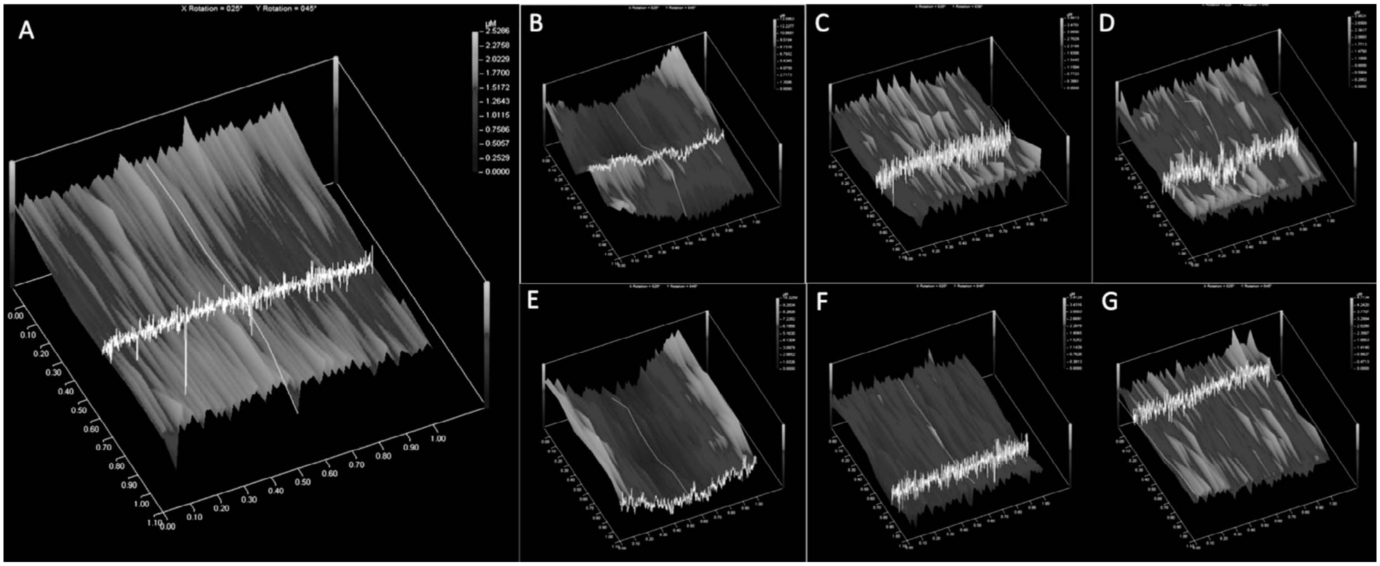

Figure 1. *Representative roughness images from composite Z350 XT: (A) Phase 1—Surface smoothness promoted by Mylar strip. (B, C, D) Phase 2—Surface smoothness promoted by different finishing and polishing systems: OneGloss, TopGloss, and Sof-Lex, respectively. (E, F, G) Phase 3—Surface smoothness after tooth brushing of the specimens.*

length were initially stored as a file on the spectrophotometer software and transferred to Microsoft Excel (Microsoft Excel, version 2007, Microsoft, Seattle, USA) for statistical analysis.

Statistical Analysis

A power analysis was performed using the software Minitab version 16 (Minitab Inc., State College, Pennsylvania) assuming a general full factorial design involving the main factors, an alpha value of 0.05, six specimens per group, and a global standard deviation of 1.71 for transmittance and of 0.48 for roughness. The test resulted in power of 100%. Two-way analysis of variance was used to evaluate both roughness and transmittance data. Means were compared by Tukey test (α=0.05), and regression analysis was used to investigate whether there was a correlation between transmittance and surface roughness values (α=0.05).

RESULTS

Light Transmittance

Table 3 shows the mean values of transmittance obtained for the composite resin specimens used in the study, as a function of the finishing/polishing system and the measurement phase.

The results showed that there was no effect of the polishing system on the total transmittance of the specimens, regardless of the composite resin evaluated. However, the measurement phase significantly affected the transmittance of the specimens.

Statistical differences were observed among the different phases for all composite resins evaluated (p=0.01). For Tetric N-Ceram and Empress Direct, the effect of the measurement phase on transmittance was the same, since the mean values of phases 1 and 2 were similar; however, for these materials, transmittance measurements made after phase 3 were significantly higher in relation to those measures after the two other phases. For Z350 XT, the effect of measurement phase on T was significant. It was observed that after phase 2, the T mean value significantly decreased in relation to the values obtained after phase 1. Also, after phase 3, there was a significant increase in T in relation to the values obtained after phases 1 and 2.

Surface Roughness

Table 4 shows the Ra mean values for composite resins used in the current study, as a function of the finishing/polishing system and measurement phase. Figures 1, 2, and 3 show the roughness patterns of experimental groups.

Tetric N-Ceram and Empress Direct did not have their roughness affected by the measurement phase. Only Z350 XT was affected by measurement phase, as its roughness decreased significantly after phase 2 in relation to the measurement made after phase 1. The roughness of Z350 XT after phase 3 was similar to that obtained after phase 2.

Table 3: *Mean Values and Standard Deviations of Total Transmittance (%)*[a]

	OG (OneGloss)	TG (TopGloss)	SL (Sof-Lex)	Mean
Composite Z350 XT				
P1	46.8±0.9	46.2±1.5	46.4±1.5	46.5 B
P2	40.1±0.7	39.9±1.8	39.2±2.9	39.7 C
P3	54.8±1.4	56.6±0.8	56.0±1.3	55.8 A
Mean	47.23 a	47.57 a	47.20 a	
Composite Tetric N-Ceram				
P1	22.4±0.8	22.2±0.7	21.6±0.6	22.1 B
P2	20.6±1.5	20.1±0.5	20.4±0.6	20.4 B
P3	27.4±1.0	27.1±1.2	27.1±0.6	27.2 A
Mean	23.47 a	23.13 a	23.03 a	
Composite Empress Direct				
P1	34.5±0.9	36.3±1.4	35.7±2.4	35.5 B
P2	33.3±1.6	32.9±1.6	31.8±3.2	32.7 B
P3	43.4±3.1	44.1±1.6	44.2±3.8	43.9 A
Mean	37.07 a	37.77 a	37.23 a	

Abbreviations: P1, phase 1; P2, phase 2; P3, phase 3.
[a] Distinct superscript letters indicate statistically significant differences. Capital letters refer to differences between lines, and lowercase letters refer to the differences between columns.

Table 4: *Mean Values and Standard Deviations of Surface Roughness (μm)*[a]

	OG (OneGloss)	TG (TopGloss)	SL (Sof-Lex)	Mean
Composite Z350 XT				
P1	1.21 ± 0.90	0.86 ± 0.31	1.12 ± 0.94	1.06 A
P2	1.26 ± 0.71	0.52 ± 0.22	0.60 ± 0.48	0.79 B
P3	1.06 ± 0.34	0.35 ± 0.12	0.72 ± 0.46	0.71 B
Mean	1.18 a	0.58 a	0.81 a	
Composite Tetric N-Ceram				
P1	0.82 ± 0.48	0.89 ± 0.24	0.70 ± 0.37	0.80 A
P2	1.28 ± 0.46	0.70 ± 0.21	0.51 ± 0.23	0.83 A
P3	1.12 ± 0.24	0.51 ± 0.17	0.55 ± 0.28	0.73 A
Mean	1.07 a	0.70 b	0.59 b	
Composite Empress Direct				
P1	1.29 ± 0.71	0.89 ± 0.48	0.69 ± 0.60	0.96 A
P2	1.54 ± 0.58	0.92 ± 0.81	0.48 ± 0.23	0.98 A
P3	1.55 ± 0.55	0.95 ± 0.54	0.60 ± 0.33	1.03 A
Mean	1.46 a	0.92 b	0.59 b	

Abbreviations: P1, phase 1; P2, phase 2; P3, phase 3.
[a] Distinct superscript letters indicate statistically significant differences. Capital letters refer to differences between lines, and lowercase letters refer to the differences between columns.

The regression analysis showed no correlation between light transmittance and the surface roughness for the three materials tested: Z350 XT (p=0.538), Tetric N-Ceram (p=0.334), and Empress Direct (p=0.875).

DISCUSSION

The hypothesis that the different finishing and polishing systems tested in this study would influence the total transmittance of the composite resins studied was rejected because regardless of the type of composite resin used (nanohybrid or nanofilled), all polishing systems resulted in the same level of light transmission. According to Lee,[11] one of the main components of a dental composite resin that is able to significantly affect its translucency is the inorganic filler. Therefore, it is possible to infer that the small variation in the inorganic content of the three composite resins used (52% to 59% in volume) might have been responsible in part for the similarity observed in terms of optical behavior as a function of the polishing system. These results have a clinical impact, since they indicate that the clinician can choose any of the tested finishing and polishing systems without compromising the light transmission of the final restoration. In addition, the clinician may choose the most appropriate polisher geometry to polish the different anatomic regions of the restoration.

The hypothesis that the different measurement phases could affect the transmittance of the specimens was accepted. In the case of Z350 XT, the highest transmittance observed for the first measurement (control, P1) in relation to the second measurement (after polishing, P2) is probably due to the use of the Mylar strip during polymerization of the material. The use of such a strip results in an extremely glossy surface, with reduced light scattering. For this material there was also a significant reduction in roughness after P2, which appears to be related to the lower transmittance observed after the polishing procedure.

For Tetric N-Ceram and Empress Direct, the transmittance was not affected by the polishing procedure. This finding may be explained by the fact that the microstructures of these two composite resins are significantly different from that of Z350 XT. While the microstructure of Z350 XT consists exclusively of nanoparticles of silica (20 nm) and zirconia (4 to 11 nm), Tetric N-Ceram and Empress Direct contain glass and barium fillers and are considered nanohybrid composites, with particle sizes ranging from 40 nm up to 3 μm. A previous study[10] demonstrated that direct transmittance of composite resins strongly depends on the composition of the material, particularly the type and size of inorganic particles. Furthermore, it is known that the difference between the refractive index of the

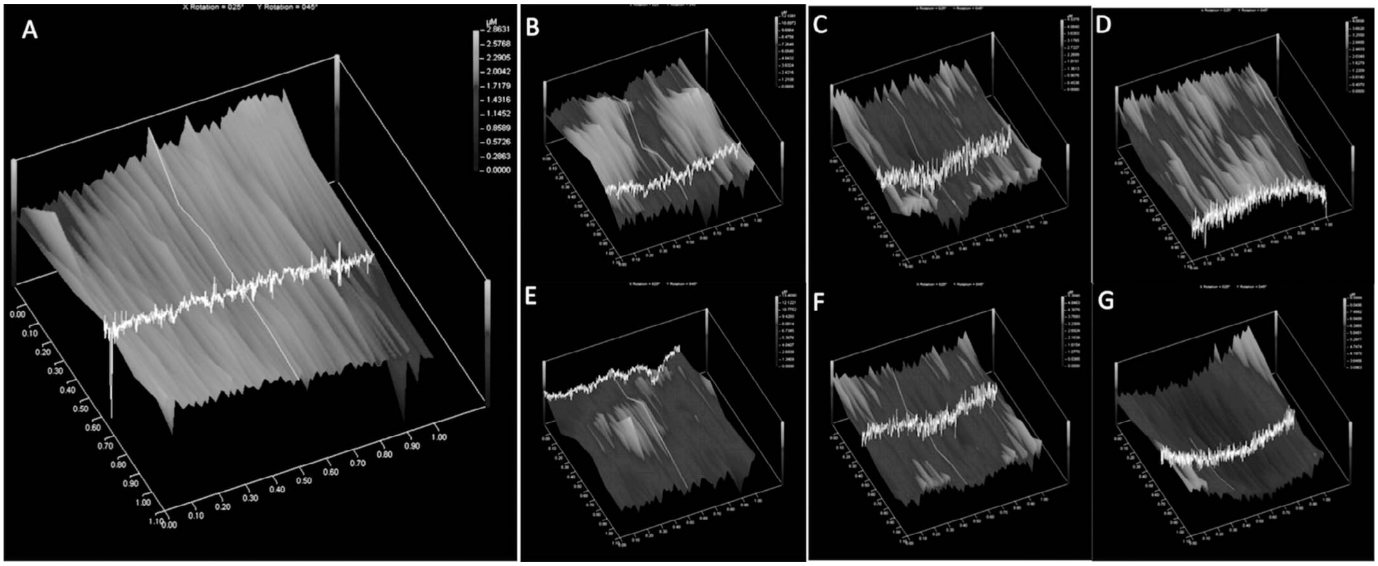

Figure 2. *Representative roughness images from composite Tetric N-Ceram: (A) Phase 1—Surface smoothness promoted by Mylar strip. (B, C, D) Phase 2—Surface smoothness promoted by different finishing and polishing systems: OneGloss, TopGloss, and Sof-Lex, respectively. (E, F, G) Phase 3—Surface smoothness after tooth brushing of the specimens.*

organic matrix and that of the filler influences the final optical properties of the composite resins.[18]

After toothbrush abrasion (P3), all composite resins tested showed significant increases in transmittance. A decrease in transmittance was expected after toothbrush abrasion because theoretically this type of abrasion adds scratches and irregularities to the surface, resulting in greater light scattering and thus lower transmittance. In fact, a previous study[12] showed that resin specimens aged in water had their transmittance reduced as the result of an increase in their opacity. Considering that the toothbrush abrasion carried out in the current investigation is a type of aging protocol, one could expect that the same increase in opacity would occur for the composite resins tested. One possible explanation for the observed increase in transmittance after brushing is the reduction of approximately 1 μm in the thickness of the specimens after they were submitted to the brushing protocol. There is a strong

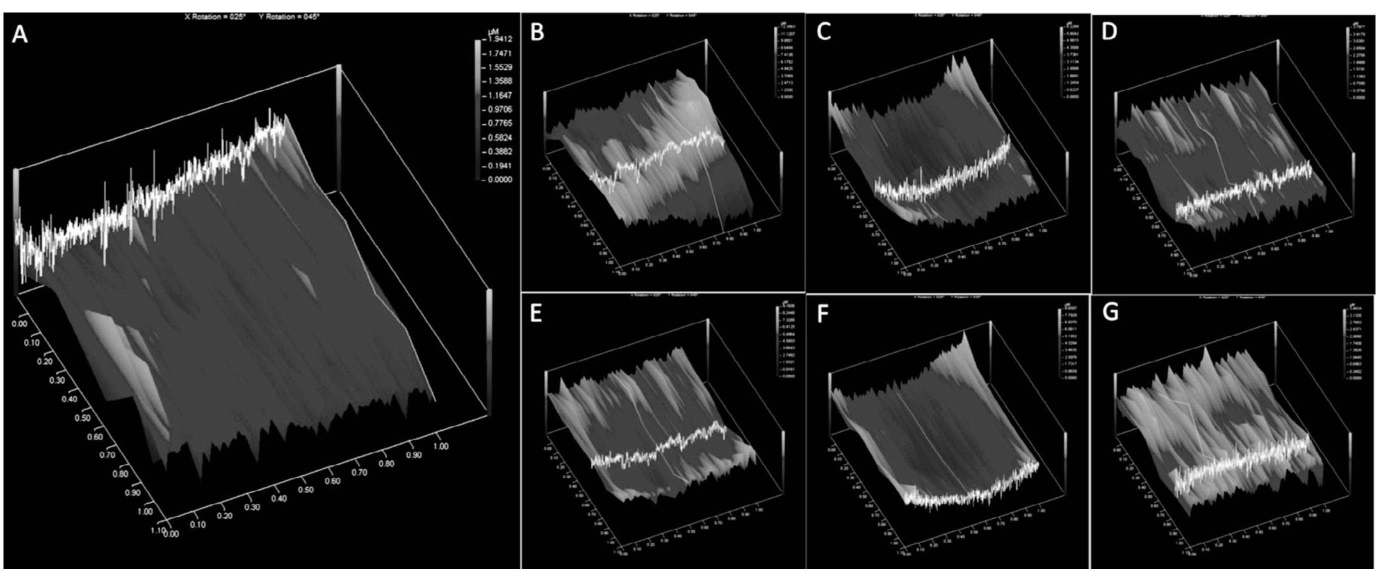

Figure 3. *Representative roughness images from composite Empress Direct: (A) Phase 1—Surface smoothness promoted by Mylar strip. (B, C, D) Phase 2—Surface smoothness promoted by different finishing and polishing systems: OneGloss, TopGloss, and Sof-Lex, respectively. (E, F, G) Phase 3—Surface smoothness after tooth brushing of the specimens.*

correlation between the thickness of the specimen and its transmittance, such that the greater the thickness, the lower the transmittance of light due to the increased scattering within the material structure.[19] From a clinical point of view, these results suggest that with time the daily brushing procedure may result in increased translucency of resin composite restorations, which may represent an undesirable shade mismatch for the restoration. To minimize this problem, a layering technique can be used to produce the restoration. In this way, more opaque colors may be used in deeper regions to decrease the impact of the increased translucency of the surface layer on the final shade of the restoration.[20]

Regarding roughness data, it was observed that the Z350 XT resin was not affected by the type of polishing system. As mentioned earlier, the microstructure of this material contains nanometric particles and clusters that responded similarly to the action of the different polishing systems used in this study. The literature[21,22] showed that the ability to obtain smoother surfaces in composite resins is related to the filler size.

The interaction of the composite resins Tetric N-Ceram and Empress Direct with the polishing system OneGloss resulted in greater surface roughness values compared to the other two polishing systems. OneGloss is composed of a tip impregnated with aluminum oxide particles. These results are in agreement with those of other studies[23,24] indicating that aluminum oxide disk systems promote smoother surfaces compared to impregnated abrasive tips. The duration of the finishing/polishing procedures may justify the higher surface roughness values observed after application of OneGloss. This system is applied to the material surface for only 15 seconds, while the Sof-Lex system, which has a similar composition, is applied for total time of 60 seconds as a result of the sequential application of disks with different abrasiveness. Sof-Lex and TopGloss systems resulted in similar roughness results for Empress Direct and Tetric N-Ceram, which is in accordance with the findings of other studies[21,25] showing that silicon diamond tips can achieve surface roughness results similar to those obtained with disks.

The results of this study indicate that there was no correlation between surface roughness and light transmittance for the materials studied. This result may be related to the fact that the specimens used in the current investigation were relatively thick (2 mm). Based on the results of this study, it is possible to conclude that knowing the microstructure of the composite resin restorative materials and the features of the polishing system is key to predicting the behavior of the restoration in terms of transmittance and roughness. The surface roughness of the restorative materials tested in this study was not affected by tooth brushing abrasion, which may be considered a positive result from the clinical standpoint.

CONCLUSIONS

Based on the results of this study, it can be concluded that

1. Regardless of the type of composite resin used (nanohybrid or nanofilled), all polishing systems resulted in the same final level of light transmission;
2. On the other hand, both polishing and toothbrush abrasion affected the transmittance of the composite resins evaluated; however, these results varied according to the composite microstructure;
3. Neither nanohybrid composite had its roughness affected by polishing or tooth brushing;
4. However, for the nanofilled composite, roughness significantly decreased after polishing and was kept at the same level after tooth brushing.

Conflict of Interest Statement

The authors of this manuscript certify that they have no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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