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Research article

Investigating on surface roughness of nanohybrid and micro-hybrid composite resins following the use of a simplified polishing system

Seyedeh Parvin Hosseini Fadabobeh[1], Mehrdad Kazemian[1]*, M.R. Malekipour Esfahani[1]

[1]*Department of Operative Dentistry, Faculty of Dentistry, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

* m.kazemian@khuisf.ac.ir

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Abstract

In this in vitro experimental study, the average surface roughness (Ra value) of Z250 microhybrid and Z350 nanohybrid composite resins was compared after polishing with the EVE simplified polishing system and the multi-step Sof-Lex discs. The study used 96 composite discs (8 × 2 mm), which were randomly divided into four subgroups: control (no finishing/polishing), polishing with Sof-Lex discs, polishing with EVE discs, and polishing with EVE discs + EVE polishing paste. Before polishing, the specimens were ground with 1200-grit silicon carbide abrasive paper. The average surface roughness of each specimen was measured before (baseline) and after polishing using a profilometer. The results were analyzed using ANOVA and Bonferroni tests. The study found that the control subgroups had the smoothest surfaces. For the Z350 subgroups, a significant difference in surface roughness was observed, with the Sof-Lex system yielding the roughest surface ($P<0.05$). The EVE discs + EVE paste system provided the smoothest surface after the control subgroup. A significant difference in surface roughness was also observed among the Z250 subgroups, with the Sof-Lex system creating significantly rougher surfaces than the EVE discs + paste system. In all eight subgroups, a significant difference in surface roughness was observed, with Z350 specimens polished with Sof-Lex discs and Z350 control specimens showing the maximum and minimum roughness, respectively. The study concludes that the two-step EVE polishing system may be preferred over the multi-step Sof-Lex discs for polishing Z250 and Z350 composites, as it provided significantly smoother surfaces. Overall, the study provides valuable insights into the effectiveness of different polishing systems in achieving desired surface roughness for composite resins.

Keywords: Surface roughness; Dental polishing; Composite resins; Microhybrid; Nanohybrid

1- Introduction

Tooth-colored restorations are widely used in dental practice, but achieving a natural anatomical form, color match with adjacent teeth, and optimal surface properties for minimal plaque retention are critical considerations when providing esthetic restorations [1]. Composite resins are the most commonly used tooth-colored restorative materials [2]. The surface beneath the Mylar strip is reported to be the smoothest composite surface [3]. The final finish of a composite surface depends on the type of finishing instrument and its filler particles. The average surface roughness, measured with a profilometer and atomic microscopy, is indicated by the Ra value, which quantifies the depths and valleys of a restoration surface. A surface roughness value <1 μm is clinically considered very smooth and highly polished. Using sub-micron polishing pastes can often achieve a smooth and polished surface with a roughness value between 0.2-0.6 μm [4]. Furthermore, it has been reported that a change in surface roughness of 0.3 μm can be detected by the tip of the tongue [5]. These findings highlight the importance of achieving optimal surface properties during the provision of tooth-colored restorations to ensure patient satisfaction and long-term success.

Use of tooth-colored restorations has become widespread worldwide. However, creating a natural anatomical form, achieving excellent color match with the adjacent teeth, and optimization of surface properties of restorations for minimal plaque retention are critical factors to consider in provision of esthetic tooth-colored restorations [1]. Composite resins are the most commonly used tooth-colored restorative materials [2]. It has been reported that the smoothest composite surface is the surface beneath the Mylar strip [3]. The final finish of a composite surface depends on the type of finishing instrument and its filler particles. The average surface roughness, indicated with Ra, is quantified by measuring the depths and valleys of a restoration surface by using a profilometer and atomic microscopy. An average surface roughness value < 1 μm is clinically considered very smooth and highly polished. A smooth and polished surface with a roughness value between 0.2-0.6 μm can be often achieved by using sub-micron polishing pastes [4]. Also, it has been reported that change in surface roughness by 0.3 μm can be detected by the tip of the tongue [5].

Attempts are ongoing to fabricate composite finishing systems suitable for all four steps of finishing and polishing [6-7]. Irrespective of the class of cavity and its position, a finished and polished surface is clinically important and determines the esthetics and longevity of restorations [7]. Polishing refers to reduction of roughness and scratches caused by the finishing instruments [8]. Final polishing of restoration surfaces is often performed with polishing diamond discs and abrasive silicon carbide polishing cups. Sof-Lex flexible discs (3M ESPE) available in the market are practically the gold-standard for finishing and polishing of composite restorations. They have a flexible surface with different grits, and create a smooth surface. Other series of Sof-Lex discs, produced by other manufacturers, have a thin plastic or polymeric support, which allows their access to embrasures and interproximal areas. It has been reported that consecutive use of all four abrasive discs yields the smoothest surface achievable [9]. Achieving a polished composite surface is a primary challenge in clinical success of these restorations [10]. Aside from esthetics, appropriate finishing and polishing is imperative for oral health since rough surfaces provide a suitable environment for dental plaque accumulation and subsequent gingival irritation, development of caries, and discoloration of restoration. Thus, it is important to find the most effective polishing system for adhesive restorations [11]. The manufacturers are attempting to produce polishing systems with easier application and fewer steps to simplify the finishing and polishing procedure. The two-step EVE Twist polishing system was recently introduced to the market to simplify the finishing and polishing procedure of composite resins. However, the efficacy of this novel polishing system is still in need of further investigations.

Hybrid composite resins have two mixed filler types of fine and micro-fine in their composition. Hybrid and microhybrid composite resins have optimal mechanical properties and wear resistance, which make them suitable for application in high stress-bearing areas in the oral cavity. However, they gradually lose their surface smoothness over time and become rough and dull [12]. With the advances in nanotechnology, nanohybrid composites were introduced to the market, which are composed of nanometer particles along with larger particles (0.04-5 µm). The surface of nanohybrid composites also becomes dull after several years of clinical service [12]. Considering the novelty of the EVE polishing system, this study sought to compare the average surface roughness (Ra value) of a nano-hybrid and a microhybrid composite resin following the use of EVE simplified polishing system versus the multi-step Sof-Lex discs. The purpose of this *in vitro* study was to compare the effectiveness of the EVE simplified polishing system with the multi-step Sof-Lex discs in achieving a smooth surface finish on Z250 microhybrid and Z350 nanohybrid composite resins. Surface roughness is a critical factor in the long-term clinical success of composite restorations, as it affects the material's wear resistance, susceptibility to staining, and maintenance of a natural-looking appearance. The innovation of this study lies in the evaluation of a simplified polishing system for composite resins, which could potentially reduce the time and effort required for achieving optimal surface smoothness.

2- Materials and Methods

This *in vitro*, experimental study evaluated 96 composite discs (8 mm in diameter and 2 mm in height) fabricated from Z250 microhybrid and Z350 nanohybrid composite resins. Sample size was calculated to be 96 assuming.

2-1- Specimen preparation

A total of 48 discs were fabricated from Filtek Z250 microhybrid composite (3M ESPE, St. Paul, MN, USA) and 48 discs were fabricated from Filtek Z350 nanohybrid composite (3M ESPE, St. Paul, MN, USA). For this purpose, a plastic mold with 2 mm thickness and 8 mm diameter was used. A Mylar strip was placed over a glass slab and the mold was placed over the Mylar strip. Adequate amount of the respective composite was applied into the mold, another Mylar strip was placed over it, and the composite surface was condensed with a glass slab. Light curing was then performed using a curing unit (Demi, Kerr, Orange, CA, USA) with 750 nm light intensity. Each side was cured for 30 s. Each disc was then coded to mark its group and subgroup. All specimens, except for the control subgroup, were ground by 1200-grit silicon carbide abrasive paper under running water to eliminate the non-polymerized layer. Next, the specimens in each composite group (n=48) were randomly divided into the following four subgroups (n=12): Control: No finishing and polishing were performed for this subgroup, and the surface under the Mylar strip was evaluated. Sof-Lex discs: Specimens in this subgroup underwent polishing with Sof-Lex discs (3M ESPE, St. Paul, MN, USA). EVE discs: Specimens in this subgroup underwent polishing with two-step EVE discs (EVE; Germany). EVE discs + EVE polishing paste: Specimens in this subgroup underwent polishing with two-step EVE discs (EVE; Germany) and EVE polishing paste. The composite discs were held by a hemostat during the polishing procedure.

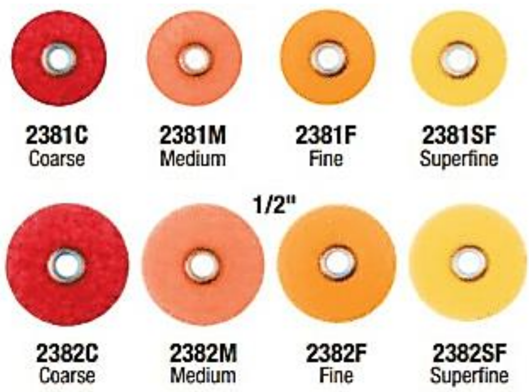

Fig. 1 A set of 85 discs for finishing and polishing, known as Soflex, is available.

Fig. 1 shows the Soflex is a collection of 85 discs that are specifically designed for finishing and polishing various materials. These discs are made from high-quality materials and are manufactured using advanced technology to ensure that they deliver exceptional performance and precision. They are widely used by professionals in the fields of dentistry, jewelry making, and metalworking, among others. The Soflex discs come in a variety of shapes, sizes, and grits to cater to different polishing and finishing requirements. They are typically color-coded to make it easy to distinguish between them and select the appropriate disc for the task at hand.

The specimens in the Sof-Lex disc subgroups were first polished with purple disc installed on a mandrel. This disc was used for 30 s on each specimen, and each disc was only used for two specimens. The specimens were then rinsed with water for 10 s, and debrided with air spray for 5 s. The orange disc was then used for 30 s (per each specimen surface). After rinsing with water for 10 s and debridement with air spray for 5 s, yellow disc was used for 30 s followed by rinsing with water for 10 s and debridement with air spray for 5 s. In the two-step EVE disc subgroups, first the pink disc was used for pre-polishing (medium) of each specimen for 30 s, followed by 10 s of rinsing and debridement with air spray for 5 s.

Next, the beige disc was used for high-shine polishing (fine) of each specimen for 30s, followed by 10s of rinsing, and debridement with air spray for 5s. In the two-step EVE discs + paste subgroups, first the pink disc was used for pre-polishing (medium) of each specimen for 30 s, followed by 10 s of rinsing, and debridement with air spray for 5 s. Then, the beige disc was used for high-shine polishing (fine) of each specimen for 30s, followed by 10s of rinsing and debridement with air spray for 5s. Afterwards, the EVE polishing paste was applied on each specimen with felt disc for 30s, followed by 10s of rinsing, and debridement with air spray for 5s.

2-2- Measuring the surface roughness:

The surface roughness of specimens was first measured at baseline prior to the polishing procedure using a profilometer (Surftest-211; Mitutoyo, Kanagava, Japan). After polishing, the specimens were rinsed with water and allowed 7 days to completely dry. Next, the average surface roughness (Ra) of specimens was measured again by the same profilometer in 0.08 mm sections with a speed of 0.1 m/s. The measurements were repeated twice at 1 mm distance from the center of each specimen. The average surface roughness of each subgroup was then calculated. The second measurement of surface roughness was taken after the specimens had undergone the various polishing procedures. Specifically, the specimens were rinsed with water and allowed 7 days to completely dry before the second measurement was taken. The average surface roughness (Ra) of each specimen was measured using the same profilometer in 0.08 mm sections with a speed of 0.1 m/s. The measurements were repeated twice at 1 mm distance from the center of each specimen to ensure accuracy. The average surface roughness of each subgroup was then calculated based on these measurements.

2-3- Statistical analysis

The Kolmogorov-Smirnov test was first applied to assess the normal distribution of data. Since data were normally distributed (P>0.05), comparisons were performed using ANOVA followed by the Bonferroni test (for pairwise comparisons) via SPSS version 25 (SPSS Inc., IL, USA) at 0.05 level of significance. Data were analyzed using one-way ANOVA and Bonferroni test to determine the statistical significance of the difference in mean surface roughness (Ra value) between the control and experimental subgroups. A p-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS software (version 25, IBM Corp., Armonk, NY, USA).

3- Results and Discussion

Table 1 presents the average surface roughness of the subgroups. As shown, in Z350 specimens, the average surface roughness was higher in Sof-Lex subgroup by 0.242. The minimum average surface roughness was noted in the control subgroup (0.076). In Z250 specimens, the average surface roughness was higher in the Sof-Lex subgroup by 0.160. The minimum average surface roughness was noted in the control subgroup (0.077). The difference in the average surface roughness of Z350 specimens was statistically significant (P=0.001). Thus, pairwise comparisons of the surface roughness of the four subgroups were carried out by the Bonferroni test (Table 2).

Table 1: average surface roughness of the subgroups

Composite group	Polishing subgroup	Ra		P value
		average	Std. deviation	
Z350	Control	0.076	0.018	0.001
	Sof-Lex	0.242	0.034	
	EVE discs	0.154	0.016	
	EVE discs + paste	0.104	0.016	
Z250	Control	0.077	0.015	0.001
	Sof-Lex	0.160	0.031	
	EVE discs	0.145	0.019	
	EVE discs + paste	0.105	0.024	

As shown, all pairwise comparisons yielded significant differences (P=0.001). The difference in the average surface roughness of Z250 specimens was statistically significant as well (P=0.001).

Table 2: Pairwise comparisons of the surface roughness of the four subgroups of Z350 composite resin

Group I	Group J	average difference	Std. deviation	P value
Control	Sof-Lex	-0.166	0.006	**0.001
	EVE discs	-0.077	0.006	**0.001
	EVE discs + paste	-0.028	0.006	**0.001
Sof-Lex	EVE discs	0.089	0.006	**0.001
	EVE discs + paste	0.139	0.006	**0.001
EVE discs	EVE discs + paste	0.050	0.006	**0.001

Table 3: Pairwise comparisons of the surface roughness of the four subgroups of Z250 composite resin

Group I	Group J	average difference	Std. deviation	P value
Control	Sof-Lex	-0.083	0.007	**0.001
	EVE discs	-0.067	0.007	**0.001
	EVE discs + paste	-0.028	0.007	**0.001
Sof-Lex	EVE discs	0.016	0.007	0.128
	EVE discs + paste	0.055	0.007	**0.001
Eve discs	EVE discs + paste	0.039	0.007	**0.001

Thus, pairwise comparisons of the surface roughness of the four subgroups were carried out by the Bonferroni test (Table 3).

As shown, the difference in surface roughness between the Sof-Lex system and EVE discs was not significant (P=0.128). However, all other pairwise comparisons yielded significant differences (P=0.001). General comparison of all 8 subgroups by ANOVA revealed a significant difference in surface roughness (P=0.001). Thus, pairwise comparisons of all 8 subgroups were carried out (Table 4), which revealed significant differences in all comparisons (P=0.001), except for the difference between the Z350 and Z250 control groups (P=0.999), Z350 EVE discs and Z250 Sof-Lex discs (P=0.999), Z350 and Z250 EVE discs (P=0.999), and Z350 and Z250 EVE discs + paste subgroups (P=0.999). Fig. 2 shows an overview of the comparison of surface roughness of all 8 subgroups.

Table 4: Pairwise comparisons of the surface roughness of all eight subgroups of Z350 and Z250 composite resins

Z350 subgroups	Z250 subgroups	average difference	Std. deviation	P value
Control	Control	-0.001	0.007	0.999
	Sof-Lex	-0.084	0.007	**0.001
	EVE discs	-0.066	0.007	**0.001
	EVE discs + paste	-0.029	0.007	**0.001
Sof-Lex	Control	0.165	0.007	**0.001
	Sof-Lex	0.083	0.007	**0.001
	EVE discs	0.099	0.007	**0.001
	EVE discs + paste	0.137	0.007	**0.001
EVE discs	Control	0.076	0.007	**0.001
	Sof-Lex	-0.006	0.007	0.999
	EVE discs	0.011	0.007	0.999
	EVE discs + paste	0.048	0.007	**0.001
EVE discs + paste	Control	0.027	0.007	**0.001
	Sof-Lex	-0.057	0.007	**0.001
	EVE discs	-0.039	0.007	**0.001
	EVE discs + paste	-0.001	0.007	0.999

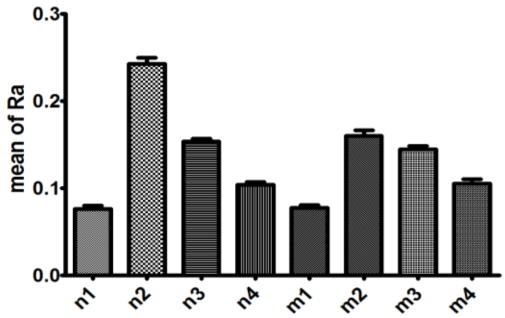

Fig. 2 Overview of the comparison of the average surface roughness (Ra) of all 8 subgroups (n1: nanohybrid control, n2: nanohybrid Sof-Lex, n3: nanohybrid EVE discs, n4: nanohybrid EVE discs + paste; m1: microhybrid control, m2: microhybrid Sof-Lex, m3: microhybrid EVE discs, m4: microhybrid EVE discs + paste)

This study compared the average surface roughness (Ra value) of a nano-hybrid and a micro hybrid composite resin following the use of EVE simplified polishing system versus the multi-step Sof-Lex discs. The results showed that the control subgroups had the smoothest surface. This result was expected since evidence shows that the smoothest composite surface is obtained under the Mylar strip [3]. However, this surface is not optimal due to the presence of oxygen-inhibited layer, and must be removed by finishing and polishing. A significant difference existed in surface roughness of Z350 subgroups, and the Sof-Lex system yielded the roughest surface ($P<0.05$). EVE discs + EVE paste yielded the smoothest surface after the control subgroup. The difference in surface roughness was also significant among the Z250 subgroups. The Sof-Lex system created significantly rougher surfaces than the EVE discs + paste system. A significant difference existed in surface roughness of all 8 subgroups as well, and Z350 specimens polished with the Sof-Lex discs and Z350 control specimens showed the maximum and minimum roughness values, respectively. Kemaloglu et al. [13] concluded that the number of procedural steps had no significant effect on the efficacy of finishing and polishing. However, they added that in use of nanohybrid composite, a polishing system with decreased procedural steps is preferred to multi-step systems. Our results were in agreement with their findings. Patel et al. [14] reported higher surface roughness following the use of Sof-Lex polishing system, compared with one-step PoGo polishing system, indicating that use of polishers with fewer steps would yield smoother surfaces. Their results were in line with ours as well. Erdemir et al. [15] found no significant difference in surface roughness of three composite resins containing nanoparticles polished with one-step and multi-step polishing systems. Their results were different from our findings, which may be due to the use of different composite types and polishing systems.

Korkmaz et al. [16] found no significant difference in surface roughness of nano-hybrid and microhybrid composite resins polished with OptraPol, Sof-Lex, and PoGo polishing systems, which was different from our results. Another study also reported that the number of finishing and polishing steps had no significant effect on the quality of finishing and polishing, and the two-step systems were similar to multi-step systems in terms of the quality of polished surfaces [13]. Controversy in the results can be attributed to the use of different types of composite resins and polishing systems. The polishing mechanism of two-step EVE polishing system appears to be based on a silicon base with abrasive particles and its lamellar design, which results in greater and more effective contact with the composite surface, creating a uniform polish. In our study, the Sof-Lex discs created significantly rougher surfaces than EVE discs + paste in Z350 composite specimens. According to the manufacturer, Z350 nanohybrid composite in the shade used in this study has higher amounts of nanocluster particles than nanoparticles, which may explain the rougher surface of this composite in some polishing subgroups such as the Sof-Lex subgroup [17]. Polishing pastes are applied after using the polishing discs to create a smoother surface. Polishing pastes contain the finest abrasive particles that can greatly minimize the surface roughness and are recommended for use on different composite resins, irrespective of the type of polishing system used. This statement was confirmed in the present study since the EVE discs + paste subgroups yielded a significantly smoother surface than the EVE disc subgroups. Production of bio composite materials with sutible surface roughness and development of bone tissue engineering aims to create biomaterials and scaffolds that can support the regeneration of damaged or diseased bone tissue [18-21]. One promising approach to creating these scaffolds is through the use of additive manufacturing techniques, such as 3D printing [22-24]. Several studies have investigated the use of different materials and fabrication methods to develop scaffolds for bone tissue engineering [25-29]. For example, a recent study explored the use of 3D printed poly L-lactic acid scaffolds coated with alginate/carbon nanotubes for bone engineering applications. The researchers fabricated and simulated these scaffolds using finite element analysis [30-34]. Additionally, the study investigated the effect of incorporating graphene nanosheets and copper oxide nanoparticles on the mechanical and thermal properties of composites [35-37]. In addition to material selection and modification, researchers have also studied the impact of fabrication parameters on the properties of 3D printed scaffolds [35-38]. One study optimized the fabrication parameters for chitosan/PLA scaffolds, while another examined the selection of process parameters in RepRap additive manufacturing systems for PLA scaffold production. Moreover, dental research has focused on investigating the properties of dental materials and their applications [35-40]. For instance, studies have examined the bond strength of composite resin to white mineral trioxide aggregate and the effect of different surface treatments. Other studies have investigated the microshear bond strength of composite to deep and superficial dentin using universal adhesives with different pH values in self-etch and etch & rinse modes [41]. Furthermore, research has explored the impact of personality traits on the harmony of smile appearance in patients applying for smile makeovers [41-42]. These studies demonstrate the diverse approaches being taken in dentistry-related research, with a focus on developing materials and techniques that can improve dental health and aesthetics [41-43]. A morphological observation shows a significant difference in surface roughness was noted among the three polishing subgroups in Z250 composite specimens, and the Sof-Lex system resulted in the roughest surface. However, the difference between the Sof-Lex and EVE discs did not reach statistical significance. However, the Sof-Lex system caused significantly higher surface roughness than the EVE discs + paste. Also, the EVE discs + paste yielded a significantly smoother surface than the EVE discs alone. These results were also expected considering the advantages of the polishing pastes described earlier. Comparison of all 8 subgroups revealed that Z350 nanohybrid composite polished with Sof-Lex discs had the roughest surface while the control Z350 specimens had the smoothest surface. Moreover, the control subgroups of the two composites had no significant difference in surface roughness. The surface roughness of Z350 specimens polished with the Sof-Lex system was significantly higher than that of Z250 specimens polished with the same system. This finding may be due to the fact that we used the B shade of Z350 nanohybrid composite, in which the nanocluster particles are dominant, according to the manufacturer. These particles may be scraped off the surface during polishing and yield a rougher surface compared with Z250 composite polished with the same system. In the incisal shade of Z350 nanohybrid composite, the nanomer particles are dominant, and they probably show more nanofill properties. However, considering the contradictory results regarding the surface behavior of nanohybrid and microhybrid composite resins, further studies are still required to obtain more reliable results. It should be noted that this study had an *in vitro* design. Thus, generalization of results to the clinical setting must be done with caution.

4- Conclusion

Based on the results of this study, it can be concluded that the two-step EVE Twist polishing system is a preferable option to the multi-step Sof-Lex discs for achieving smoother surfaces in Z250 and Z350 composites. These findings suggest that the EVE polishing system can be a more effective alternative to Sof-Lex discs for achieving a smooth surface finish on composite resins. The study's findings have the potential to pave the way for the development of more efficient and effective polishing systems for composite restorations, thereby improving the clinical outcomes for patients.

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