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Original article

Assessment of Surface Roughness and Microhardness of Resin Composites after different Finishing and Polishing Procedures

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Abstract

The aim of this in vitro study was to evaluate the influence of three different finishing and polishing (F&P) procedures on the surface roughness and microhardness of four resin composite restorative materials. A total of 160 disc-shaped specimens (10 mm × 2 mm) were prepared in metal mold using four resin composites and stored in distilled water at 37˚C for 24 h. The specimens were then divided into four experimental groups (n=40) according to the type of resin composite. Gp1: Microhybrid composite (Dynamic plus), Gp2: Nanohybrid composite (Nexcomp), Gp3: Supernano composite (ES-TELITE Σ QUICK), and Gp4: Nanoceramic composite (ZENIT). For each type of resin composite the forty specimens were further divided into four sub-groups (A, B, C, & D) based on the type of finishing and polishing procedure as follow: A- Sandpaper, B- Fine diamond bur, C- Astropol cups and discs (two-step) F&P system, and D- Sof-lex discs (four-step) F&P system. Surface roughness measurements were made for all specimens using a USB digital surface profile gauge, and data were recorded using computer software (Elcomaster 2, Elcometer Instruments). The surface Microhardness of the specimens was measured using Digital Display Vickers Microhardness Tester. The obtained data statistically analyzed using SPSS software. Significant differences in surface roughness and microhardness were found according to the type of F&P systems and resin composite (P<0.05). The smoothest surface value was recorded for nanoceramic composite. The highest microhardness value was obtained with microhybrid composite finished with the Soflex discs (four-step) F&P systems. Based on the limitations of this in vitro study, the following conclusions were drawn. The surface roughness and microhardness of the tested resin composites were greatly influenced by the F&P procedure. Among the tested composites, nanoceramic and supernano composites exhibited the lowest surface roughness, while the nanohybrid composite had the highest surface roughness when finished with the Soflex F&P system. The microhybrid composite had the highest microhardness. The smoothest surface finish was achieved when using a fine diamond bur, particularly with the supernano and nanoceramic composites. One-step procedures showed the best results.

Keywords: *Composite Resins, Finishing and Polishing System, Surface Roughness, Microhardness.*

Introduction

Resin composites have become one of the most extensively studied materials in the field of dentistry. Patients and clinicians prefer these materials due to their excellent esthetic properties, moderate cost, and ability to adhere to tooth structure. Smooth surface finish is a desirable feature for satisfactory and esthetic restorations, and with the development of resin composites, achieving this has become a goal [1].

In the restorative procedure, finishing and polishing are performed to obtain a smooth and shiny surface of the restoration, taking into consideration esthetics and the maintenance of healthy periodontal tissues. Finishing involves contouring, shaping, and smoothing to achieve an ideal anatomy, while polishing is done to remove roughness and scratches caused by the finishing devices [2-4]. Optimal finishing and polishing are crucial clinical steps in restorative dentistry that impact both esthetics and the longevity of restorations [2]. Improper finishing and polishing can lead to surface roughness, which is associated with gingival irritation, plaque accumulation, surface staining, and poor esthetics. These issues may, in turn, result in enamel demineralization, recurrent dental caries, and periodontal problems [1]. Even a minor change in surface roughness of 0.3 mm can be detected by the patient's tongue, potentially compromising the quality of the entire restorative work [5].

Microhardness is crucial for dental materials in resisting masticatory forces, increasing wear resistance, and providing greater longevity for restorations. When microhardness of the

composite decreases, the material becomes more susceptible to scratches, bacterial adhesion, discoloration, and restoration failure [6].
There is a wide variety of instruments and materials commercially available for finishing and polishing procedures in dentistry. These include abrasive systems with aluminum oxide, carbide compounds, diamond abrasives, silicon dioxide, zirconium oxide, and zirconium silicate, as well as polishing instruments such as coated abrasive discs and strips, stones, aluminum oxide or diamond pastes, soft or hard rubber cups or points, wheels, or brushes impregnated with abrasives [7,4]. These instruments and systems are available as one-, two-, three-, or four-step finishing and polishing systems. The effectiveness of a polishing system depends on the hardness of the cutting particles and materials, and the ability to produce a smooth surface depends on the system's capacity to cut the filler particles and organic matrix of the resin composites [8]. Several studies have been conducted to evaluate the effect of different finishing and polishing systems on different types of resin composites [8-11]. However, these studies have produced varied results, leaving no widely recommended finishing and polishing systems or instruments for specific types of composites [12]. Therefore, the aim of this in vitro study was to assess the influence of three different finishing and polishing procedures on the surface roughness and microhardness of four resin composite restorative materials.

Methods

A total of 160 disc-shaped specimens were prepared from four different brands of composite materials. These specimens were divided into four groups of 40 specimens each, with each group corresponding to a specific composite material.
In Group 1, the composite used was Microhybrid composite (Dynamic Plus). In Group 2, the composite used was Nanohybrid composite (Nexcomp). In Group 3, the composite used was Supernano composite (ESTELITE Σ QUICK). Lastly, in Group 4, the composite used was Nanoceram composite (ZENIT).
To prepare the composite specimens, the resin composite material was condensed into a metal mold with five circular holes, each measuring 10 mm in diameter and 2 mm in thickness. The specimens were then cured using a light curing unit from 3M ESPE, Germany. After curing, the specimens were finished with six strokes in the same direction using 600 grit Buehler sandpaper from Lake Bluff, USA. This was done to achieve a standard rough surface. The specimens were then rinsed with water and stored in distilled water at 37˚C for 24 hours in an incubator.
Three different finishing and polishing systems were utilized in this study, all of which were operated with the same slow-speed handpiece. To prevent heat build-up and the formation of grooves, the handpiece was constantly in motion with a repetitive stroking action. There was a conscious effort to standardize the stroke, downward force, and polishing time for all the instruments used. The specific finishing and polishing instruments were standardized across all systems with general accordance to the individual manufacturer's instructions.
For each type of resin composite, the 40 specimens were randomly divided into four groups (A, B, C, D), based on the type of finishing and polishing procedure applied, as follows:
Group A (n=10) involved the removal of the superficial layer of cured specimens, which is the resin-rich surface layer, using sandpaper (control group).
Group B (n=10) followed the procedure in sub-group A, but with the addition of diamond finishing burs. Each bur was used for only three times.
Group C (n=10) followed the procedure in sub-group A, then employed a two-step finishing and polishing system, specifically the Astropol® cups and discs from Ivoclar Vivadent, Amherst, NY, USA.
Group D (n=10) followed the procedure in sub-group A, and utilized a four-step finishing and polishing system called Sof-lex discs from 3M-ESPE, Dental Products, St. Paul, MN, USA. Aluminum oxide-impregnated discs were used.
After each finishing and polishing procedure, resin composite discs were washed to remove debris. Then, they were placed in individual vials containing 20 ml of distilled water and kept incubated at 37°C for 24 hours [11,4].
To measure the surface roughness of all the specimens in all sub-groups, a USB digital surface profile gauge (Elcometer 224/2, Elcometer Instruments, Great Britain) was used. The data were recorded using computer software (Elcomaster 2, Elcometer Instruments). For each surface, the mean roughness value was determined with an 8mm cut-off value and a stylus traversing distance of 5.0 mm. The radius of the tracing diamond tip was 2.5 μm, and a measuring force of 10 mN was applied. Three readings were taken at different locations on the specimen surface, and the mean surface roughness value was calculated from these readings. The roughness value (Ra) for each specimen was recorded as the average of these three readings. The profilometer was calibrated after every five specimen measurements to ensure reliable readings.

To measure microhardness, a Digital Display Vickers Micro-Hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) was used. The Vickers hardness testing machine applied a load of 100g to the surface of the specimens for 10 seconds. Three indentations were recorded from each specimen, evenly spaced over a circle with a minimum distance of 0.5 mm between adjacent indentations. The measurements were made on the surface of each specimen using a Vickers diamond indenter and a 20X objective lens. The microhardness value (HV) was obtained as the average of these readings. The length of the diagonals of the indentations was measured using a built-in scaled microscope, and Vickers values were converted into micro-hardness values.
The collected data for surface roughness and microhardness were computerized and statistically analyzed using SPSS version 25 software. ANOVA test was used to evaluate the effect of finishing and polishing procedures on the surface roughness and microhardness of the tested resin composites. Tukey's post hoc test was performed for multiple comparisons to determine significant differences. A p-value of ≤ 0.05 was considered to indicate a statistically significant difference between all tests.

Results

According to Table 1, the distribution of average roughness scores varies based on the type of composite used and the polishing techniques applied. It is evident that the control group, which used sandpaper, had higher roughness scores (0.26) compared to the other groups, regardless of the type of composite tested. Notably, all differences in roughness scores between different materials and polishing techniques were statistically significant (P=0.000). However, the type of composite did not have a significant impact on the choice of polishing technique (P=0.365). Although the average roughness in microhybrid and nanohybrid composites appeared to be higher and more consistent than in other composite types, this difference was not found to be statistically significant (P=0.124). Furthermore, there were no significant differences observed among the polishing techniques, but Astropol and soflex seemed to yield more homogenous and comparable results compared to the other techniques.

Table 1: Mean Values and Standard Deviations of Surface Roughness (Ra, μm) of Resin Composites and Polishing Techniques

Material	Group	Mean	Std. Deviation	N
Microhybrid	Fine diamond bur	0.253	0.003	10
	Astropol	0.254	0.002	10
	Soflex	0.254	0.003	10
	Control	0.257	0.004	10
	Total	0.254	0.003	40
Nanohybrid	Fine diamond bur	0.253	0.003	10
	Astropol	0.256	0.002	10
	Soflex	0.257	0.004	10
	Control	0.256	0.001	10
	Total	0.256	0.003	40
Supernano	Fine diamond bur	0.251	0.001	10
	Astropol	0.253	0.003	10
	Soflex	0.252	0.004	10
	Control	0.255	0.004	10
	Total	0.252	0.003	40
Nanoceram	Fine diamond bur	0.251	0.001	10

	Astropol	0.253	0.003	10
	Soflex	0.252	0.004	10
	Control	0.255	0.004	10
	Total	0.252	0.003	40
Total	Fine diamond bur	0.253	0.003	40
	Astropol	0.254	0.003	40
	Soflex	0.255	0.004	40
	Control	0.255	0.003	40
	Total	0.254	0.004	160

In Figure 1, the roughness resulting from different polishing techniques used with various types of composites is shown. When comparing the different types of polish, it can be observed that Astropol generally yielded higher roughness, except for the nano-hybrid composite. Conversely, Soflex demonstrated higher roughness when used with the nanohybrid composite compared to other types of polish. Additionally, when considering the overall results, Supernano and nanoceramic composites exhibited lower roughness when different polishing techniques were employed. It is worth noting that Astropol (two-step) consistently produced high surface roughness across all types of composites. Furthermore, Soflex, when used with the nanohybrid composite, resulted in higher surface roughness compared to other F&P systems.

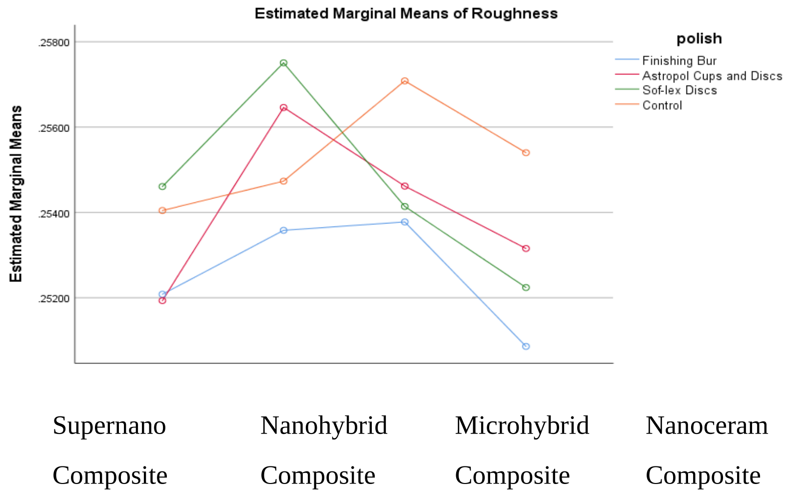

Figure 1: The homogenous distribution of groups by surface roughness.

Table 2 presents the distribution of average microhardness scores based on the type of composite and polishing techniques used. It is evident that Microhybrid composite exhibits the highest average microhardness value of 75.29±2.56, surpassing other composite types and the overall microhardness of the study samples (74.71±1.69). Comparing microhardness values across materials reveals substantial differences (p=0.009), particularly in relation to Microhybrid composite versus Nanohybrid and Supernano composites. Notably, the nanoceramic composite does not exhibit significant differences compared to other composites. In terms of polishing techniques, no statistically significant differences were observed (p=0.417). Bur and Soflex discs resulted in the lowest hardness when used with supernano and nanohybrid composites, respectively, in comparison to other composites and polishing techniques. Interestingly, Astropol demonstrated higher microhardness when employed with nanohybrid and nanoceramic composites (Figure 2).

Table 2: Mean Microhardness Values (VHN kg/mm2) of the Tested Resin Composite Materials and Polishing Techniques

Material	Group	Polishing	Std. Deviation	N
Microhybrid	Fine diamond bur	75.89	3.19	10
	Astropol	73.67	2.02	10
	soflex	76.61	2.74	10
	Control	74.98	1.26	10
	Total	75.29	2.56	40
Nanohybrid	Fine diamond bur	73.99	0.83	10
	Astropol	74.84	2.11	10
	soflex	73.60	0.68	10
	Control	74.24	0.75	10
	Total	74.16	1.33	40
Nanoceramic	Fine diamond bur	74.02	0.77	10
	Astropol	75.15	0.86	10
	soflex	74.61	1.38	10
	Control	74.86	1.56	10
	Total	74.66	1.22	40
Supernano	Fine diamond bur	73.40	0.43	10
	Astropol	74.55	1.14	10
	soflex	74.07	0.58	10
	Control	75.13	0.95	10
	Total	74.29	1.02	40
Total	Fine diamond bur	74.32	1.89	40
	Astropol	74.55	1.66	40
	soflex	74.72	1.93	40
	Control	74.86	1.17	40
	Total	74.71	1.69	160

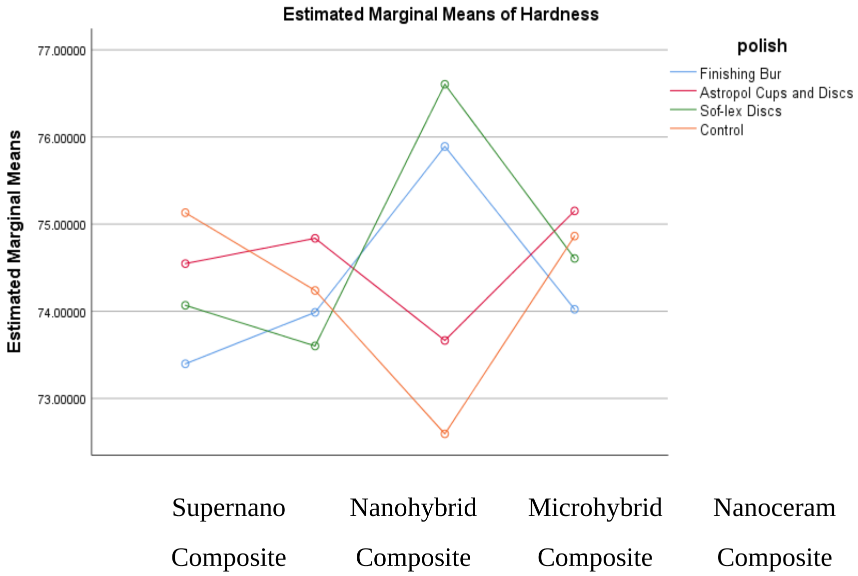

Figure 2: The homogenous distribution of group by microhardness.

Discussion

Achieving excellent finishing and polishing is crucial for enhancing the esthetics and lifespan of composite restorations. It has been established that surface finish plays a significant role in both aesthetics and dental function [13]. Improper finishing and polishing procedures can lead to inflammation in the periodontal tissues and reduce the clinical survival time [13]. In this study, four commonly used resin composites available in the local market were selected for examination, as they are preferred by most dentists. Additionally, three frequently used finishing and polishing systems in the local area were investigated.

The results of this study showed that microhybrid and nanohybrid composites exhibited a higher and more uniform surface roughness compared to other types of composites. These findings can be attributed to the chemical composition of these materials and the use of specific finishing and polishing systems. In this context, Guler et al., 2018 mentioned that the type of resin composite and the techniques employed for finishing and polishing can influence the smoothness of the surface [14].

Different polishing outcomes can be achieved using identical techniques depending on the type of resin composite due to the softness of the resin matrix and the hardness of the filler particles [4]. Factors such as particle size, polishing system type, and degree of polymerization also play a crucial role [15]. Wheeler et al., 2020 suggested that as the surrounding resin wears away, filler particles tend to deplete, leading to the conclusion that increasing the resin's hardness is preferable for achieving uniform polishing [13].

In general, the one-step finishing and polishing systems resulted in lower surface roughness compared to other types of systems. Specifically, our results indicated a surface roughness of 0.253 for microhybrid composite when finished and polished with a diamond bur, which aligns with the findings of Daud et al., who reported a mean surface roughness of between 0.26 µm and 2.82 µm for microhybrid composite finished with a bur [16].

Among the various types of resin composites examined in the study, the control group treated with sandpaper exhibited an increase in surface roughness values. This observation is likely due to the removal of the resin-rich layer during the restoration process before the finishing and polishing procedures take place.

The nanohybrid composite finished and polished with the Soflex system produced the highest mean surface roughness value of 0.2575 µm. This finding is consistent with the study conducted by Alfawaz in 2017, where it was found that the mean surface roughness value of nanocomposite, following the use of Soflex discs, was significantly higher compared to other finishing and polishing systems [10].

Regarding the supernano and nanoceram composites, they exhibited the lowest surface roughness among all the tested composites when finished with the fine diamond bur one-step finishing and polishing procedure. Our findings are in line with the study conducted by Atabek et al., which demonstrated that nanoceram composites produced the smoothest surface when utilizing a one-step finishing and polishing system. Both supernano and nanoceram composites exhibited lower roughness values compared to microhybrid and nanohybrid composites. consistent with their study [17]. These findings emphasize the significant

impact of different finishing and polishing techniques on the surface roughness and microhardness of resin composites.
The use of Soflex discs with aluminum oxide as the abrasive on a rigid matrix generally results in a slightly smoother surface. The discs are designed to flatten the filler particles and abrade the softer resin matrix at the same rate, as mentioned by Kumari et al. [4]. However, our results showed that the two-step and four-step systems evaluated in this study behaved similarly. Interestingly, the nanohybrid composite polished with the Soflex four-step system exhibited a higher surface roughness. This could be attributed to the larger and irregular filler size, causing the nanomer and nanocluster to detach along with the softer matrix during polishing, which in turn increases roughness [18]. Similar findings were reported previsouly [19].
In addition, it was found that Soflex yielded lower roughness values compared to the Astropol polishing systems when used with microhybrid and nanoceram composites. This could be due to the coarser abrasive particles present in the Astropol systems as suggested by Hassan et al. 2015 [20]. The effectiveness of a polishing system depends on the hardness of the cutting particles and the materials being polished [4,21]. However, our results contradict the findings of Antonson et al. [22], who reported that Sof-Lex achieved the lowest roughness value among the other finishing and polishing systems in their study. On the other hand, Mitra et al., supported the idea of homogeneous abrasion with the use of Sof-Lex aluminum oxide discs [23].
In line with the present study, Buchgraber et al. [24] found that the Soflex fine and superfine discs produced smoother surfaces compared to the other finishing and polishing systems. They also noted a significant difference in roughness between Nanofill and other types of composites, with Nanofill composite yielding the smoothest surface. These findings align with our results where Soflex produced smoother surfaces than the Astropol polishing systems with certain types of composites. However, the type of composite did not have a significant effect on the polishing technique (P=0.365). This could be attributed to the compositional nature of Soflex discs and the Astropol systems. Abzal et al., suggested that the aluminum oxide particles present in Sof-Lex discs resulted in a superior finishing surface with less roughness compared to the diamond abrasive particles in Astropol systems, despite the latter providing a good surface finish [25].
The differences in surface roughness observed after finishing and polishing between the various systems could be attributed to the different shapes and arrangements of the particle sizes within the resin matrix. Previous studies have reported that the shape of aluminum oxide disks, such as those used in Soflex, can make them challenging to use efficiently, particularly in the posterior region of the mouth [25,26].
Our research findings indicate that the Soflex finishing and polishing system resulted in a smoother surface compared to Astropol and the control group. This aligns with the Kumari et al. study [4]. However, the results of our study suggest that both Astropol (2-step system) and Soflex (4-step system) are homogeneous and more comparable within each type of composite.
Furthermore, our results demonstrate that for most resin composites examined in this study, the four-step Soflex polishing disc yielded significantly lower surface roughness, followed by Astropol. This finding is consistent with the study by Dhananjaya et al., who also reported that Soflex polishing systems produced lower roughness compared to the Astropol polishing system [27]. These discrepancies in results can be attributed to differences in hardness, type of abrasive, and the instruments' geometry used in the finishing and polishing systems [29].
Microhardness, defined as a material's resistance to indentation [11], was measured in our study. The mean VHN values obtained immediately after finishing and polishing with sandpaper ranged from 74.24 to 75.13. This relatively high range may be attributed to the fact that abrasive sandpaper was used to simulate clinical conditions, where it is responsible for removing the surface-rich layer in the organic matrix.
In the current research, the microhybrid composite finished with Soflex discs exhibited the highest microhardness value, followed by the diamond bur, the control group, and the lowest microhardness value was observed with Astropol F&P system. The increase in microhybrid composite hardness can be attributed to the reduction in surface roughness. It can be expected that there is a relationship between surface roughness and microhardness, as lower surface roughness typically indicates higher hardness. Additionally, our results show that the nanohybrid composite had higher surface roughness when finished with Soflex polishing systems, resulting in lower microhardness values.
Furthermore, we found that the nanoceramic composite exhibited higher microhardness values, particularly when finished with Astropol F&P systems, compared to other finishing and polishing systems. Conversely, the Supernano composite demonstrated the lowest microhardness values when finished with the diamond bur. These values align with the lower

surface roughness observed for these two composites and the respective finishing and polishing systems.
The obtained results may be attributed to various factors affecting microhardness, including composite properties like the type of organic matrix, size and distribution of loading particles, as well as factors related to abrasive systems such as the flexibility of the material used for abrasive impregnation, abrasive hardness, size and shape, and the speed and manner of instrument application [4].
The different microhardness values observed for these composites can be attributed to variations in their filler-to-resin ratio and the hydrolytic breakdown of the silane/filler particle bond. It has been documented that filler particles may dislodge from the material's outer surface, leading to surface roughness and a decrease in hardness. Furthermore, the microhardness value depends on the degree of conversion and the type of filler [29]. It is important to interpret the obtained variance values with caution, as the use of restorative materials and polishing systems in clinical practice may be restricted by the accessibility and flatness of the surface to be finished. Additionally, most of the latest polishing systems are disk-shaped.

Conclusion

Based on the limitations of this in vitro study, the following conclusions were drawn. The surface roughness and microhardness of the tested resin composites were greatly influenced by the finishing and polishing procedure. Among the tested composites, nanoceramic and supernano composites exhibited the lowest surface roughness, while the nanohybrid composite had the highest surface roughness when finished with the Soflex F&P system. The microhybrid composite had the highest microhardness. The smoothest surface finish was achieved when using a fine diamond bur, particularly with the supernano and nanoceramic composites. One-step procedures showed the best results.

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