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Original Article

Effect of different polishing systems and speeds on the surface roughness of resin composites

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Abstract

Aims and Objectives: The objective of this study was to compare surface roughness of a nano-spherical resin composite using four different multi-step polishing disc systems at five different speeds.

Materials and Methods: In total, 154 discs samples were prepared using a supra-nano spherical resin composite. The samples were divided into negative and positive control groups and the following four finishing and polishing disc systems: Sof-Lex, Bisco Finishing Discs, OptiDisc, and Super-Snap. Each polishing disc system was applied at five different speeds (2000, 5000, 10,000, 15,000, and 20,000 revolutions per minute [RPM]) (n = 7). The surface roughness of samples was measured using a profilometer. One sample from each group was evaluated by scanning electron microscopy and atomic force microscopy. Two-way analysis of variance was used to evaluate the average roughness (Ra) data from the profilometric experiments using statistical software (GraphPad Prism4-GraphPad Software; La Jolla, CA, USA). The mean values were compared using the Bonferroni test (P = 0.05).

Results: The mean roughness ranged from 0.07 μm to 0.41 μm. The smoothest surfaces were obtained with OptiDisc at 20,000 RPM and Super-Snap at 20,000 RPM. The Bisco Finishing Discs group at 2,000 RPM showed the highest surface roughness values. For all polishing systems, the roughness at 20,000 RPM was lower than that at other speeds.

Conclusion: Within the limitations of the present in vitro study, it can be concluded that the polishing performance was in the following order: Super-Snap > OptiDisc > Sof-Lex > Bisco Finishing Discs. In addition, the surface roughness decreased as the polishing speed increased.

Keywords: Multi-step polishing; profilometer; resin composite; speed; surface roughness

INTRODUCTION

Today, with the increasing interest of people in aesthetics, resin composite restorations that can mimic natural tooth appearance have become frequently preferred by dentists. While choosing the properties of the restorative material for the restorative treatment to be selected, the patient's esthetic expectation, location of the tooth in the mouth, tooth condition and color, and localization of the lesion in the tooth are factors that should be taken into consideration.[1]

Resin composites are the most preferential materials in all posterior and anterior cavity classifications in dentistry applications, which give very good results in terms of both aesthetics and function. With the developing technology and studies, the physical and mechanical properties of these materials are being improved day-by-day and the studies on this subject continue.

The factors affecting the clinical life of the composite are dependent on the characteristics of the material and

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can include the monomer type, length, organic phase of the composite, filler ratio of the inorganic phase, type, shape, filler size, and polymerization procedure, as well as the factors related to the clinical application that affect the clinical life of the restoration, such as incremental placement, polymerization techniques, surface finishing, and polishing.[2]

Duly-made surface corrections and polishing play an essential role in increasing the clinical performance of the composite material by reducing the accumulation of bacterial plaque, gingival problems, and risk of caries by creating a slippery surface.[3,4] A well-polished restoration enhances oral function because food glides more easily over the occlusal and embrasure surfaces during mastication and minimizes wear. A literature review proposed a surface-roughness threshold of 0.2 μm for bacterial plaque retention.[5] Surface roughness can also affect patient comfort because the tongue can discern irregularities above a threshold of 0.3 μm.[6]

Dentists place the composite in the cavity to obtain a glossy surface. They start with gross finishing, contouring, and fine finishing. To determine the surface roughness of dental materials and the efficiency of various finishing and polishing systems, optical and scanning electron microscopy (SEM) are often used.[7-9] Profilometers are also used for analyzing quantitative data of the surface along with confocal microscopy and interferometry using atomic force microscopy (AFM).[10-13]

In addition, literature is limited on the efficiency of different polishing speeds on surface roughness. Clinicians want to use the technique they are most familiar with, as they understand its effectiveness; therefore, it is important to demonstrate which polishing system should be used and at what speed for current composites.

The purpose of this study was to compare the surface roughness of nano-spherical resin composites obtained using four different multi-step polishing disc systems at five different speeds on a nanospherical resin composite using a profilometer. Random samples were also selected from each group, and the surface texture was evaluated using AFM and SEM Our primary null hypothesis was that there is no difference in surface roughness between the different polishing disc systems tested at the same speed. According to the hypothesis of this study, it has been claimed that increasing the polishing speed has an effect on the increase of surface roughness.

MATERIALS AND METHODS

The resin composite and polishing systems used in this study are summarized in Table 1.

Preparation of samples

In total, 154 disc samples were prepared with a supra-nano spherical resin composite (Estelite Sigma Quick, Tokuyama Dental, Japan).

The cylindrical blocks were obtained through two vertical composite 2-mm increments using cylindrical metal molds (10-mm diameter × 2-mm depth). Mylar strips (Hawe Transparent Strip, Kerr Hawe, Switzerland) were placed on the top of the uncured resin composites. The mold was condensed between glass plates to extrude the excess material. The samples were light-cured on the top surface with a light emitting diodes light unit (SmartLite Focus, Dentsply Sirona, USA) for 40 s and removed from the molds.

After being cured under Mylar strips, the samples ($n = 7$) were left untreated and were used as positive controls. To ensure uniform initial roughness, the resin composite surface was roughened using 600-grit silicon carbide (SiC) sandpaper for 15 s at 250 revolutions per minute (RPM) in an automatic polisher.

Then, all samples were immersed in distilled water at 37°C and stored in an incubator for 24 h. The samples ($n = 7$) were not polished and were used as negative controls.

The remaining samples were divided into four groups for the four different polishing systems. The samples in each group were polished with Sof-Lex Contouring and Polishing Discs (3M Espe, St. Paul, MN, USA), Bisco Finishing Discs (Bisco Dental, USA), OptiDisc (Kerr Corporation, USA), or the Super-Snap Rainbow Technique Kit (Shofu Dental, Japan).

Each group was further divided into five subgroups for the polishing process at five different speeds. For the four test groups, the samples were polished at five different speeds (2,000, 5,000, 10,000, 15,000, and 20,000 RPM) ($n = 7$), with coarse, medium, fine, and superfine aluminum oxide discs using linear movements provided by a handpiece (KaVo Dental, Bismarckring, Germany). After each polishing step, the sample was rinsed with water spray for 15 s and air-dried to produce a smooth uniform surface. Each disc was used only once, and the polishing time was 15 s for each disc for all the samples. To avoid operator variability, all finishing and polishing procedures were performed by the same operator.

Profilometric examinations

Quantitative profile analysis and surface roughness of the samples were evaluated using a contact mode profilometer (Surftest SJ-301 Mitutoyo, Japan). For each sample, three measurements from different locations were obtained with a cutoff length of 0.25 mm, a tracing length of 0.8 mm, and a stylus speed of 0.25 mm/s. The average roughness values were derived from three readings.

Scanning electron microscopy observations

The qualitative surface micromorphology of the samples was imaged using SEM (Hitachi Regulus 8230 FE-SEM, Japan). SEM images were captured at ×500, ×1000, ×2500, and ×5000 magnification.

Atomic force microscopy observations

In addition, images were taken from one sample from each group using an atomic force microscope operated in noncontact mode (Park Systems XE 100 Atomic Force Microscope, Korea) (10000 μ at 4000 speed [10 × 10]).

Statistical analysis

Two-way analysis of variance was used to evaluate the average roughness (Ra) data from the profilometric experiments using statistical software (GraphPad Prism4-GraphPad Software; La Jolla, CA, USA). The mean values were compared using the Bonferroni test ($P = 0.05$ was considered statistically significant).

RESULTS

Table 2 shows the mean and standard deviation of different polishing disc systems and speed combinations. Statistically significant differences ($P < 0.0001$) were found between the different polishing systems and speeds using analyses of variance. The interaction between the polishing system and speed was extremely significant ($P < 0.0001$). The 20,000 RPM polishing groups for both OptiDisc and Super-Snap reported the least mean values of 0.07 ± 0.01 and 0.07 ± 0.02, respectively. However, no significant differences were found between OptiDisc 20,000 RPM, OptiDisc 15,000 RPM, Super-Snap 20,000 RPM, Super-Snap 15,000 RPM, Super-Snap 10,000 RPM, and Sof-Lex 20,000 RPM groups ($P > 0.05$). For all polishing systems, 20,000 RPM provided lower roughness than other speeds. The Bisco Finishing Discs group at 2,000 RPM showed the highest surface roughness values of 0.41 ± 0.04 ($P < 0.05$). On comparing all test groups, the mean Ra was found to be in the following order: Bisco Finishing Discs > Sof-Lex > OptiDisc > Super-Snap [Figure 1].

SEM and AFM were conducted on samples in different groups [Figure 2] to ascertain whether a correlation could be established with profilometric examinations and surface visualization at higher magnifications. The AFM images of the polished samples

Table 1: Materials used in the study

Material	Material type	Material properties	Ingredients	Manufacturer's instructions	Company
Estelite sigma quick	Nano-spheric resin composite		82% by weight (71% by volume) of silica-zirconia filler and composite filler, BIS-GMA, TEGDMA	Curing time of 20 s using a light curing unit with a wavelength range of 400-500 nm	Tokuyama Dental, Japan
Sof-Lex contouring and polishing discs	Polishing disc	Gross reduction (50-90 μm, coarse) Contour (10-40 μm, medium) Finish (3-9 μm, fine) Polish (1-7 μm, superfine)	Aluminum oxide-coated discs Urethane-coated paper	Use a light touch and slow-speed hand piece Rinse and dry surface between discs sequence Course and medium discs: 10,000 RPM Fine and superfine discs: 30,000 RPM Polishing time: 15-20 s	3M ESPE, St. Paul, MN, USA
Bisco finishing disc	Polishing disc	Contour (coarse) Finish (medium) Polish (fine) Super polish (ultrafine)	Aluminum oxide-coated discs	No recommended RPM or polishing time	Bisco Inc., Schaumburg IL, USA
OptiDisc finishing and polishing discs	Polishing disc	Contour (80 μm, coarse) Finish (40 μm, medium) Polish (20 μm, fine) High-gloss polish (10 μm, superfine)	Polyethylene Synthetic polymers Aluminum oxide	10,000 RPM for all discs Polishing time is left to the clinician	Kerr Corporation, USA
Super-Snap rainbow technique kit	Polishing disc (manufactured without a metal center)	Contour (coarse) Finish (medium) Polish (fine) Super polish (superfine)	Disposable silicon carbide, aluminum oxide grit	Recommended RPM: 10,000-12,000 (max, 15,000) with no water spray Polishing time: 15 s	Shofu Inc., Kyoto, Japan

RPM: Revolutions per minute

Table 2: Means and standard deviation of surface roughness (μm)

	Sof-Lex	Bisco finishing discs	OptiDisc	Super-Snap	Mylar	600 grid
2K	$0.27\pm0.02^{f,g}$	0.41 ± 0.04^{i}	$0.19\pm0.02^{d,e,f}$	$0.23\pm0.02^{e,f}$		
5K	$0.25\pm0.05^{f,g}$	$0.29\pm0.03^{g,h}$	$0.18\pm0.03^{d,e}$	$0.14\pm0.02^{b,c,d}$		
10K	0.24 ± 0.01^{f}	$0.26\pm0.02^{f,g}$	$0.16\pm0.01^{c,d,e}$	0.08 ± 0.01^{a}		
15K	0.17 ± 0.04^{d}	$0.17\pm0.02^{d,e}$	$0.1\pm0.01^{a,b}$	0.09 ± 0.01^{a}		
20K	$0.11\pm0.01^{a,b,c}$	$0.14\pm0.02^{b,c,d}$	0.07 ± 0.01^{a}	0.07 ± 0.02^{a}		
Control					$0.12\pm0.0^{b,c}$	0.33 ± 0.03^{h}

Different superscript letters in a row indicate statistical significance

at 20,000 RPM and of those in the control groups corroborated the findings of the profilometric analysis. Although minor surface irregularities and scratches could be detected in some areas under SEM evaluation, polishing discs produced mostly uniform surfaces at 20,000 RPM.

DISCUSSION

Finishing and polishing operations on the restoration surface aim to smooth the surface with abrasives that start with a coarse grain and continue with a finer grain. The process is related to the hardness of the abrasive material and the surface. Many studies have found that a multi-step polishing system achieves satisfactory surface roughness.[14,15] When using these systems, manufacturers recommend different polishing speeds. Clinically, it is easiest to control the speed of rotary instruments during finishing and polishing. However, no studies have previously compared multi-step systems at different speeds, as evaluated in this study.

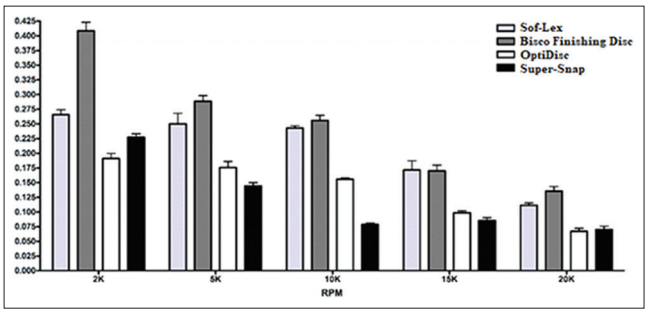


Figure 1: Comparison of average roughness (Ra) among polishing disc systems with different speeds

In this study, a combination of three techniques surface profile analysis profilometers, SEM, and AFM was chosen. Based on the results, the first hypothesis, which postulated no difference in surface roughness between the different polishing systems tested at the same speed, was rejected. The second hypothesis was accepted because polishing speed had a significant impact on surface roughness. For all groups, surface roughness decreased as polishing speed increased.

Mylar strips induced smooth restoration surfaces.[16,17] Likewise, resin composites polymerized in contact with mylar strips had a resin-rich surface layer; hence, finishing and polishing are required.[18] In our study, many groups were smoother than the mylar strip group, probably owing to the rugosity of the strips.

This study standardized as many variables as possible. A single brand of composite restorative material was used in the study to minimize the effect of the type of

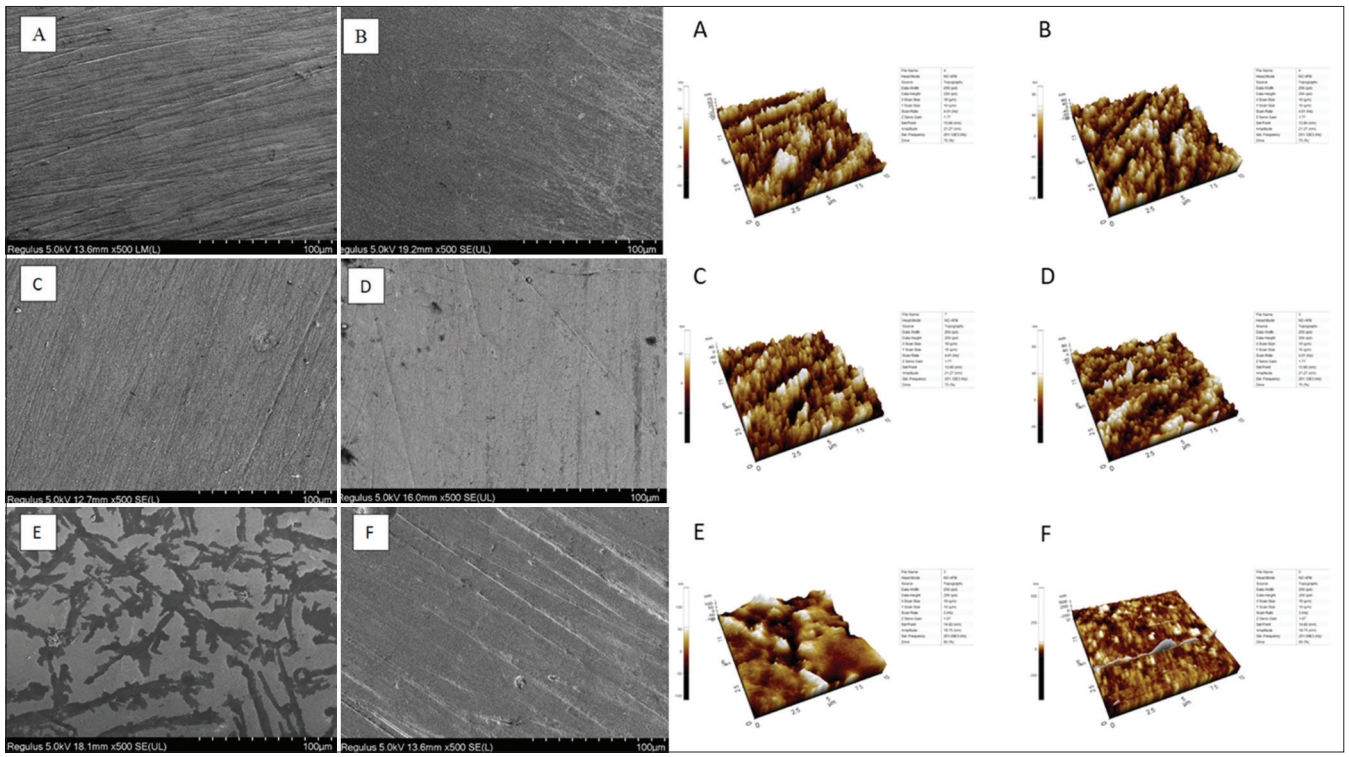


Figure 2: SEM (left) and AFM (right) images of the resin composite after polishing with, (A) Sof-Lex; (B) Bisco Finishing Discs; (C) OptiDisc; (D) Super-Snap the surface has few pitting or scratches, and it is almost smooth; (E) Mylar; (F) 600 Grit SiC paper (×500), SEM: Scanning electron microscopy, AFM: Atomic force microscopy

restorative material and reveal potential differences in the polishing systems. An Estelite Sigma Quick resin composite was used in this study. The standard form of the 200-nm fillers (supra-nano) produced by the sol-gel method and spherical filler technology creates perfect polishability by changing the refractive index.[19] As Turssi and Ferracane[20] reported, the inclusion of smaller filler particles makes composites more polishable to achieve lower roughness values.[20] A previous study reported that the surface roughness value for Estelite Sigma Quick (A2 shade) polished with 3000-grit SiC paper was 0.32 μm. In our study, the Ra value on polishing with 600-grit SiC paper was 0.33 μm. These values are close to 0.2 μm, which has been established as the threshold for bacterial adhesion.[5] Furthermore, in the present study, samples in the different groups had Ra values between 0.07 μm and 0.41 μm. For most samples, this value was below or near the clinically acceptable threshold of 0.2 μm.

In this study, the pressure applied during the polishing was controlled in a conscious effort to standardize this pressure with a controlled force and an intermittent, gentle contact rhythm. In addition to the intermittent polishing method, the disk array was rinsed and dried for 15 s to avoid overheating.[21] One study showed that the temperature increase in dry-interval polishing with bis-finishing discs at 15,000 RPM for 120 s was <42°C,[22] which could cause irreversible damage to the pulp as reported by Zach and Cohen.[21] Although the effects of previous finishing instruments on the surface roughness of resin composites have been well studied, the results are controversial. According to the results of our study, compared to Sof-Lex, the Super-Snap polishing kit applied to the surface of composite samples produced decreased surface roughness. These results are consistent with the results of similar studies investigating the efficacy of the Super-Snap polishing kit and Sof-Lex on different composite surfaces.[17,18] However, some studies have shown that smoother surfaces were obtained with Sof-Lex than with Super-Snap.[7,8]

The differences in the efficiency of the polishing systems are caused by the hardness, size, and arrangement of the abrasive particles. When the abrasive particles are harder than the fillers in resin composites, the polishing system is effective. Otherwise, the polishing instrument removes the matrix, but the filler particles protrude from the surface.[23] In this study, the used multi-step finishing disc systems have different compositions (i.e. Super-Snap has a SiC abrasive, while others have aluminum oxide). The hardness of aluminum-oxide abrasive particles (2100 KHN) is lower than that of SiC particles (2500 KHN).[24] In addition, the filler particles in Estelite Sigma Quick are composed of zirconia and silica with a hardness of approximately 1600 KHN and 820 KHN, respectively.[25] Therefore, polishing systems seem to be suitable for restorative materials. However, the Bisco Finishing Disc system produced the roughest surfaces at all speeds. The average sizes of the abrasive particles of the other three systems were similar, but there was no information available on the size of the abrasive particles used in the Bisco Finishing Disc system. It is likely that differences in the abrasive size or pattern caused these results.

This study determined the effects of polishing systems and speeds on the removal of surface roughness. To the best of our knowledge, no previous study has been conducted with a similar methodology to study the effects of finishing and polishing systems at different speeds to corroborate or contradict the results obtained in the present study.

Polishing finishes with the gradual erasing of the existing skin, and superficial lines on the surface become invisible. However, the clinician's inability to adequately control may cause an excessive increase in temperature and excessive abrasion of the surface. In contrast, fast and effective polishing can be performed with the use of high-speed rotating abrasives.

Possible deviation can be attributed to factors related to operator variabilities such as pressure applied to the resin composite, development of dexterity, and experience of the operator.

CONCLUSION

Within the limitations of the present *in vitro* study, it can be concluded that the polishing performance of the four test systems was in the following order: Super-Snap > OptiDisc > Sof-Lex > Bisco Finishing Discs. In addition, the surface roughness decreases as the polishing speed increases. For a smooth composite surface, the polishing discs used by clinicians should be flexible, the abrasives used should be harder than the fillers of the composite, and limited pressure should be applied to the polishing disc when in contact with the surface.

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Conflicts of interest
There are no conflicts of interest.

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