EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 4039:4051, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 17-08-2022 • Accept Date : 19-09-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.156850.2220

THE EFFECT OF DIFFERENT POLISHING METHODS ON THE SURFACE ROUGHNESS OF RESIN COMPOSITES (AN IN-VITRO STUDY)

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ABSTRACT

Objective: To evaluate the effect of one-step, two-step, and multi-step polishing systems on the surface roughness of nanofilled and suprananofilled resin composite materials.

Materials and Methods: A total of 56 resin composite discs were prepared (divided into 2 main groups of 28 discs each, as nanofilled and suprananofilled resin composite groups, using split Teflon mold and cured against Mylar celluloid strip. Except for control group, samples were ground with wet 600-grit silicon carbide paper, and then subdivided into 3 groups (n = 7) in each main group, as multi-step, two-step, and one-step polishing systems. Each polishing protocol was done according to manufacturer's instructions using a kitchen scale to maintain pressure of each stroke approximately 30-40 gm. Scanning electron microscope was used to scan all samples, and the images were subjected to Gwyddion 2.56, (An SPM data visualization and analysis tool supported by the Czech Metrology Institute, 2020) to attain surface roughness average data, which were statistically analysed by two-way ANOVA followed by Tukey's post hoc test.

Results: The suprananofill groups as well as the one-step polisher groups had the least statistically significant surface roughness average values ($p<0.001$). Whereas the multi-step polisher groups had the highest statistically significant surface roughness average values followed by the two-step polisher, then the control groups ($p<0.001$).

Conclusion: The one-step polishing system produces the smoothest surface, even smoother than setting against matrices, whereas polishing pastes produces the roughest surface. The suprananofill resin composite can obtain a smoother surface than the nanofill resin composite.

KEYWORDS: Polishing, Surface roughness, nanofilled composite, Suprananofill composite, Omnichroma.

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INTRODUCTION

Critical features of dental resin composites which serve as esthetic restorations, are to be polishable to smooth, glossy surface, one mimicking that of dental enamel. Various factors contribute to the acquisition of a high-quality surface during finishing and polishing and to maintain that surface quality over time.[1] The most significant changes in resin composites have been made by far through improvements within the filler system, including variations in filler size, morphology, volume, distribution, or chemical composition. Since the dispersed fillers establish distinct differences in the material mechanical and optical properties, they provided a basis of valid resin composites classifications.[2] The evolution of commercially available dental composites has been characterized by a determined effort by manufacturers to reduce filler size in order to produce a final product capable of achieving outstanding surface properties.[3]

A smooth surface depends not only on composite type but also on finishing and polishing systems used in removing excess material and restoring morphology to achieve optimum function.[4] The search for ideal finishing and polishing system for resin composites has resulted in significant improvements in both the material aspect and the used techniques. Several systems have been invented and available in the market which have variant protocols and incorporate different materials. Some of them have been introduced as multi-step, two-step or one-step finishing and polishing systems with the goal of achieving smooth surface with fewer steps and reduced application time. In fact, it has been found that the effectiveness of the available finishing/polishing systems noticeably influenced not only by the abrasive particles and instrument geometry, but also on wet/dry conditions, the applied pressure/speed and the time spent with each abrasive.[5] In addition, the finishing and polishing outcome are also affected whether the procedure is done immediate/delayed, the direction and type of motion of the finishing and polishing, as well as the finishing/polishing steps or combined systems.[6,7]

A smooth surface has been always a prime target of resin composite restorations as it affects not only their aesthetic appearance but also other properties. Roughness value between 0.25- 0.5 μm could be easily detected by the tip of the tongue causing unpleasant tactile perception by the patient. This range is encompassment of natural enamel's one, which was reported by Willems et al with average surface roughness score of 0.64 ± 0.25 μm for healthy enamel surface.[8] A rough surface may lead to plaque accumulation, discoloration, secondary caries, abrasive wear kinetics and higher risk of fracture.[6] According to many studies, surface roughness of 0.2 μm promotes adherence of bacteria and surface roughness of 0.7 μm results in plaque accumulation.[9,10] However, authors lack standardization in what concerns the recommended minimum surface roughness threshold values. A recent systematic review on this issue highlights that instead of a threshold, a range of surface roughness exists, in which polishing is considered adequate for biological and physical factors, and it is material dependant.[11]

Presence of so many varieties and continuous innovations in both the resin composite material and the finishing/polishing systems are very challenging to the operator in selection of the best system that gives superior polishability and surface smoothness. Currently, many attempts have been made to determine which abrasion system provides the most polished surface for resin composites, and several methods have been introduced without reaching a consensus that verifies which is the best. Moreover, the abrasive wear of contemporary resin composites is material dependent, and cannot be deducted from its category.[12] Accordingly, the objective of this study was to evaluate the in vitro surface roughness of differently filled resin composite categories subjected to different polishing protocols.

This study was conducted to evaluate the effect of one-step, two-step, and multi-step polishing systems on the surface roughness of nanofilled and suprananofilled resin composite materials. The null hypothesis tested was, neither the polishing system, nor the type of resin composite had significant effect on the surface roughness average of resin composite.

MATERIALS AND METHODS

Study design:

A total of 56 resin composite discs were prepared (divided into 2 main groups of 28 discs each according to the tested composite material). Each group was randomly sub-divided into 4 groups of 7 each, a control group which received no surface treatment and 3 experimental groups manually ground with wet 600-grit silicon carbide paper as a pre-roughening step for the employed polishing system. Details about the resin composite materials being used are mentioned in Table 1.

Specimen preparation:

Each composite disc was prepared using split Teflon mold with a cylindrical cavity of (10 mm) diameter and (2 mm) depth. A microscope glass slide 1-2 mm thick was placed under the mold. A straight, transparent Mylar strip was interposed between the microscope glass slide and the mold. The composite material was inserted in a single increment into the mold using a smooth, round ended condenser with slight overfilling. Care was taken to avoid any air inclusions or folds in the composite. A Mylar strip was placed over the resin composite surface and another glass slide was gently pressed over the strip to flatten the surfaces and remove any excess. With the curing tip touching and being perpendicular to the glass slide, the composite was polymerized using SDI Radii Plus LED Curing Light device with the intensity of 1400 mW / cm^2 for 60 s through Mylar strip and glass slide. Additional polymerization was done on both sides of the specimen for 20 s each after removing the strip and glasses. The output intensity was measured every 5 specimens using a

Table (1) Composition of the resin composite used

Material		**Filtek™ Z350 XT Universal Restorative**	**Palfique Omnichroma**
Filler		Non-agglomerated/non-aggregated 20 μm silica filler Non-agglomerated/non-aggregated 4 -11 μm zirconia filler Aggregated zirconia/silica cluster filler (comprised of 20 μm silica and 4 to 11 μm zirconia particles). The Enamel shades average cluster particle size of 0.6 -10 μm	Uniformly sized suprananospherical filler of SiO2 and ZrO2 plus a round-shaped composite filler all with a particle size of 260 μm
Filler Content	**wt%**	78.5	79.0
	vol%	63.3	68.0
Monomer		bis-GMA, UDMA, TEGDMA, bis-EMA(6) resins, and PEGDMA[1]	UDMA and TEGDMA
Shade		A2 Enamel shade	-
Manufacturer		3M ESPE Dental Products, St. Paul, MN, USA	Tokuyama Dental, Tokyo, Japan

[1]Bis-GMA: Bisphenol A diglycidimethacrylate: UDMA: Urethane dimethacrylate; EMA: ethylmethacrylate; TEGDMA: triethylene glycol dimethacrylates; PEGDMA: polyethylene glycol dimethacrylate

radiometer to ensure that the value is ≥ 1400 mW/cm^2. The mold was disassembled, and each sample was checked to exclude any visible voids after removal from the mold and the bottom of the disc was labeled. The flash excess on the margins of the polymerized discs were trimmed carefully without any adjustment to the Mylar-formed surface. The specimens were handled using dressing tweezers applied to the sides of the specimen to protect the surface from any damage or contamination and molded into acrylic molds with the experimental surface facing upward.

Finishing and polishing procedures

The surface of the composite disc cured against the mylar strip (except for the control groups) was used as the experimental surface. Then, it was manually ground for 30 seconds with wet 600-grit silicon carbide paper under slight pressure and in varying directions then rinsed and air-dried to standardize the beginning point in all specimens representing the finishing step prior to polishing procedure. Details about the polishing systems being used are mentioned in Table 2.

In order to reduce variations, the same operator carried on all the polishing procedures with the same slow-speed handpiece (NSK FX25 1:1 Dental Low Speed Handpiece, Japan) at a very slow rotational speed of 3000 rpm using a kitchen scale as a pressure guide maintaining feather light intermittent pressure 30-40 gm (approximately 0.3 newton) representing the polishing protocol. Every stroke was applied in the same direction in a planar motion. Each polishing instrument was used only once and discarded following each use. The polishing procedures were performed as follows:

Group 1: Multi-step Enamel Plus Shiny polishing pastes (Micerium, Italy): The three polishing pastes used with a sequence of progressively finer polishing paste. Shiny A 3μm diamond paste was applied with a goat hair brush Shiny S each for 20 seconds. Then, Shiny B 1μm was applied with a different goat hair brush for 20 seconds, and finally, Shiny C aluminum-oxide paste was used with the disc felt Shiny FD for 20 seconds as a final polishing step. All were used under dry condition with thorough rinsing with air-water spray for ten seconds and air drying for five seconds after each step as recommended by the manufacturer.

Group 2: Two-step Super-Snap X-treme discs (Shofu INC, Japan): fine (green) and superfine (red) used sequentially each for 20 seconds under dry condition. After each step, all specimens were thoroughly rinsed with air-water spray for ten seconds and air dried for five seconds as recommended by the manufacturer.

Table (2) Composition and list of the polishing systems used

Polishing system	**OneGlos^s®**	**Super-Snap X-treme**	**Enamel Plus Shiny**
No of application steps	One-step	Two-step	Multi-step
Matrix	Synthetic rubber (Polyvinylsiloxiane)	Base film (polyesther) Mounting core (PVC)	Polyethyleneglykol
Abrasives	Aluminum oxide Al2O3 and Slicone oxide SiO2 grains	Aluminum oxide	Shiny A: diamond powder Shiny B: diamond powder Shiny C: Aluminium oxide powder
Particle size	mean alumina particle size 85 μm	SS Green 20 μm SS Red 7 μm	Shiny A: 3 μm Shiny B: 1 μm Shiny C: N/A
Manufacturer	Shofu INC, Japan	Shofu INC, Japan	Micerium, Italy

Group 3: One-step OneGloss® (Shofu INC, Japan): PS Silicone Polisher IC Inverted Cones Points were used in a light feather pressure (representing the polishing mode only) for 20 s with intermittent water spray as recommended by the manufacturer.

All specimens were thoroughly rinsed with air-water spray for 10 seconds then stored in 100% humidity container at 37° C for 24 hours before being scanned with scanning electron microscope (SEM) to evaluate average surface roughness *(Ra)*.

Sample scanning & surface roughness measurements

After polishing the resin composite samples according to their assigned groups, the samples were scanned using scanning electron microscope at 4000x magnifications using backscattered electron detector (BSED). After which the scan of each sample was analyzed using Gwyddion 2.56, (An SPM data visualization and analysis tool supported by the Czech Metrology Institute, 2020) in order to gain the average surface roughness *Ra* of each sample.

For image analysis, the scanned picture was imported using the Gwydion Software then "calculate roughness parameters" option was selected to start retrieving the surface roughness average *(Ra)* data.

Measuring average surface roughness was done at four consistent levels, 2 horizontal planes and 2 vertical planes perpendicular on others and dividing the scan into thirds, to ensure that the whole scan surface is equally represented in the resulting value. Then, the Surface Roughness Average *(Ra)* values collected from each sample were inserted into an Excel sheet for mean value calculations. The quantitative data was collected and used to perform the statistical analysis and results for each group.

Statistical analysis:

Numerical data were explored for normality by checking the data distribution using Shapiro-Wilk test. Data showed parametric distribution so; they were represented by mean and standard deviation (SD) values. Two-way ANOVA followed by Tukey's post hoc test was used to study the effect of different tested variables and their interaction. Comparison of main and simple effects were done utilizing pooled error term of the ANOVA model with benferroni correction. The significance level was set at p ≤0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.2 for Windows (R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/).

RESULTS

Effect of resin composite

Mean and standard deviation (SD) values of surface roughness (*Ra*) for different resin composites were presented in Table (3).

Nanofill (10.66±6.30 nm) had a significantly higher value than Suprananofill (9.61±5.56 nm) (p<0.001).

TABLE (3): Mean ± standard deviation (SD) of surface roughness (*Ra*) for different resin composites

Surface roughness (Ra) (mean±SD)		p-value
Nanofill	**Suprananofill**	
10.66±6.30	9.61±5.56	**<0.001***

****; significant (p ≤ 0.05) ns; non-significant (p>0.05)***

Effect of polishing system

Mean and standard deviation (SD) values of surface roughness (*Ra*) for different polishing systems were presented in Table (4).

There was a significant difference between different groups (p<0.001). The highest value was found in multi-step (19.95±1.51 nm), followed by two-step (7.81±0.88 nm), then control (7.69±0.90 nm), while the lowest value was found in one-step (5.07±0.61 nm). Post hoc pairwise comparisons showed multi-step to have a significantly higher value than other groups (p<0.001). In addition, they showed one-step to have a significantly lower value than other groups (p<0.001).

TABLE (4): Mean ± standard deviation (SD) of surface roughness (Ra) for different polishing systems

Surface roughness (Ra) (mean±SD)				p-value
Control	Multi-step	Two-step	One-step	
7.69±0.90^{B}	19.95±1.51^{A}	7.81±0.88^{B}	5.07±0.61^{C}	**<0.001***

Means with different superscript letters are statistically significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Effect of resin composite with each polishing system

Mean and standard deviation (SD) values of surface roughness (*Ra*) for different resin composites and polishing systems were presented in Table (5) and Figures (1).

Control:

Nanofill (8.26±0.69 nm) had a significantly higher value than Suprananofill (7.13±0.73 nm) (p=0.009).

Multi-step:

Nanofill (21.13±0.79 nm) had a significantly higher value than Suprananofill (18.77±1.02 nm) (p<0.001).

Two-step:

Nanofill (7.88±0.90 nm) had a higher value than Suprananofill (7.74±0.93 nm) yet the difference was not statistically significant (p=0.739).

One-step:

Nanofill (5.37±0.56 nm) had a higher value than Suprananofill (4.78±0.55 nm) yet the difference was not statistically significant (p=0.172).

TABLE (5): Mean ± standard deviation (SD) of surface roughness (Ra) for different resin composites and polishing systems

Polishing system	Surface roughness (Ra) (mean±SD)		p-value
	Nanofill	Suprananofill	
Control	8.26±0.69	7.13±0.73	**0.009***
Multi-step	21.13±0.79	18.77±1.02	**<0.001***
Two-step	7.88±0.90	7.74±0.93	**0.739ns**
One-step	5.37±0.56	4.78±0.55	**0.172ns**

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

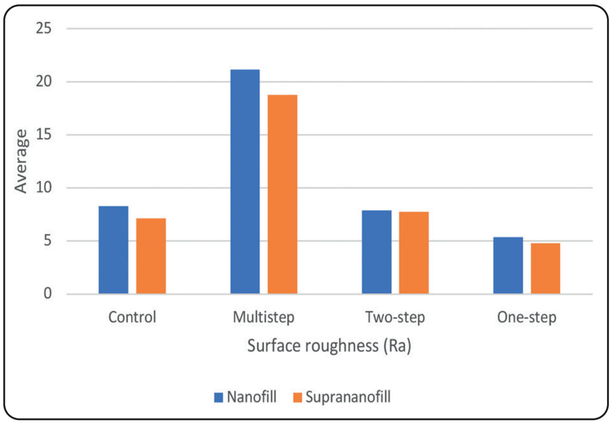

Fig. (1): Bar chart showing average surface roughness (*Ra*) for different resin composites and polishing systems (A).

DISCUSSION

Several finishing and polishing systems have been introduced with the aim of obtaining smooth surface resin composite restoration. Conventionally, multi-step systems are routinely used by dental professionals as their effectiveness has been well established.[13,14] More recently, single-step and two-step polishing protocols have been introduced by several manufacturers, to be less time consuming and more cost effective whilst maintaining at least comparable aesthetic results.[15,16] The specifications of the finishing/polishing protocol applied as well as the restorative material, can be associated with changes in the surface roughness.[6] Besides, the satisfactory polishing of resin composite depend also on the filler type, loading, particle size and morphology.[17] Although their effects on surface roughness of resin composites have been studied for years, there is still no consensus on which system could be more efficient and less time consuming. Therefore, this study aimed to investigate the influence of polishing system (one-, two- and multi-step) and type of resin composite (nanofilled and suprananofilled) on the surface roughness of the resin composites. Special emphasis was given to include various polishing systems with different numbers of application steps to evaluate the results for different restorative composite materials.

In this study the pre-roughening was done with a wet 600-grit silicon carbide paper (equivalent to the yellow-coded finishing stone) to insure even initial surface topography, followed by randomized allocation of samples into the experimental groups. Several studies performed pre-roughening of the surfaces with either diamond or tungsten carbide burs to simulate the clinical procedures,[16] however pre-roughening with diamond burs creates inhomogeneous surface texture which may increase scattering of the results and may yield different surface roughness on different dental materials which makes it difficult to compare between them, because of the different the initial values.[18] The selection of the discoid shape of the applied polishing instruments, to reduce the effect of geometry of the polishing systems.[6] Moreover, the resin composite surface employed in this study was flat, therefore, it might be easier to create a smooth surface with relatively flat polishing tips as they come in direct contact with the specimens.

All polishing procedures were applied by the same operator according to their corresponding manufacturers recommendations in order to achieve predictable results. Moreover, the speed, pressure, motion used during the polishing were fixed, guided by the range of their manufacturers, to reduce the variability for all polishing protocols. The press-on force during the polishing procedure in this study was controlled using a kitchen scale to keep it at approximately 0.3 newton, representing the light pressure needed for the polishing procedure. In addition, rehearsal on the applied pressure was done prior to the experiment with other composite discs samples mounted on the kitchen scale, which were disregarded and not included in the experimental samples, to insure the standardization of each stroke within the range of approximately 30-40 grams during the polishing procedure. SEM allows instinctive visualization and qualitative assessment of surface structure and roughness.[19] The surfaces of resin composite samples were scanned by SEM to represent the basic 2D topography of the resin composite at 4000x magnification, on which Gwyddion was used to gain statistical quantities from the raw SEM data with a 3D reconstruction model using the SEM (backscattered electron detector) scans based on stereo-vision concept.[20]

The type of resin composite influenced the surface roughness outcome in this study, similar to several studies that reported that the effect of several material factors, such as the size, shape, type and distribution of the inorganic fillers over the surface roughness.[21] However, this was not in accordance with other works in the literature stated that even with a considerable difference in resin composite types, they do not certainly exhibit different surface topography in terms of the surface roughness.[22,23] According to the findings of this study, the nanofill had a significantly higher surface roughness value than suprananofill ($p<0.001$). These findings are in accordance with other studies that showed the superior surface morphology of the suprananofill resin composite.[24,25] The Omnichroma (OM) has a careful design of widely dispersed spherical organic fillers with a distribution of various particle sizes, spherical inorganic fillers of 260 nm in diameter were evenly distributed at almost the same density both within the organic filler and within the surrounding resin base and the coupling process that tightly joins all of them. In contrast, the heterogenous and irregular shape of the filler particles and cluster system are more dominant in the Filtek™ Z350 XT composite (FK). Resin composites with spherical fillers tended to show the highest degree of smoothness and gloss compared with composites filled with irregular fillers,[26] as irregular particles protruding from the surface produce sharper edges compared to spherical fillers, which results in higher surface roughness measurements.[1]

The difference found in surface properties as surface roughness can be a result of the extremely tight contact between the various fillers and the resin base in OM. Furthermore, the degradation in the organic filler has been reported to be almost at the same extent of that of the surrounding matrix confirming significant improvement of the coupling technology for each of the interface areas in OM.[27] Besides, it is possible that the higher filler content of OM (68% by volume) than that of the FK (63.3% by volume), worked in the favour of the suprananofill resin composite.[14] The high concentration of closely packed fine filler particles decreases interparticle spacing, which makes the composite material less susceptible to lose particles by the abrasive, all conducive to the smooth homogenous surface.[5,28] A lower ratio of fillers/organic matrix means more organic matrix which is less hard than the filler and can show some irregularities after polishing.[29]

The FK nanofill resin composite contains not only nano-scaled silica/ zirconia fillers but also nanoclusters produced in a broad range of sizes.[30] The nano agglomerate size in the enamel shade used in this study, (an average cluster particle size of 0.6 to 10 microns) is considered even larger than the particle size of the OM (average 0.26 μm). Moreover, the improper use of nanotechnology may cause a significant increase in viscosity or excessive undesired agglomerate, which could undo the advantage of nanotechnology, mainly regarding the polishing aspect, since these may behave as larger particles.[31] The results of the present study are in disagreement with the proposal of nanotechnology, as through the manufacturing process of nanofill composite, each nanoparticle is silanized individually, even those inside the agglomerates. Thus, for a nanofill composite to be effectively polished, it is necessary that the agglomerates breakup into their primary nanoparticles during the procedure when the surface is being cut, and this controlled cutting of the agglomerate inhibits the loss of larger particles. Therefore, the high *Ra* values found in this study could be due to the non-uniform and incomplete detachment of the particles of the agglomerates. In addition, those agglomerated nano particles could possibly fell off due to lack of retention within the resin matrix during polishing,[32] however other studies did not observe the same finding.[33]

The polishability of resin composite is influenced also by the resin matrix, while relatively soft resin wears faster than harder filler particles, this prevents homogenous abrasion and result in surface irregularities.[34] It is important to underline that the final hardness of resin matrix result not only from the characteristics of individual monomers, but above all, from the interactions that occur in the monomer mixture and the characteristics of the resulting polymer network.[35] Previous studies have indicated that UDMA/TEGDMA matrices have higher hardness values than Bis-GMA based matrices do; as UDMA has a lower viscosity and is more flexible than Bis-GMA, which result in a higher conversion and denser polymer network.[36] The presence of aromatic rings and urethane bonds increases the resin hardness values.[37] It is possible that the higher relative hardness of UDMA based matrix of OM have contributed to the more homogenous abrasion and efficient polishing than the Bis-GMA based matrix of FK.

Although there are several works in literature state that a greater surface smoothness is obtained by the polyester matrix,[9,25] this study showed that the groups that did not receive finishing and polishing, in other words, whose surface micromorphology was obtained only by means of the mylar strip, were not the ones with the lowest surface roughness values. Despite the effort exerted to standardize the methodology in this study, it is possible that the surface set against the polyester matrix was not free of imperfections due to the nature of the resinous matrix as well as the possible flaws and irregularities within the polyester matrix itself. The surface produced was only as good as the mylar strip itself and any surface imperfections existing in the matrix will be reproduced in the surface of the samples.[38] This finding reinforces the importance of the finishing and polishing. With respect to this issue, some authors declared that finishing and polishing procedures are essential to obtain surface smoothness, as they remove the excess of restoration and any possible surface irregularities. These procedures prevent critical problems related to the quality of the restoration, such as staining, bacterial plaque retention, gingival irritation and recurrent caries. Moreover, removing the most superficial resin-rich layer is essential to maintain the surface quality and microhardness of the resin composite.[39,40]

Apart from intrinsic factors related to the resin-based composite material, the surface roughness of resin composites depends on extrinsic factors, such as the finishing and polishing technique and the abrasive tools applied.[41] In this study, a statistically significant difference was observed among the polishing systems in terms of the surface roughness, which was similar to other studies.[22] The highest value was found in Enamel Plus Shiny polishing pastes (ES) multi-step, followed by Super-Snap X-treme aluminium oxide discs (SS) two-step, while the lowest surface roughness value was found in OneGloss® (OG) one-step polishers. This is not in accordance with the claim that to achieve high surface quality, at least four finishing/polishing steps are required, and the greater the number of polishing steps, the better the surface smoothness attained.[42] Whereas the OG had the superior surface smoothness in this study, this was not the case in other studies that reported a higher surface roughness parameters with the OG.[15,33] This could be because in those studies, the press-on force was not controlled and this issue was not even mentioned or discussed although it is the basis of this system. The OG system combines both finishing and polishing within the same disc, while controlling the differential pressure applied, as the polishing step needs approximately 30% of the pressure used in the finishing step. On the contrary, the pressure here was strictly controlled during the whole polishing procedure to 0.3 N (approximately 30-40 grams), the polishing pressure recommended by the manufacturer, as it has been used only in a polishing mode.

It is possible that the OG system has polished both the organic and inorganic components of the resin composite equally and thus be able to create a highest smoothness without causing any surface damage. In addition, this was the only system used with intermittent water cooling according to the manufacturer instructions, unlike the other two- and multi-step systems, that is why OG acted in a polishing mode more than the other systems. Dry finishing/polishing procedures have been revealed to be less successful,[20] attributed to the separation of abrasive particles from the polishing tool which could embed into the resin composite surface, increasing the surface roughness parameter. Moreover, the use of water coolant with the rubber disc prevents strain of the molecular arrangement of the resin matrix and prevents detachment of the filler particles from the heat-softened resin.[43]

The two-step system SS discs obtained the second smoother surface among the used polishing systems. The fact that aluminium oxide coated finishing and polishing discs can obtain a very smooth surface with minimal surface irregularities is supported by several studies.[5,9,25] The effectiveness of abrasive discs and the ability to produce a regular, smooth surface mainly depends on flattening the filler particles and abrading the softer resin matrix at an equal rate.[34] In this study, the aluminum oxide discs were used as a partial polishing system, using only the last fine and superfine discs sequentially. Therefore, this could have affected the outcome that it could not surpass the OG, conforming to higher *Ra* values obtained with the partial three step system instead of the full system in several studies.[5,25] Moreover, the press-on force is less transmitted with the flexible SS discs as they can bend and counteract the exerted pressure,[44] whereas the OG rubber discs are stiffer and do not deflect with the same pressure,[42,45] causing more efficient polishing. Besides the dry polishing protocol, the grit of the polishing discs may also contribute to the changes in surface temperature, in fact when the disc is switched from a greater grit size to a smaller grit one, the temperature does not decrease, contrariwise the temperature rise.[46]

When the roughness values obtained from these systems were compared, it was evident that the three-step ES polishing paste system was not as effective as the OG and SS despite having more application steps. The three-step polishing system produced the largest *Ra* value, driven by the fact that the grooves introduced by the pre-roughening regime were not polished away when compared to the other polishing protocols. This could be attributed to the noticeable difference of abrasive particle size between the 600-grit silicon carbide sandpaper representing the finishing step (equivalent to 30 μm) and the first polishing paste used in the polishing sequence "Shiny A" (equivalent to 3 μm). Therefore, this system probably needs a finishing step before polishing to achieve a smoother surface prior to polishing and shining. The ES polishing paste system has been reported to damage the resin composites by creating scratches on their surfaces.[47] Similarly in this study, the surfaces of the resin composite samples polished with ES were characterized by scratches probably caused by the hardness of the goat hair brush, as well as possibly retained voids from the polyester matrix adaptation or the pre-roughening step. In addition, polishing pastes can probably act in a more aggressive, pre-polishing mode when applied in a dry condition, which may lead to crystallization of the colloidal contaminants and scratches.[6]

An interaction was found in the present study, which is in accordance with the results of previous studies evaluating polishing systems and resins composite.[16,33] Generally, the nanofill had higher values of average surface roughness than the suprananofill resin composite in the control and all the polishing groups, however, the difference was not statistically significant in the two-step and one-step groups. Among the polishing systems used, the three-step polishing paste was the only system containing diamond, which is a very hard element that can promote deep wear. The abrasive particles that promote deep wear result in the exposure of both nanofillers and larger cluster filler particles present in the FK, considering that the size of filler particles is related positively to the composite surface roughness.[17] In contrast, deep wear would expose suprananofiller particles only on the sub-subsurface of OM, providing a smoother surface. Whereas the one-step and two-step polishing systems containing aluminium oxide only or with silicone oxide did not create the same wear and exposed only the subsurface layer rich in smaller nanosized filler particles in FK or suprananofiller filler particles in OM.

The matrix and filler particles have different hardness, which may affect the polishability of the resin composites. Insufficient abrasiveness of the polisher particles compared with the fillers within resin composite will mostly abrade the matrix, leaving the filler particles in protrusion. In addition, inefficiently bonded fillers may debond and dislodge, leaving a dull surface. Therefore, the results imply that the combination of resin composite and polisher has an impact on the result, with some polishers leaving an excellent surface on some resin composites but a less optimal surface on others.[33]

The effect of the polishing system on surface roughness of resin composite material seems to be both system- and material-dependant. Clinically, OM suprananofill resin composite may be recommended as a better choice regarding smoothness and surface quality. Besides, intraoral adjustment of direct composite resin restorations with OG one-step polishing system, seems to be a better option in terms of decreasing surface roughness and improving surface properties. However, all the polishing systems and both resin composites studied can demonstrate a surface roughness average *(Ra)* lower than the baseline value that could promote bacterial adherence ($Ra = 0.2\mu$m). Taking this into account, all polishing materials and both resin composites can be considered clinically acceptable alternatives.

CONCLUSION

Within the limitations of this study, the following conclusions could be suggested:

1. No polishing system can reach surface roughness average *(Ra)* above the clinically accepted threshold. However, the one-step polishing system produces the smoothest surface, even smoother than setting against matrices.
2. Polishing pastes not preceded by a pre-polishing step produces the roughest surface.
3. The type of resin composite significantly affects the surface roughness, the suprananofill resin composite can obtain a smoother surface than the nanofill resin composite.

Conflict of interest

The authors declare that they have no financial interest in the materials used in this study. This study was a part of Ghadeer Abo-Eldahab's Master thesis in the partial fulfillment of the requirements of the master's degree in Operative Dentistry, Faculty of Dentistry, Ain Shams university.

REFERENCES

1. Amaya-Pajares SP, Koi K, Watanabe H, da Costa JB, Ferracane JL. Development and maintenance of surface gloss of dental composites after polishing and brushing: Review of the literature. J Esthet Restor Dent. 2022;34(1):15–41.
2. Lutz F, Phillips RW. A classification and evaluation of composite resin systems. J Prosthet Dent. 1983;50(4):480–8.
3. Ferracane JL. Resin composite - State of the art. Dent Mater. 2011;27(1):29–38.
4. Daud A, Gray G, Lynch CD, Wilson NHF, Blum IR. A randomised controlled study on the use of finishing and polishing systems on different resin composites using 3D contact optical profilometry and scanning electron microscopy. J Dent. 2018;71(January):25–30.
5. Yadav RD, Jindal D, Mathur R. A Comparative Analysis of Different Finishing and Polishing Devices on Nanofilled, Microfilled, and Hybrid Composite: A Scanning Electron Microscopy and Profilometric Study. Int J Clin Pediatr Dent. 2016;9(3):201–8.
6. Jefferies SR. Abrasive Finishing and Polishing in Restorative Dentistry: A State-of-the-Art Review. Dent Clin North Am. 2007;51(2):379–97.
7. Jaramillo-Cartagena R, López-Galeano EJ, Latorre-Correa F, Agudelo-Suárez AA. Effect of Polishing Systems on the Surface Roughness of Nano-Hybrid and Nano-Filling Composite Resins: A Systematic Review. Dent J. 2021;9(95).
8. Willems G, Lambrechts P, Braem M, Vanherle G. Composite resins in the 21st century. Quintessence Int. 1993;24(9):641–658.

9. Sahbaz C, Bahsi E, Ince B, Bakir EP, Cellik O. Effect of the Different Finishing and Polishing Procedures on the Surface Roughness of Three Different Posterior Composite Resins. Scanning. 2016;38(December 2015):448–54.

10. Nair VS, Sainudeen S, Padmanabhan P, Vijayashankar L V, Sujathan U, Pillai R. Three-dimensional evaluation of surface roughness of resin composites after finishing and polishing. J Conserv Dent. 2016;91–5.

11. Dutra DAM, Pereira GKR, Kantorski KZ, Valandro LF, Zanatta FB. Does finishing and polishing of Restorative materials affect bacterial adhesion and biofilm formation? a systematic review. Oper Dent. 2018;43(1):37–52.

12. Han JM, Zhang H, Choe HS, Lin H, Zheng G, Hong G. Abrasive wear and surface roughness of contemporary dental composite resin. Dent Mater J. 2014;33(6):725–32.

13. Da Costa J, Ferracane J, Paravina RD, Mazur RF, Roeder L. The effect of different polishing systems on surface roughness and gloss of various resin composites. J Esthet Restor Dent. 2007;19(4):214–24.

14. Janus J, Fauxpoint G, Arntz Y, Pelletier H, Etienne O. Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach. Dent Mater. 2010;26(5):416–25.

15. Pala K, Tekçe N, Tuncer S, Serim ME, Demirci M. Evaluation of the surface hardness, roughness, gloss and color of composites after different finishing/polishing treatments and thermocycling using a multitechnique approach. Dent Mater J. 2016;35(2):278–89.

16. Da Costa JB, Goncalves F, Ferracane JL. Comparison of two-step versus four-step composite finishing/ polishing disc systems: Evaluation of a new two-step composite polishing disc system. Oper Dent. 2011;36(2):205–12.

17. Marghalani HY. Effect of filler particles on surface roughness of experimental composite series. J Appl Oral Sci. 2010;18(1):59–67.

18. Hoelscher D, Neme A, Pink F, Hughes P. The effect of three finishing systems on four esthetic restorative materials. Oper Dent. 1998;23(1):36–42.

19. Petrovic B, Stefanovic S, Kojic S, Porcic M, Jevremov J, Stojanovic G. A pattern of metatarsal bovine bone surface alterations produced by human permanent teeth - An experimental approach. J Archaeol Sci Reports. 2019;27(January):101961.

20. Baroudi K, Kaminedi R, Penumatsa N, Priya T. The influence of finishing/polishing time and cooling system on surface roughness and microhardness of two different types of composite resin restorations. J Int Soc Prev Community Dent. 2014;4(5):99.

21. Ergücü Z, Türkün LS. Surface roughness of novel resin composites polished with one-step systems. Oper Dent. 2007;32(2):185–92.

22. Kocaagaoglu H, Aslan T, Gürbulak A, Albayrak H, Taşdemir Z, Gumus H. Efficacy of polishing kits on the surface roughness and color stability of different composite resins. Niger J Clin Pract. 2017;20(5):557–65.

23. Costa G de FA da, Fernandes ACB de CJ, Carvalho LA de O, de Andrade AC, de Assunção IV, Borges BCD. Effect of additional polishing methods on the physical surface properties of different nanocomposites: SEM and AFM study. Microsc Res Tech. 2018;81(12):1467–73.

24. 24. Can Say E, Yurdagüven H, Yaman BC, Özer F. Surface roughness and morphology of resin composites polished with two-step polishing systems. Dent Mater J. 2014;33(3):332–42.

25. Aytac F, Karaarslan ES, Agaccioglu M, Tastan E, Buldur M, Kuyucu E. Effects of Novel Finishing and Polishing Systems on Surface Roughness and Morphology of Nano-composites. J Esthet Restor Dent. 2016;28(4):247–61.

26. Ereifej NS, Oweis YG, Eliades G. The effect of polishing technique on 3-D surface roughness and gloss of dental restorative resin composites. Oper Dent. 2013;38(1):E1–12.

27. Maesako M, Kishimoto T, Horie T, Suzuki M, Inoue K, Mizuno A, et al. Microstructural properties and surface properties of a new resin composite employing structural color technology. J Hard Tissue Biol. 2021;30(1):7–12.

28. Branco AC, Colaço R, Figueiredo-Pina CG, Serro AP. A state-of-the-art review on the wear of the occlusal surfaces of natural teeth and prosthetic crowns. Materials (Basel). 2020;13(16).

29. Monterubbianesi R, Tosco V, Sabbatini S, Orilisi G, Conti C, Özcan M, et al. How Can Different Polishing Timing Influence Methacrylate and Dimethacrylate Bulk Fill Composites? Evaluation of Chemical and Physical Properties. Biomed Res Int. 2020;2020.

30. 3M ESPE. Filtek™ Z350 XT Universal Restorative System technical product profile.

31. da Silva JM, da Rocha DM, Travassos AC, Fernandes VV Jr

RJ. Effect of different finishing times on surface roughness and maintenance of polish in nanoparticle and microhybrid composite resins. Eur J Esthet Dent. 2010;5(3):288–298.

32. Zhang L, Yu P, Wang XY. Surface roughness and gloss of polished nanofilled and nanohybrid resin composites. J Dent Sci. 2021;16(4):1198–203.

33. Dennis T, Zoltie T, Wood D, Altaie A. Reduced-step composite polishing systems - a new gold standard? J Dent. 2021;112:103769.

34. Babina K, Polyakova M, Sokhova I, Doroshina V, Arakelyan M, Novozhilova N. The effect of finishing and polishing sequences on the surface roughness of three different nanocomposites and composite/enamel and composite/cementum interfaces. Nanomaterials. 2020;10(7):1–14.

35. Ding Y, Li B, Wang M, Liu F, He J. Bis-GMA Free Dental Materials Based on UDMA/SR833s Dental Resin System. Adv Polym Technol. 2016;35(4):396–401.

36. Szczesio-Wlodarczyk A, Domarecka M, Kopacz K, Sokolowski J, Bociong K. An evaluation of the properties of urethane dimethacrylate-based dental resins. Materials (Basel). 2021;14(11):1–15.

37. Barszczewska-Rybarek IM. Characterization of urethane-dimethacrylate derivatives as alternative monomers for the restorative composite matrix. Dent Mater. 2014;30(12):1336–44.

38. Yap AUJ, Sau CW, Lye KW. Effects of finishing/polishing time on surface characteristics of tooth-coloured restoratives. J Oral Rehabil. 1998;25(6):456–61.

39. Reis AF, Giannini M, Lovadino JR, dos Santos Dias CT. The effect of six polishing systems on the surface roughness of two packable resin-based composites. Am J Dent. 2002;15(3):193–197.

40. Sarac D, Sarac YS, Kulunk S, Ural C, Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. J Prosthet Dent. 2006;96(1):33–40.

41. Bansal K, Gupta S, Nikhil V, Jaiswal S, Jain A, Aggarwal N. Effect of Different Finishing and Polishing Systems on the Surface Roughness of Resin Composite and Enamel: An In vitro Profilometric and Scanning Electron Microscopy Study. Int J Appl basic Med Res. 2019;9(3):154–158.

42. Heintze SD, Forjanic M, Rousson V. Surface roughness and gloss of dental materials as a function of force and polishing time in vitro. Dent Mater. 2006;22(2):146–65.

43. Hachiya Y, Iwaku M, Hosoda H, Fusayama T. Relation of finish to discoloration of composite resins. J Prosthet Dent. 1984;52(6):811–4.

44. Lehmann A, Nijakowski K, Potempa N, Sieradzki P, Król M, Czyż O, et al. Press-on force effect on the efficiency of composite restorations final polishing—preliminary in vitro study. Coatings. 2021;11(6):1–11.

45. Heintze SD, Reinhardt M, Müller F, Peschke A. Press-on force during polishing of resin composite restorations. Dent Mater. 2019;35(6):937–44.

46. Jones CS, Billington RW, Pearson GJ. The effects of lubrication on the temperature rise and surface finish of amalgam and composite resin. J Dent. 2007;35(1):36–42.

47. Kemaloglu H, Karacolak G, Turkun LS. Can Reduced-Step Polishers Be as Effective as Multiple-Step Polishers in Enhancing Surface Smoothness? J Esthet Restor Dent. 2017;29(1):31–40.