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THE EFFECT OF DIFFERENT POLISHING METHODS ON THE SURFACE ROUGHNESS OF TWO SCALPEL FINISHED RESIN COMPOSITES

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ABSTRACT

Aim: to evaluate the effect of different polishing methods on the surface roughness (Ra) of two scalpel finished resin composites.

Materials and Methods: Seventy two resin composite discs were prepared and cured against Mylar strip and divided into two groups (n=36) according to type of resin composite material, Group A1 (nano filled) and Group A2 (nano hybrid). Except for the control group (B0), samples were finished with scalpel blade, then divided into 5 subgroups (n=6) according to the polishing method, subgroup B1 (scalpel finished only and not followed by polishing), subgroup B2 (Sof-Lex Extra Thin Polishing discs), subgroup B3 (Sof-Lex Spiral wheels), subgroup B4 (Sof-Lex polishing strips) and subgroup B5 (polishing paste and brush). Samples were scanned using SEM, scans were analyzed by Gwyddion 2.59 Image Analysis Software to attain surface roughness average Ra data, which were statistically analyzed by two-way ANOVA and Turkey Post Hoc test.

Results: There was a significant interaction between the resin composite material and the polishing protocol. Nano hybrid A2 had a significantly higher value than nano filled A1. And between the different finishing and polishing methods, there was a significant difference between different groups. The highest value was found in B1, followed by B4, then B2, B0 and B5, while the lowest value was found in B3.

Conclusion: Scalpel is a good finishing tool for resin composite to produce a smoother micro surface ready for polishing. Nano filled resin composite produces a smoother surface than nano hybrid resin composite with different polishing methods.

KEYWORDS: Dental Polishing, Scalpel Finishing, Resin Composite, Surface Roughness.

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INTRODUCTION

Finishing and polishing of resin composite restorations are important steps in restorative dentistry. A highly polished surface decreases plaque accumulation, gingival irritation, color change and provides better esthetics. Therefore, the smoothness of a restoration is of great importance for its success.(1) Finishing is defined as the gross reduction or contouring of the restoration to obtain ideal anatomy. Polishing refers to the reduction of surface roughness and scratches created by the finishing instruments.(2)

In current resin composite materials the average filler particle size has been decreased to obtain better color stability and greater wear resistance, strength and smoothness. Nanotechnology provided nano composites with higher translucency, easier polishability and long term polish retention together with good physical properties and wear resistance.(3)

The surface obtained by the Mylar stripe is perfectly smooth, but it is rich in resin-polymer that is easily abraded in the oral environment, exposing unpolished, rough, inorganic fillers and may contain some voids.(3) Therefore, the outermost resin layer must be removed by finishing to produce a relatively standard and stable surface increasing the wear resistance of the resin composite surface.(4)

A variety of materials and techniques have been used for finishing and polishing.(3) Improper finishing and repeated polishing using rotary instruments can induce surface and subsurface micro-cracks and jeopardize the restoration surface and the marginal integrity of the resin composite restoration due to vibrations and overheating.(5)

On the other hand using a scalpel blade for finishing the polymerized resin composite restorations can improve the quality of the final surface by developing natural contours and characteristics and by removing the excess restorative material at the margins of restorations and to finish the inaccessible interproximal areas leaving a smoother micro surface ready for polishing.(6)

Other benefits for scalpel finishing include fine finger perception and enhanced control of movement preserving the adjacent natural enamel surfaces from abrasive damage. Also, avoiding over cutting of the restorative material with no heat generation and formation of surface and sub surface microcracks. Finishing with a scalpel blade compared to traditional rotary instruments will lead to a smoother micro surface ready for polishing, simplifying and shortening the polishing procedures(6,7)

As there is no universally clinically accepted strategy, the resultant surface roughness was affected by the characteristics of the resin composite material, the finishing and polishing tools including their shape, flexibility and hardness of abrasive particles.(3,8) Therefore this study highlighted the effect of using scalpel and different polishing methods for assessment of surface roughness of two different resin composite material surfaces. The null hypotheses tested were that there would be no difference in surface roughness (1) among the polished resin composites or (2) among the different polishing systems when used on the same resin composite.

MATERIALS AND METHODS

A total of 72 resin composite disc specimens were prepared and divided into two main groups. Group A1: nano filled (Filtek Z350XT,3M ESPE,St Paul, USA) and Group A2: nano hybrid (Filtek Z250XT,3M ESPE,St Paul, USA) (table 1) using split Teflon mold (10 mm x 2 mm) following the manufacturer instructions.

The resin composite was deposited in a single layer inside the mold using a double flat instrument. And the upper surface of the mold was covered with a mylar strip and a glass slide was pressed on to ensure the surface flatness and smoothness, then removed before curing by a Radii-Plus Light Cure device (SDI, Australia) with the intensity of 1400 mW/cm2 for 20 seconds according to the manufacturer instructions. The tip of the device was placed in touch with the mylar strip perpendicular to the composite surface, and the intensity of the output light of the device was initially monitored by the radiometer device and among each group preparation.

Each main group was divided into six sub groups according to the finishing and polishing tool used (n=6) (table 2). Then with exception of the control group (B0) all specimens were molded into acrylic molds with the surface being finished and polished facing upward and then each specimen was finished with scalpel blade no.15 placed at 45 degree to the specimen in a peeling motion in one direction with 10 strokes with light pressure(6) and the scalpel

TABLE (1): Materials composition, manufacturer and lot number:

Product	Type	Resin matrix	Filler (type/size)	Filler (wt%/vol%)	Manufacturer	Lot number
Filtek Z350XT (A2,Enamel)	Nanofilled	Bis-GMA*, UDMA**, TEGDMA***, PEGDMA, Bis-EMA****	Zirconia, zirconia cluster filler (4–11 nm), silica cluster (20 nm)	78.5/63.3	3M ESPE, St Paul, USA	NE02935
Filtek Z250XT (A2)	Nanohybrid	Bis-GMA*, UDMA**, Bis-EMA****, PEGDMA, TEGDMA***	20nm silica, zirconia/ silica (0.1–10 µm)	81.8/67.8	3M ESPE, St Paul, USA	NC92622

Bis-GMA*: Bisphenol A diglycidimethacrylate: UDMA**: Urethane dimethacrylate; EMA*: ethylmethacrylate; TEGDMA***:triethylene glycol dimethacrylate.***

TABLE (2): Finishing and polishing tools composition, manufacturer and lot number:

Product	Composition	Manufacturer	Lot number
Scalpel blade no.15	Carbon steel disposable surgical blades	SteriLance medical (Suzhou), china	F0212
Sof-Lex Extra Thin Polishing discs	Polyester film, Aluminum oxide different grits: - Fine: 24 µm - Superfine: 8 µm	3M ESPE, St Paul, USA	NA96122
Sof-Lex Spiral wheels	Thermoplastic elastomer impregnated with aluminum oxide Particles	3M ESPE, St Paul, USA	N995293
Sof-Lex polishing strips	Plastic strip impregnated with aluminum oxide different grits: -Medium -Fine –superfine	3M ESPE, St Paul, USA	NC59362
Polishing paste	Shiny A: 3 micron diamond paste Shiny B:1 micron diamond paste Shiny C: aluminum oxide paste	ENA HRi, Micerium S.p.A., Italy	1904046
Polishing brush	Goat hair to be used with diamond polishing paste Felt wheel to be used with aluminum oxide paste	ENA HRi, Micerium S.p.A., Italy	1904046

blade was used for each specimen individually then replaced and renewed and for standardization this process was performed by a single operator.

After that the specimens were mechanically cleaned for 10 minutes in ultrasonic device (MCS, Digital Ultrasonic cleaner, CD-4860, 6000ml) filled with distilled water. Finally, all the specimens were stored at room temperature in 100% humidity container for 24 hours till the polishing procedure.[9]

The scalpel finished specimens then subdivided into 5 subgroups (n=6) according to the polishing method and with exception of the scalpel finished group without polishing (B1) all specimens were polished according to the manufacturer instructions by using a slow speed hand piece (NSK Dental Low Speed Hand piece FX-25 Set Japan) at 3000 rpm without water coolant in a planar motion and with intermittent light pressure (average 40 g)(10) which controlled through the whole procedure using a scale . All procedures were done by the same operator for standardization .

1- Sof-Lex Extra Thin Polishing discs (B2):

The Sof-Lex XT Discs (fine-superfine) were sequentially used . The fine grit disc was used for 15 seconds. Final polishing of each composite specimen was done using the superfine grit disc for 15 seconds. The specimen was rinsed and dried after each polishing procedure.

2- Sof-Lex Spiral wheels (B3):

The beige Sof-Lex Spiral Pre polishing Wheel was used for 15 seconds. The composite specimens were then polished with the pink Sof-Lex Spiral Polishing Wheel for 15 seconds. The specimen was rinsed and dried after each polishing procedure.

3- Sof-Lex polishing strips (B4):

The Sof-Lex polishing strips (gray/yellow) were used sequentially, both ends of the gray strip were firmly grasped and drawn over the composite specimen surface in a vigorous, seesaw motion for 15 seconds. Then the yellow strip was used for 15 seconds. The specimen was rinsed and dried after each polishing procedure.

4- Polishing paste and brush(B5):

A small portion of the polishing paste (shiny A) was applied to cover the whole composite specimen surface and the goat hair polishing brush was used for 15 seconds . The same procedure was repeated using (shiny B) polishing paste with goat hair polishing brush and finally was repeated using (shiny C) polishing paste with felt wheel polishing brush. The specimen was rinsed and dried after each polishing procedure .

After polishing the resin composite specimens according to their assigned groups, they were scanned using Scanning Electron Microscope (SEM) at different magnifications using backscattered electron detector (BSED). After which the 3000x scan of each specimen was analyzed using Gwyddion 2.59 software (SPM data visualization and analysis tool, supported by the Czech Metrology Institute, 2019) in order to gain the surface roughness average Ra values that were statistically analyzed by two-way ANOVA and Turkey Post Hoc test. Representative specimens from each group were randomly selected to qualitatively evaluate the resin composite specimens surface (Fig.1,2).

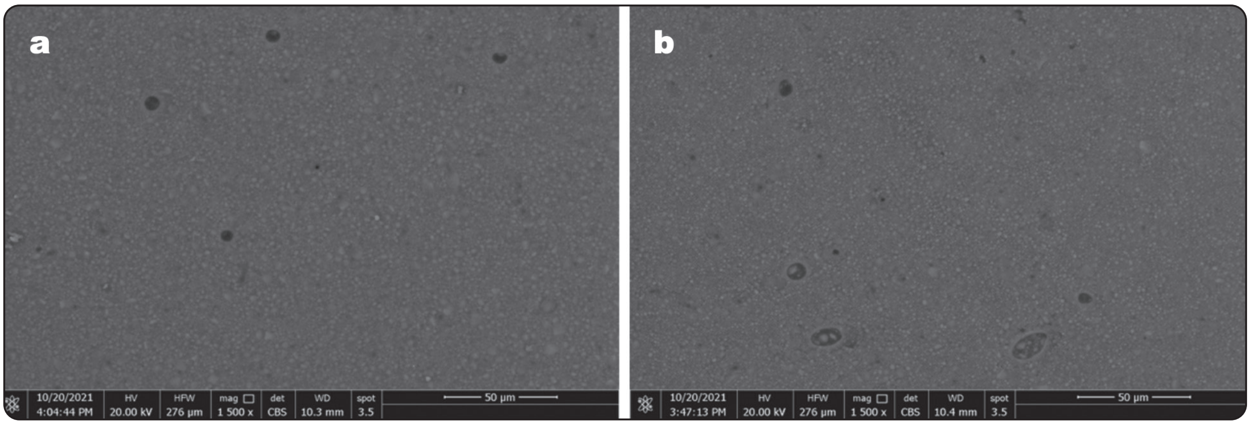

Fig. (1) Scanning electron microscope photograph of resin composite surface of the control group (Mylar strip) at 1500x magnification power a.FiltekTM Z350 XT b. FiltekTM Z250 XT.

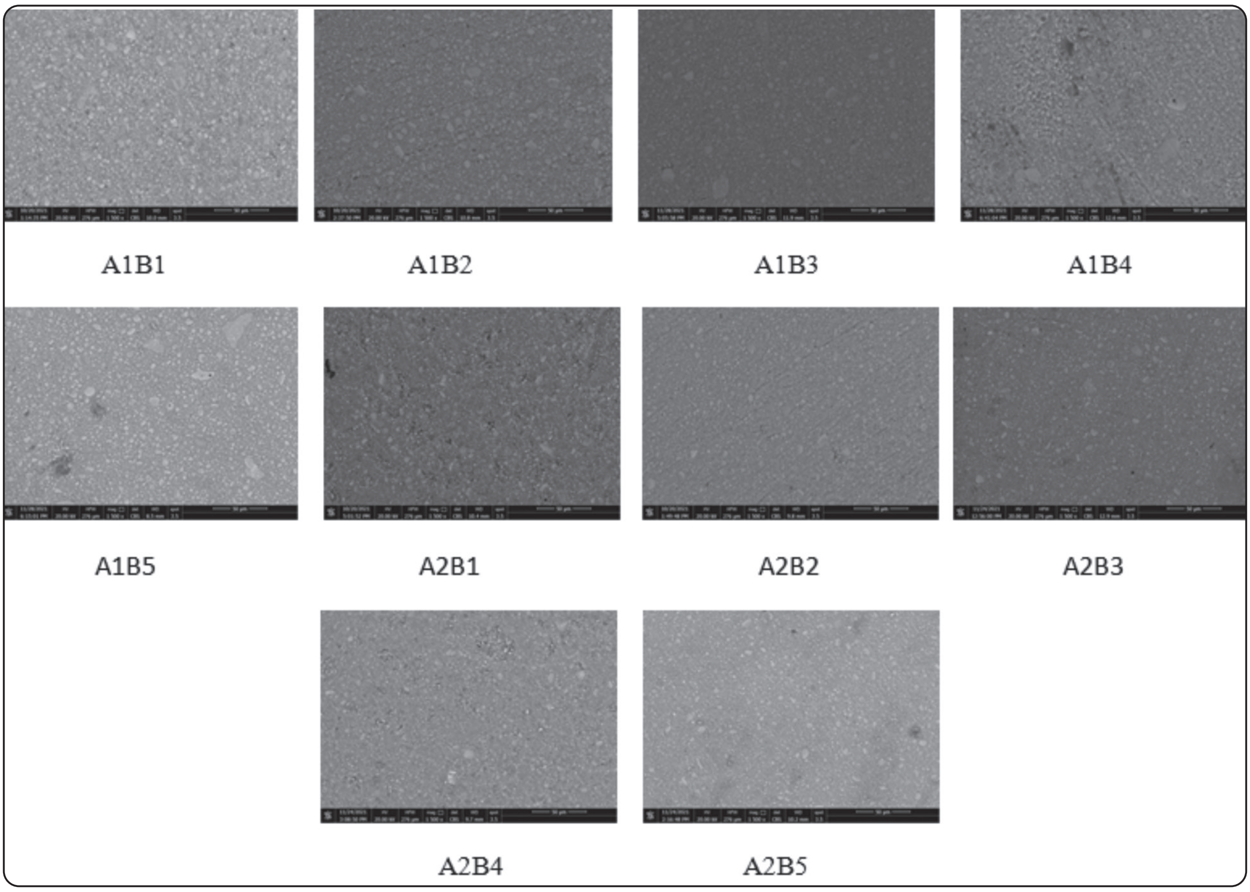

Fig. (2) SEM scans of representative samples.

RESULTS

Two-way ANOVA followed by Turkey Post-Hoc test revealed that the type of the material and the polishing method used after scalpel finishing of resin composite affected the surface roughness (Ra) values.

1-Effect of different variables and their interaction:

Effect of different variables and their interaction on surface roughness (Ra) values were presented in table (3). There was a significant interaction between composite material and polishing protocol (p=0.002).

TABLE (3): Two-way ANOVA followed by Post-Hoc test for the effect of different variables and their interactions on surface roughness (Ra) values of resin composite restorative material

Source	Sum of Squares	Df	Mean Square	f-value	p-value
Composite material	491.43	1	491.43	94.30	<0.001*
Polishing protocol	1072.29	5	214.46	41.15	<0.001*
Composite material * Polishing protocol	115.26	5	23.05	4.42	0.002*
Error	312.68	60	5.21		

df=degree of freedom*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

2- Effect of resin composite restorative material regardless of the polishing protocol:

Mean and standard deviation (SD) values of surface roughness (Ra) for different composite materials were presented in table (4) .

A2 (24.20±4.96) had a significantly higher value than A1 (18.98±4.27) (p<0.001).

TABLE (4): Mean and standard deviation (SD) values of surface roughness (Ra) for different resin composite restorative materials

Surface roughness (Ra) (mean±SD)		**p-value**
A1	**A2**	
18.98±4.27	24.20±4.96	**<0.001***

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

3- Effect of polishing protocol regardless of the resin composite restorative material:

Mean and standard deviation (SD) values of surface roughness (Ra) for different polishing protocols were presented in table (5) .

There was a significant difference between different groups (p<0.001). The highest value was found in B1 (28.66±5.43), followed by B4 (24.10±0.80), then B2 (21.81±2.35), B0 (18.88±2.87) and B5 (18.52±3.75), while the lowest value was found in B3 (17.55±5.07). Post hoc pairwise comparisons showed B1 to have significantly higher value than other groups (p<0.001). In addition, they showed B2 and B4 to have significantly higher values than B0, B3 and B5 (p<0.001).

4- Effect of resin composite restorative material within each polishing protocol:

Mean and standard deviation (SD) values of surface roughness (Ra) for different composite materials within each polishing protocol were presented in table (6).

- **B0:** A2 (21.54±0.74) had a significantly higher value than A1 (16.23±0.82) (p<0.001).
- **B1:** A2 (32.51±5.39) had a significantly higher value than A1 (24.81±0.44) (p<0.001).
- **B2:** A2 (23.70±1.88) had a significantly higher value than A1 (19.92±0.21) (p=0.006).
- **B3:** A2 (21.98±3.02) had a significantly higher value than A1 (13.12±0.50) (p<0.001).

- **B4:** A2 (24.68±0.26) had a higher value than A1 (23.52±0.73) yet the difference was not statistically significant (p=0.380).
- **B5:** A2 (20.79±4.27) had a significantly higher value than A1 (16.25±0.54) (p=0.001).

5- Effect of polishing protocol within each resin composite restorative material:

Mean and standard deviation (SD) values of surface roughness (Ra) for different polishing protocols within each composite material were presented in table (7).

- **A1:** There was a significant difference between different groups (p<0.001). The highest value was found in B1 (24.81±0.44), followed by B4 (23.52±0.73), then B2 (19.92±0.21), B0 (16.23±0.82) and B5 (16.25±0.54), while the lowest value was found in B3 (13.12±0.50). Post hoc pairwise comparisons showed B1 to have significantly higher value than other groups except for B4 (p<0.001). In addition, they showed B4 to have significantly higher value than B0, B3 and B5 (p<0.001). Finally, they showed B2 to have significantly higher value than B3 (p<0.001).

TABLE (5): Mean and standard deviation (SD) values of surface roughness (Ra) for different polishing protocols regardless of the resin composite restorative material

Surface roughness (Ra) (mean±SD)						p-value
B0	**B1**	**B2**	**B3**	**B4**	**B5**	
18.88±2.87^{C}	28.66±5.43^{A}	21.81±2.35^{B}	17.55±5.07^{C}	24.10±0.80^{B}	18.52±3.75^{C}	**<0.001***

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

TABLE (6): Mean and standard deviation (SD) values of surface roughness (Ra) for different resin composite restorative materials within each polishing protocol

Polishing protocol	Surface roughness (Ra) (mean±SD)		p-value
	A1	**A2**	
B0	16.23±0.82	21.54±0.74	**<0.001***
B1	24.81±0.44	32.51±5.39	**<0.001***
B2	19.92±0.21	23.70±1.88	**0.006***
B3	13.12±0.50	21.98±3.02	**<0.001***
B4	23.52±0.73	24.68±0.26	**0.380ns**
B5	16.25±0.54	20.79±4.27	**0.001***

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

TABLE (7): Mean and standard deviation (SD) values of surface roughness (Ra) for different polishing protocols within each resin composite restorative material

Composite material	Surface roughness (Ra) (mean±SD)						p-value
	B0	B1	B2	B3	B4	B5	
A1	16.23±0.82^{CD}	24.81±0.44^{A}	19.92±0.21^{BC}	13.12±0.50^{D}	23.52±0.73^{AB}	16.25±0.54^{CD}	<0.001*
A2	21.54±0.74^{B}	32.51±5.39^{A}	23.70±1.88^{B}	21.98±3.02^{B}	24.68±0.26^{B}	20.79±4.27^{B}	<0.001*

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

- **A2:** There was a significant difference between different groups ($p<0.001$). The highest value was found in B1 (32.51±5.39), followed by B4 (24.68±0.26), then B2 (23.70±1.88), B3 (21.98±3.02) and B0 (21.54±0.74), while the lowest value was found in B5 (20.79±4.27). Post hoc pairwise comparisons showed B1 to have significantly higher value than other groups ($p<0.001$).

Qualitative analysis of SEM scans

The control specimens SEM scans at (1500x) magnification for FiltekTM Z350 XT (Fig.1,a) and FiltekTM Z250 XT (Fig.1,b) showed a smooth uniform surface of the resin composite samples, but multiple air voids were observed which indicated that the surface must be finished and polished as the unpolished surface still has some defects.

The scalpel roughened group samples SEM scans (Fig.2) showed that the surface is still smooth and uniform with no linear grooves or scratches after finishing with both resin composite materials used but dislodgement of some fillers was observed in FiltekTM Z250XT more than FiltekTM Z350XT. This explained the higher surface roughness values in both groups more than the control group and also in nano hybrid more than the nano filled resin composite.

The SEM scans for both polished resin composite materials (Fig.2) showed a smooth well-polished surface of the B3 and B5 groups, while scratches and voids appeared on B2 and B4.

DISCUSSION

In this study, results showed a statistically significant difference between the two resin composite materials evaluated. Nano filled resin composite (Filtek Z350 XT) had the smoothest surface regardless of the polishing method used, which consents with many previous studies.[11–15]

This might be due to the chemical composition of Filtek Z350 XT , which contains only nano fillers arranged as nanomers and nanoclusters. These clusters are formed of individual primary nanoparticles bonded together by weak intermolecular forces and these nanoparticles may break away from the nanoclusters during wear or polishing. While the numerous large voids at the surface of the nano-hybrid (Filtek Z250 XT) observed by SEM resulting from the plucking out of the large voluminous fillers contribute to the higher roughness of this resin composite.[16]

Additionally, Filtek Z250 XT still uses (PEGDMA) as a main matrix with more double bonds than (Bis-EMA 6 and UDMA), leading to less adequate curing than Filtek Z350 XT. Inadequate curing would create fewer polymers and a poor bond between the filler and the matrix which may lead to more detachment of fillers during finishing and polishing with subsequent increase in surface roughness in nano hybrid resin composite.[13]

Resin composite specimens in this study were finished using a scalpel blade no.15 which showed higher surface roughness values than the control and the polished groups but with a smooth micro surface with less voids, grooves or scratches. Also, after polishing the surface roughness could be decreased to values comparable to that of the control group. This might be due to less friction and heat avoiding surface and subsurface micro-cracks. These findings in agreement with the observations by Kup et al. (2015), as they reported in their study that scalpel finishing could be considered a reliable method to finish resin composite producing a smoother micro surface ready for polishing.[6]

Both resin composite materials polished with Sof-Lex polishing strips had a surface with many scratches and voids and had the highest surface roughness values following the scalpel roughened groups. This might be due to the time used with polishing strips could be insufficient to provide a smoother surface. This is in agreement with results of Nagammai et al.(2022).[17]

The multi-step technique using soflex extra thin polishing discs didn't produce the smoothest surface in this study. This might be due to the discrepancy between the size of abrasive particles present in the abrasive polishing disks and abraded resin material which could be the reason to create the scratches or roughs on the polished surface. This is in agreement with the results by Alfawaz et al.(2017).[12]

This is in disagreement with the results of many previous studies which reported that soflex discs produced the smoothest surface and still the best polishing instrument for both nano filled and nano hybrid resin composites due to their flexibility and their capability to cut the filler particles and matrix equally as aluminum oxide was reported to have higher hardness than most filler particles in resin composites.[13,16,18,19]

Soflex spiral wheels provided the smoothest surface with nano filled resin composite. This might be due to the design of the Sof-Lex Spiral Wheel that include 2 parallel rows of 15 individually radiating elastomeric bristles uniformly impregnated with abrasives. This flexible form can adapt well to the resin composite surface to minimize heat formation and unwanted pressure. This is in agreement with the results reported by Pala et al.(2016).[20]

This is in disagreement with the results by Wheeler et al.(2020), as they reported a higher surface roughness with soflex spiral wheels but they justified this to insufficient time for polishing (20 seconds).[21] The diversity in results might be due to the use of different finishing methods as scalpel finishing of resin composite provided a smoother surface with less voids, scratches, surface and subsurface micro cracks.

Polishing using paste and brush provided the smoothest surface with nano hybrid resin composite. This might be due to the composition of the material which contain nanoparticles, which wore down the varying sizes of filler particles. Also, the paste format of the material might have influenced this wear, favoring the sliding of the particles across the surface. This is in agreement with the results by many previous studies which recommended the use of polishing paste with nano filled and nano hybrid resin composites.[22,23]

CONCLUSION

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

1- Scalpel is a good finishing tool for resin composite to produce a smoother micro surface ready for polishing.

2- The nano filled resin composite produces a smoother surface than nano hybrid resin composite with different polishing methods.

3- Sof-lex spiral wheels are the best polishing tool for nano filled resin composite.

4- Polishing paste and brush are the best polishing system for nano hybrid resin composite.

Clinical Recommendation

Scalpel finishing technique provided a pre polished smoother micro surface free of scratches and cracks ready for polishing and can be clinically considered as a tooth friendly way for finishing resin composite restorations.

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