Effect of Polishing Pressure and Surface Wetness on Surface Roughness of Two Resin Composites of Different Filler Types(An In-Vitro Study)

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Abstract

Aim: This study to assess effect of different polishing pressures (either Light, medium and heavy) and surface condition (either dry or wet) using one step polishing system on the surface roughness of the nano-filled and nano hybrid composites.

Materials and methods: A total of 100 specimens were prepared from nanofilled (Filtek Z350 XT) and nanohybrid (Filtek Z250 XT) were used in this study. The specimens were divided into two main groups according to the type of resin composite used (A). The first group (A1) nano-filled composite and the second group (A2) nanohybrid composite. Each group was then subdivided into five subgroups (B), the first subgroup (B0) was the control group as the specimens were only cured upon a celluloid matrix without being subjected to any polishing protocol, the second subgroup (B1) was subjected to intermediate (F=100 gm) then light pressure (F=30gm) during the polishing procedure, the third subgroup (B2) was subjected to heavy (F=300gm), intermediate (F=100gm) then light pressure (F=30gm) while polishing, the fourth subgroup (B3) was subjected to heavy force (F=300 gm) then light force (F=30gm) while polishing and the fifth subgroup (B4) was subjected to heavy then intermediate force. Each subgroup except the control subgroup was divided into two classes according to the surface condition (C) during polishing (either dry (C1) or wet (C2)). Cylindrical discs of light-cured resin composite (nanofilled and nanohybrid composites), 10 mm in diameter and 5 mm in thickness, were prepared in a Teflon mold.

The polishing procedure was performed as follows: **Class 1 and 2:** nanofilled and nanohybrid composite discs were only cured upon a celluloid matrix without being subjected to any polishing protocol. **Class 3**: nanofilled composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 4**: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 5: nanofilled composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 6:** nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 7:** nanofilled composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 8**: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 9**: nanofilled composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 10**: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 11:** nanohybrid composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 12**: nanohybrid

composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 13**: nanohybrid composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 14**: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 15:** nanohybrid composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 16: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 17**: nanohybrid composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. **Class 18**: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s. All specimens were stored in 100% humidity container at 37^{o} C for 24 hours before being scanned with Environmental scanning electron microscopy (SEM) to evaluate average surface roughness (Ra). Specimens were scanned using scanning electron microscope at 1000x magnifications using backscattered electron detector (BSED). After which the 1000x scan of each specimen 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 specimen. 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 were collected and used to perform the statistical analysis and results for each group. The data were statically analyzed. Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using three-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test and the pooled error term of the three-way model. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at $p < 0.05$. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows.

Results:

Nano-hybrid (9.20±1.53) had a significantly higher value than Nano-filled (6.78±1.89) ($p<0.001$). There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (10.38±1.14), followed by HIL (heavy then Intermediate then light pressure) (8.51±1.55), then control group (7.54±1.21), and HI (heavy then intermediate pressure) (6.81±1.54), while the lowest value was found in HL (heavy then light pressure) (6.47±1.89). Post hoc pairwise comparisons showed IL to have significantly higher value than other groups ($p<0.001$). In addition, they showed HIL to have significantly higher value than HL and HI groups ($p<0.001$). Finally, Wet polishing (8.52±2.06) had a significantly higher value than dry polishing (7.56±2.23) ($p<0.001$).

Conclusions: Press-on force during polishing procedure as well as surface condition (either dry or wet) have a profound effect on the surface roughness of nano-filled and nano-hybrid resin composites.

Keywords: nano-filled composite, nano-hybrid composites, press-on force, dryness and wetness, polishing, one step polishing system

DOI: 10.48047/ecb/2023.12.9.213

Introduction:

In aesthetic dentistry, resin composites are the most commonly used materials in the rehabilitation of the oral cavity, as they meet all the requirements of preservation of the tooth, aesthetic characteristics, and the durability in the medium and in the long term [1-2]. In order to preserve the aesthetic characteristics of the tooth to be restored, it is critical to take into account the surface features of restorative materials such as surface roughness, gloss, and color stability [3-4-5]. It has been reported in research that a material should be capable of attaining and maintaining an average value of roughness below 0.2 um in vitro [6] since in anything above this value, plaque retention occurs. For this reason, it has been assumed that restoration irregularities affect the accumulation of plaque itself as well as the durability, discoloration, and aesthetic appearance of the material used. Nano technology is of great interest in resin composites research as it reduces the polymerization shrinkage and improves the mechanical properties, such as tensile strength, compressive strength and resistance to fracture, due to high filler loading and distribution through nano-clusters technology used with nano-filled composite. Meanwhile, nanohybrid composite are hybrid resin composites with nanofiller in a pre-polymerized (PPF) filler form, so that they can be handled and polished easily, showing a higher retention of surface polish and long-term gloss than other types of resin [15]. Polishing of directly placed restorations is annoying for many dentists. Although data from representative clinical surveys are not available, we may estimate that many dentists do not spend much time and effort on the polishing procedure or they even empower this step to their dental assistants [11,12]. A smooth surface reduces accumulation of the plaque, improves aesthetics, reduces the risk of material staining and wear and is good for the patient's comfort [22–23]. Surface gloss will be more maintained if the dentists spend more time in initial polishing of resin composites to accomplish a high initial gloss [16–17]. Finishing and polishing of the restoration does not mean to smoothen the restoration surface only but also to contour the restoration, to remove any overhangs and excess material, and/or to reshape the restoration to obtain an adequate anatomical form. In order to improve or maintain the aesthetic appearance of a restorative material, it is important for the surface roughness to be equal to or less than the roughness of tooth enamel in occlusal contact areas [4-7]. Therefore, the surface treatment with a suitable finishing and polishing technique with proper pressure application is considered an essential procedure in order to achieve a desirable aesthetic result and to increase the longevity of the tooth restoration [8-9-10].

Roughly, the dental market distinguishes between three different polishing systems: (a) three-step systems with finisher (for contouring), polisher and high gloss polisher; (b)two-step systems with finisher and polisher and (c) one-step systems that is to perform both finishing and polishing in one step. It seems to be variations between different dentists with regard to the use of one-step, two-step or three-step polishing systems. The survey carried by the North American test institute Dental Advisor has revealed that 69% of the US clinical consultants surveyed using single-step polishers [(20)]. Recently, diamond polishers have been introduced to decrease clinical time for restoration. These are known as "one-step" polishing systems as contouring, finishing, and polishing procedures can be completed using a single instrument. This type of polishing concept meets the clinical demand for obtaining a smooth surface in a minimal period of time [(14)]. The manufacturers offer different shapes to adapt with the anatomy of the tooth to be restored. Moreover, the polishers can be made of many materials, such as silicone, polyurethane and rubber. On adding small synthetic diamond particles, the polishing action on both composite and ceramic materials is enhanced [(18,20,22)]. Some manufacturers of dental polishing systems recommend dentists to use a specific press-on force, mostly 2 N or below 2 N (e.g. Kenda and Shofu). However, it is not easy for dentists to assess the press-on force. In vitro studies have shown [(13)], that the press-on force has an influence on both surface gloss and surface roughness according to the material being polished. [(24)] The statement of the problem is, during finishing and polishing procedure pressure adjustment, wetness/dryness surface condition as well as type of resin composite is crucial. So, it was beneficial to conduct this study to assess effect of different polishing pressures and wetness/dryness surface condition using one step polishing system on the surface roughness of the nano-filled and nano hybrid composites [(19,21)]. The null hypothesis tested in this study was: there was no significant difference between different polishing pressures as well as the wetness/dryness of the surface for both the nano-filled and nano hybrid composites.

Materials and methods:

The following materials and devices were used in this study. Nanofilled resin composite (Filtek Z350 XT shade A2 Body, 3M ESPE, USA). Nanohybrid resin composite (Filtek Z250 XT shade A2 body, 3M ESPE, USA). Light curing unit (3M ESPE Elipar Deep Cure, Germany). One step

finisher and polisher for composite (OneGloss, Shofu INC Japan). Sensitive kitchen balance (Sensitive Electronic Digital Kitchen Scale - 10 Kg.). Yellow coded flame diamond stone (Diaswiss flame finishing stone). Material, description, composition and manufacturer were listed in table (1).

Table (1): Material, description, composition and manufacturer.

Material	Description	Composition	Manufacturer
Filtek Z350 XT Universal Restorative	**Nanofilled** Resin Composite	filler: 78.5% by weight (63.3% by volume) combination of aggregated zirconia/silica cluster ranging from 0.6 to 1.4 μm, with the primary particle size, 5-20nm and non-agglomerated 20nm silica filler, 4 to 11 nm zirconia filler.	3M/ESPE, MN, USA
Filtek Z250 XT Universal Restorative	**Nanohybird** Resin Composite	Filler Percentage Weight: 82% Volume: 60 %The particle size distribution is 0.01μm to 3.5μm with an average particle size of 0.6μm.	3M/ESPE, MN, USA
One Gloss	One step finisher and polisher for composite	Aluminum Oxide impregnated silicone Points mounted to plastic mandrel	Shofu INC Japan

Study Design

A total of 100 specimens were prepared from nanofilled (Filtek Z350 XT) and nanohybrid (Filtek Z250 XT) for measuring the effect of 3 different pressure forces (light, intermediate and heavy forces) and the surface condition (either dry or wet) on composite surface roughness using "one step" polishing system

Specimens grouping:

The specimens were divided into two main groups according to the type of resin composite used (A). The first group (A1) nano-filled composite and the second group (A2) nanohybrid composite. Each group was then subdivided into five subgroups (B), the first subgroup (B0) was the control group as the specimens were only cured upon a celluloid matrix without being subjected to any polishing protocol, the second subgroup (B1) was subjected to intermediate (F=100 gm) then light pressure (F=30gm) during the polishing procedure, the third subgroup (B2) was subjected to heavy (F=300gm), intermediate (F=100gm) then light pressure (F=30gm) while polishing, the fourth subgroup (B3) was subjected to heavy force (F=300 gm) then light force (F=30gm) while polishing and the fifth subgroup (B4) was subjected to heavy then intermediate

force. Each subgroup except the control subgroup was divided into two classes according to the surface condition (C) during polishing (either dry (C1) or wet (C2)).

Specimen preparation:

Cylindrical discs of light-cured resin composite (nanofilled and nanohybrid composites), 10 mm in diameter and 5 mm in thickness, were prepared in a Teflon mold. Composites were packed into the Teflon mold in 3 increments of about 2 mm each and placed between two transparent Mylar strips. Each increment was cured for 40 seconds according to the manufacturer's instructions using a light-emitting diode curing unit (3M ESPE Elipar Deep Cure, Germany) with a 10 mm diameter tip. The light intensity of 1800 mW/cm2 as measured with a specific radiometer (LITEX 682 Dentamirica, USA) was used for light curing. Once the top increment was applied, its surface was covered by a celluloid strip and then a glass slab and a constant pressure was applied to provide a flat, smooth surface and to extrude the excess material. The intensity of the light was checked between specimens. Additional polymerization was done on both sides of the specimen for 20 seconds after removing the strips and glass slaps. All specimens were checked for voids using 3x magnifying loupe (UNIVET, Italy) to prevent any possible voids from being included in the roughness measurement. If voids were found, the specimen was discarded and a new specimen was obtained.

Finishing and polishing procedures:

The experimental surface of the composite disc cured against the mylar strip (except for the control group) was ground for 30 seconds with yellow coded flame finishing stone (equivalent to 600-800 grit sanding papers) (standard finished surface) with high-speed handpiece under coolant in varying directions with the same operator then rinsed and air dried to standardize the beginning point in all specimens representing the finishing step.

In order to reduce variations, the same operator carried on all the polishing procedures with the same low speed handpiece adjusted at speed of 5000 rpm. Using a kitchen scale as a pressure guide, the same operator applied pressure during the polishing procedure according to the assigned

subgroup. Polishing of the specimens was done using the one step One Gloss polishing kit (Shofu) on a kitchen scale to measure the amount of force during the polishing process. Ten strokes were applied on the surface for each assigned pressure. 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 procedure was performed as follows:

Class 1 and 2: nanofilled and nanohybrid composite discs were only cured upon a celluloid matrix without being subjected to any polishing protocol.

Class 3: nanofilled composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 4: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 5: nanofilled composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 6: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 7: nanofilled composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 8: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 9: nanofilled composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 10: nanofilled composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 11: nanohybrid composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 12: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

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Class 14: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in dry condition without coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 15: nanohybrid composite discs were subjected to intermediate (F=100 gm) for 20 s then light pressure (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 16: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate pressure (F=100gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 17: nanohybrid composite discs were subjected to heavy force (F=300 gm) for 20 s then light force (F=30gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

Class 18: nanohybrid composite discs were subjected to heavy (F=300gm) for 20 s then intermediate force (F=100 gm) for 20 s in wet condition with coolant. Then specimens were rinsed and dried with air/water syringe for a total of 10 s.

All specimens were stored in 100% humidity container at 37^{o} C for 24 hours before being scanned with Environmental scanning electron microscopy (SEM) to evaluate average surface roughness (Ra).

Scanning electron microscopy (SEM) and average surface roughness (Ra) measurements:

After polishing of the resin composite samples according to their assigned subgroup, the specimens were scanned using scanning electron microscope at 1000x magnifications using backscattered electron detector (BSED). After which the 1000x scan of each specimen 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 specimen. 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 two 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 were collected and used to perform the statistical analysis and results for each group.

Statistical analysis:

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using three-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test and the pooled error term of the three-way model. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at $p < 0.05$. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows[1].

[1]R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Results:

1- Effect of different variables and their interaction:

Effect of different variables and their interaction on surface roughness (nm) were presented in table (2)

There was a significant interaction between material-pressure ($p<0.001$) and between pressure-dryness ($p=0.001$).

Table (2): Effect of different variables and their interactions on surface roughness (nm)

Source	Sum of Squares	df	Mean Square	f-value	p-value
Material	145.75	1	145.75	347.41	**<0.001***
Pressure type	232.12	3	77.37	184.43	**<0.001***
Dryness	21.88	1	21.88	52.15	**<0.001***
Material * Pressure type	9.92	3	3.31	7.88	**<0.001***
Material* Dryness	.30	1	.30	.72	**0.400ns**
Pressure type*dryness	7.37	3	2.46	5.85	**0.001***
Material * pressure type*dryness	2.40	3	.80	1.91	**0.135ns**

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

2- Effect of material:

Mean, Standard deviation (SD) values of surface roughness (nm) for different materials were presented in table (3) and figure (1)

Nano-hybrid (9.20±1.53) had a significantly higher value than Nano-filled (6.78±1.89) ($p<0.001$).

Table (3): Mean, Standard deviation (SD) values of surface roughness (nm) for different materials

Surface roughness (nm) (mean±SD)		p-value
Nano-filled	Nano-hybrid	
6.78±1.89	9.20±1.53	**<0.001***

*; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

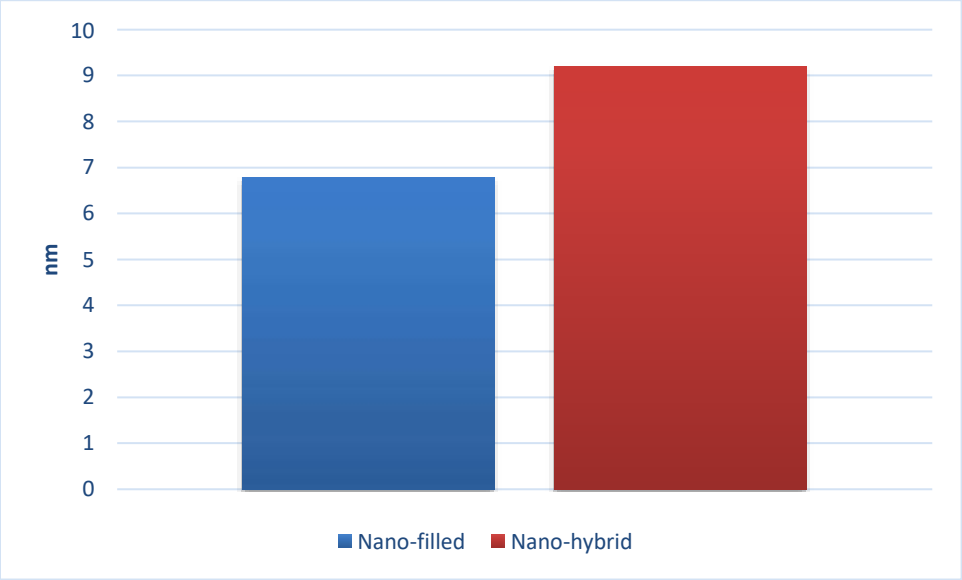

Figure (1): Bar chart showing average surface roughness (nm) for different materials

3- Effect of pressure type:

Mean, Standard deviation (SD) values of surface roughness (nm) for different pressure types were presented in table (4) and figure (2)

There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (10.38±1.14), followed by HIL (heavy then

Intermediate then light pressure) (8.51±1.55), then control group (7.54±1.21), and HI (heavy then intermediate pressure) (6.81±1.54), while the lowest value was found in HL (heavy then light pressure) (6.47±1.89). Post hoc pairwise comparisons showed IL to have significantly higher value than other groups ($p<0.001$). In addition, they showed HIL to have significantly higher value than HL and HI groups ($p<0.001$).

Table (4): Mean, Standard deviation (SD) values of surface roughness (nm) for different pressure types

Surface roughness (nm) (mean±SD)					p-value
Control	**IL**	**HIL**	**HL**	**HI**	
$7.54±1.21^{BC}$	$10.38±1.14^{A}$	$8.51±1.55^{B}$	$6.47±1.89^{C}$	$6.81±1.54^{C}$	**<0.001***

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

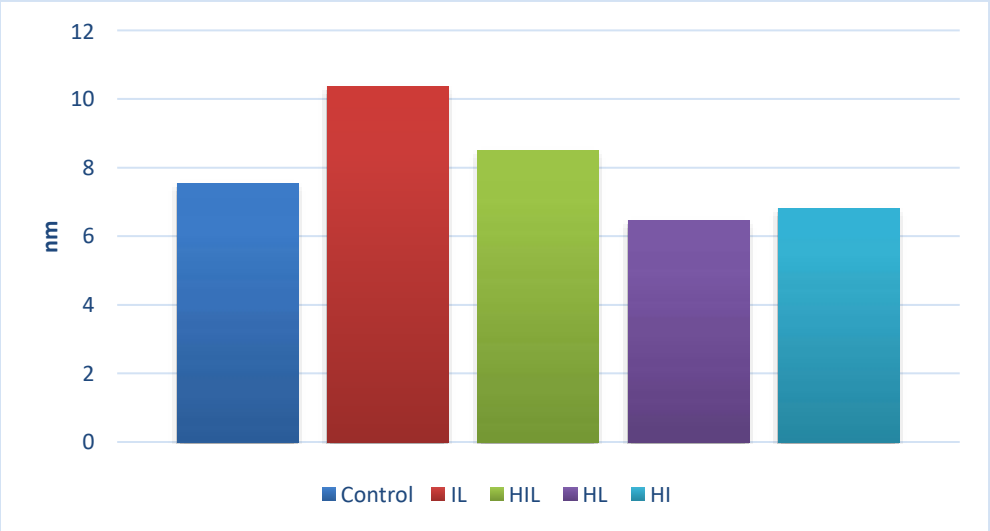

Figure (2): Bar chart showing average surface roughness (nm) for different pressure types

4- Effect of dryness:

Mean, Standard deviation (SD) values of surface roughness (nm) for dryness effect were presented in table (5) and figure (3)

Wet polishing (8.52±2.06) had a significantly higher value than dry polishing (7.56±2.23) ($p<0.001$).

Table (5): Mean, Standard deviation (SD) values of surface roughness (nm) for dryness effect

Surface roughness (nm) (mean±SD)		p-value
Dry	**Wet**	
7.56±2.23	8.52±2.06	**<0.001***

*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

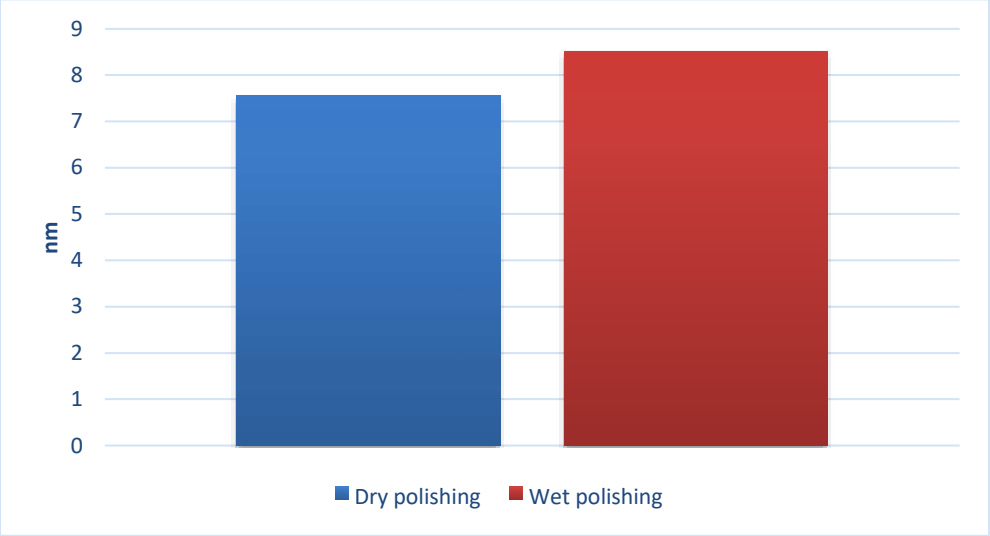

Figure (3): Bar chart showing average surface roughness (nm) for dryness effect

5- Effect of material within other variables:

Mean, Standard deviation (SD) values of surface roughness (nm) for different materials within other variables were presented in table (6) and figure (4)

1-Control:

Nano-hybrid (8.57±0.44) had a significantly higher value than Nano-filled (6.51±0.68) ($p<0.001$).

2- IL (Intermediate then light pressure):

- **Dry:**

Nano-hybrid (10.79±0.80) had a significantly higher value than Nano-filled (9.39±0.75) ($p=0.011$).

- **Wet:**

Nano-hybrid (11.35±0.80) had a significantly higher value than Nano-filled (9.97±1.17) ($p=0.039$).

3- HIL (heavy then intermediate then light pressure):

- **Dry:**

Nano-hybrid (9.85±0.55) had a significantly higher value than Nano-filled (6.70±0.31) ($p<0.001$).

- **Wet:**

Nano-hybrid (10.01±0.56) had a significantly higher value than Nano-filled (7.48±0.55) ($p<0.001$).

4- HL (heavy then light pressure):

- **Dry:**

Nano-hybrid (6.77±0.49) had a significantly higher value than Nano-filled (4.29±0.19) ($p<0.001$).

- **Wet:**

Nano-hybrid (9.20±0.39) had a significantly higher value than Nano-filled (5.60±0.51) ($p<0.001$).

5- HI (heavy then intermediate pressure):

- **Dry:**

Nano-hybrid (7.55±0.62) had a significantly higher value than Nano-filled (5.17±0.32) ($p<0.001$).

- **Wet:**

Nano-hybrid (8.66±0.92) had a significantly higher value than Nano-filled (5.87±0.67) ($p<0.001$).

Table (6): Mean, Standard deviation (SD) values of surface roughness (nm) for different materials within other variables

Pressure type	Dryness	Surface roughness (nm) (mean±SD)		p-value
		Nano-filled	Nano-hybrid	
Control		6.51±0.68	8.57±0.44	**<0.001***
IL	**Dry**	9.39±0.75	10.79±0.80	**0.011***
	Wet	9.97±1.17	11.35±0.80	**0.039***
HIL	**Dry**	6.70±0.31	9.85±0.55	**<0.001***
	Wet	7.48±0.55	10.01±0.56	**<0.001***
HL	**Dry**	4.29±0.19	6.77±0.49	**<0.001***
	Wet	5.60±0.51	9.20±0.39	**<0.001***
HI	**Dry**	5.17±0.32	7.55±0.62	**<0.001***
	Wet	5.87±0.67	8.66±0.92	**<0.001***

*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

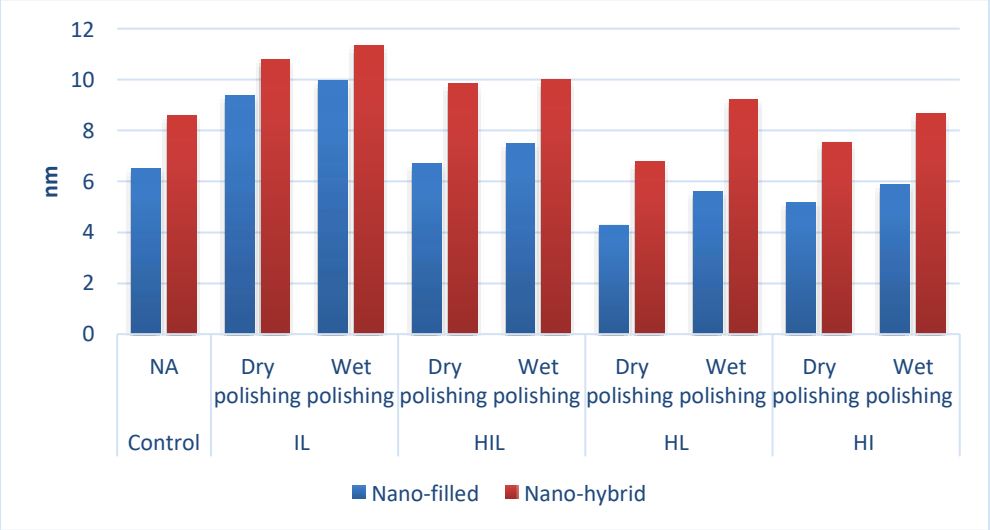

Figure (4): Bar chart showing average surface roughness (nm) for different materials within other variables

6- Effect of pressure type within other variables:

Mean, Standard deviation (SD) values of surface roughness (nm) for different pressure types within other variables were presented in table (7) and figure (5)

1- Nano-filled:

- **Dry:**

There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (9.39±0.75), followed by HIL (heavy then Intermediate then light pressure) (6.70±0.31), then control group (6.51±0.68), and HI (heavy then intermediate pressure) (5.17±0.32), while the lowest value was found in HL (heavy then light pressure) (4.29±0.19). Post hoc pairwise comparisons showed IL to have significantly higher value than other groups ($p< 0.001$). In addition, they showed HIL and the control group to have significantly higher values than HI and HL ($p<0.001$). Finally, they showed HI to have significantly higher value than HL ($p<0.001$).

- **Wet:**

There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (9.97±1.17), followed by HIL (heavy then Intermediate then light pressure) (7.48±0.55), then control group (6.51±0.68), and HI (heavy then intermediate pressure) (5.87±0.67), while the lowest value was found in HL (heavy then light pressure) (5.60±0.51). Post hoc pairwise comparisons showed IL to have significantly higher value than other groups ($p< 0.001$). In addition, they showed HIL to have significantly higher value than HI and HL ($p<0.001$).

2- Nano-hybrid:

- **Dry:**

There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (10.79±0.80), followed by HIL (heavy then Intermediate then light pressure) (9.85±0.55), then control group (8.57±0.44), and HI (heavy then intermediate pressure) (7.55±0.62), while the lowest value was found in HL (heavy then light pressure) (6.77±0.49). Post hoc pairwise comparisons showed IL and HIL to have significantly

higher values than other groups ($p< 0.001$). In addition, they showed the control group to have significantly higher value than HI and HL ($p<0.001$).

- **Wet:**

There was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (11.35±0.80), followed by HIL (heavy then Intermediate then light pressure) (10.01±0.56), then HL (heavy then light pressure) (9.20±0.39), and HI (heavy then intermediate pressure) (8.66±0.92), while the lowest value was found in control group (8.57±0.44). Post hoc pairwise comparisons showed IL to have significantly higher values than other groups ($p< 0.001$). In addition, they showed HIL to have significantly higher value than HI and the control group ($p<0.001$).

Table (7): Mean, Standard deviation (SD) values of surface roughness (nm) for different pressure types within other variables

Material	Dryness	Surface roughness (nm) (mean±SD)					p-value
		Control	IL	HIL	HL	HI	
Nano-filled	Dry	6.51±0.68^{B}	9.39±0.75^{A}	6.70±0.31^{B}	4.29±0.19^{D}	5.17±0.32^{C}	**<0.001***
	Wet	6.51±0.68^{BC}	9.97±1.17^{A}	7.48±0.55^{B}	5.60±0.51^{C}	5.87±0.67^{C}	**<0.001***
Nano-hybrid	Dry	8.57±0.44^{B}	10.79±0.80^{A}	9.85±0.55^{A}	6.77±0.49^{C}	7.55±0.62^{C}	**<0.001***
	Wet	8.57±0.44^{C}	11.35±0.80^{A}	10.01±0.56^{B}	9.20±0.39^{BC}	8.66±0.92^{C}	**<0.001***

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

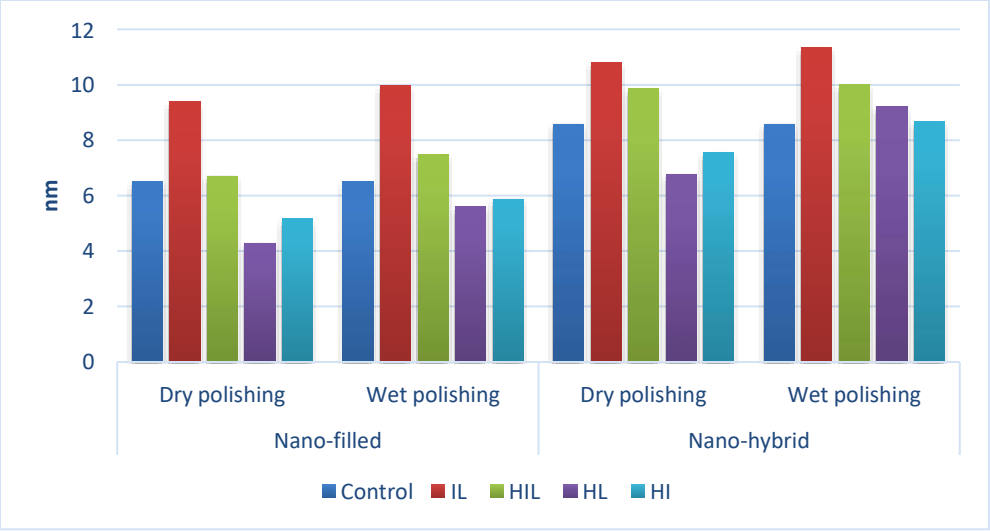

Figure (5): Bar chart showing average surface roughness (nm) for different pressure types within other variables

7- Effect of dryness within other variables:

Mean, Standard deviation (SD) values of surface roughness (nm) for dryness effect within other variables were presented in table (8) and figure (6)

1- Nano-filled:

- **IL (Intermediate then light pressure):**

Wet polishing (9.97±1.17) had a higher value than dry polishing (9.39±0.75) yet the difference was not statistically significant (p=0.333).

- **HIL (heavy then Intermediate then light pressure):**

Wet polishing (7.48±0.55) had a significantly higher value than dry polishing (6.70±0.31) (p=0.013).

- **HL (heavy then light pressure):**

Wet polishing (5.60±0.51) had a significantly higher value than dry polishing (4.29±0.19) (p<0.001).

- **HI (heavy then intermediate pressure):**

Wet polishing (5.87±0.67) had a significantly higher value than dry polishing (5.17±0.32) (p=0.042).

2- Nano-hybrid:

- **IL (Intermediate then light pressure):**

Wet polishing (11.35±0.80) had a higher value than dry polishing (10.79±0.80) yet the difference was not statistically significant (p=0.254).

- **HIL (heavy then Intermediate then light pressure):**

Wet polishing (10.01±0.56) had a higher value than dry polishing (9.85±0.55) yet the difference was not statistically significant (p=0.623).

- **HL (heavy then light pressure):**

Wet polishing (9.20±0.39) had a significantly higher value than dry polishing (6.77±0.49) (p<0.001).

- **HI (heavy then intermediate pressure):**

Wet polishing (8.66±0.92) had a significantly higher value than dry polishing (7.55±0.62) (p=0.034).

Table (8): Mean, Standard deviation (SD) values of surface roughness (nm) for dryness effect within other variables

Material	Pressure type	Surface roughness (nm) (mean±SD)		p-value
		Dry	Wet	
Nano-filled	IL	9.39±0.75	9.97±1.17	**0.333ns**
	HIL	6.70±0.31	7.48±0.55	**0.013***
	HL	4.29±0.19	5.60±0.51	**<0.001***
	HI	5.17±0.32	5.87±0.67	**0.042***
Nano-hybrid	IL	10.79±0.80	11.35±0.80	**0.254ns**
	HIL	9.85±0.55	10.01±0.56	**0.623ns**
	HL	6.77±0.49	9.20±0.39	**<0.001***
	HI	7.55±0.62	8.66±0.92	**0.034***

*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

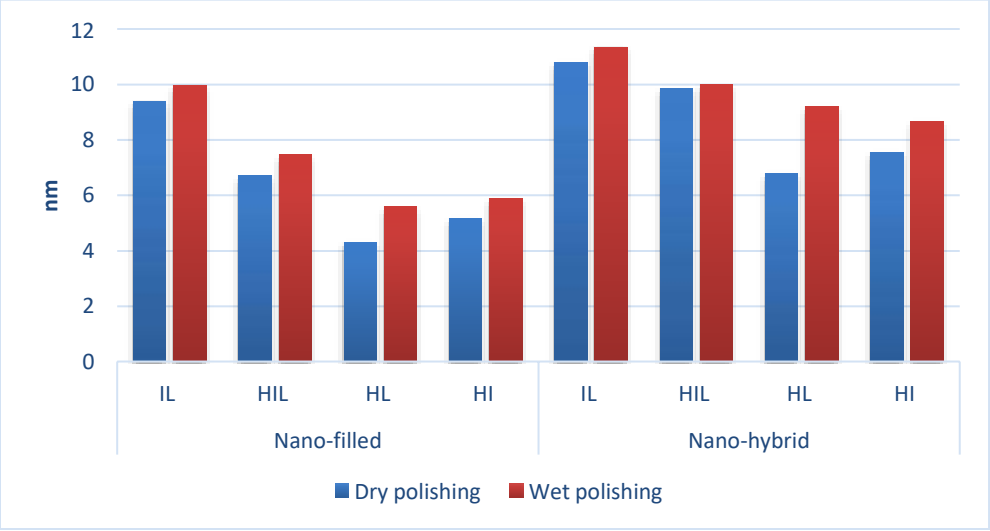

Figure (6): Bar chart showing average surface roughness (nm) for dryness effect within other variables.

Figure (7): SEM photomicrograph (x1000) of nanofilled composite without any polishing protocol (control)

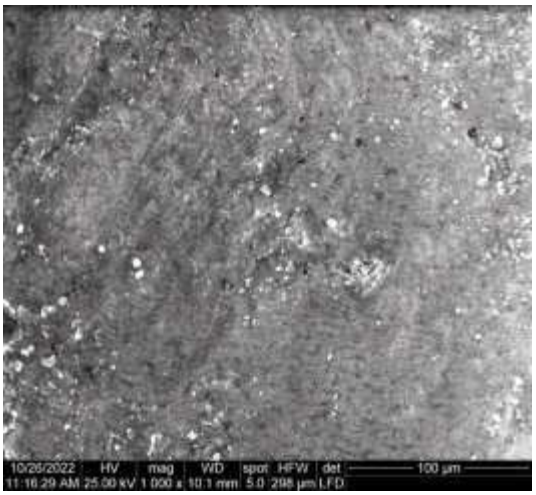

Figure (8): SEM photomicrograph (x1000) of nanohybrid composite without any polishing protocol (control)

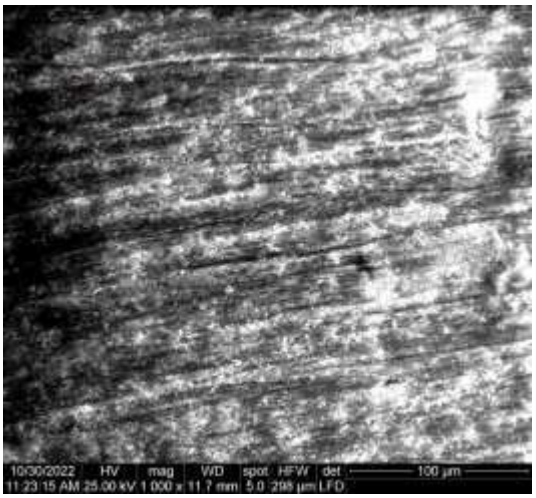

Figure (9): SEM photomicrograph (x1000) of nanofilled composite subjected to intermediate then light pressure in dry condition without coolant

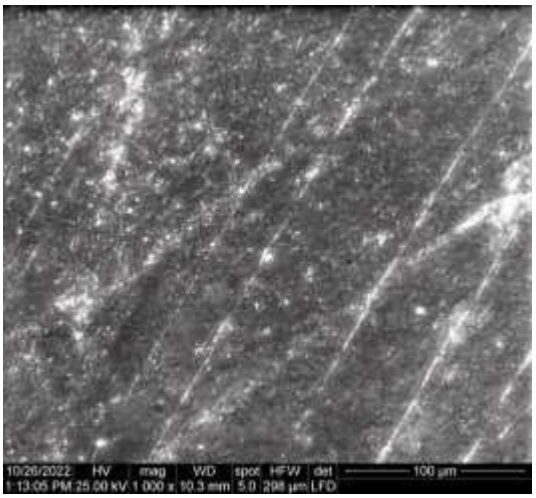

Figure (10): SEM photomicrograph (x1000) of nanohybrid composite subjected to intermediate then light pressure in dry condition without coolant

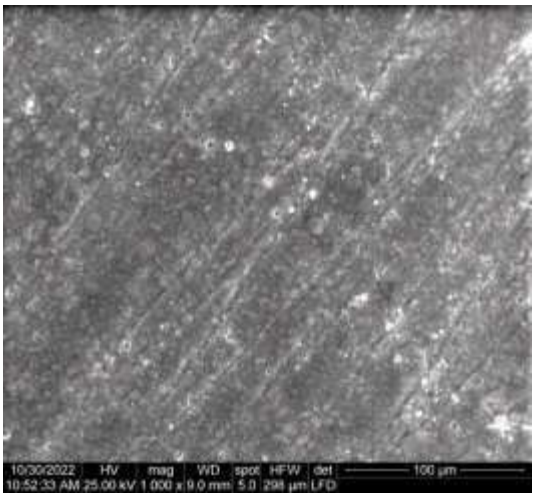

Figure (11): SEM photomicrograph (x1000) of nanofilled composite subjected to heavy then intermediate then light pressure in dry condition without coolant

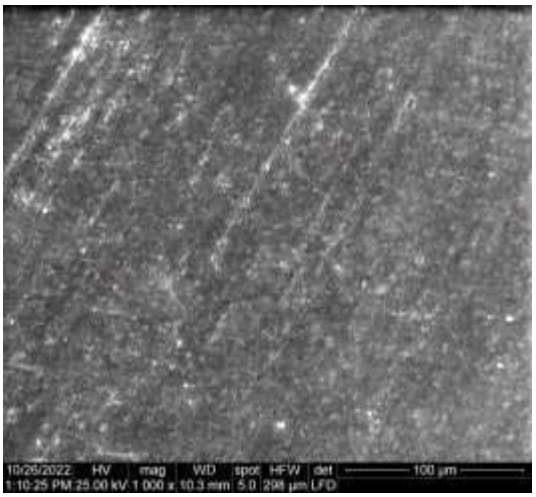

Figure (12): SEM photomicrograph (x1000) of nanohybrid composite subjected to heavy then intermediate then light pressure in dry condition without coolant

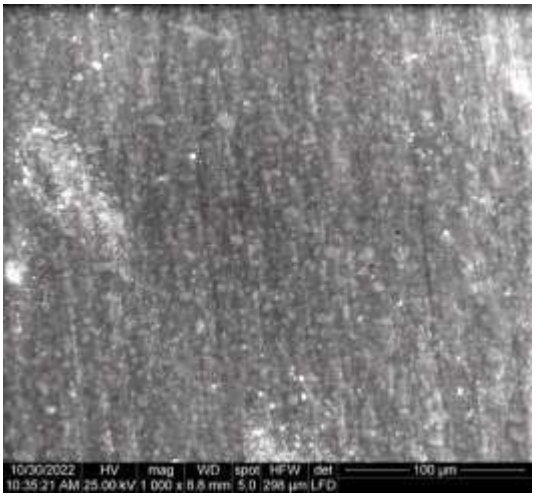

Figure (13): SEM photomicrograph (x1000) of nanofilled composite subjected to heavy force then light force in dry condition without coolant

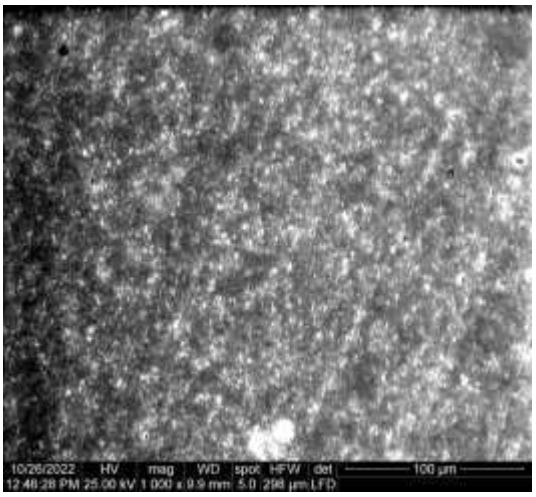

Figure (14): SEM photomicrograph (x1000) of nanohybrid composite subjected to heavy force then light force in dry condition without coolant

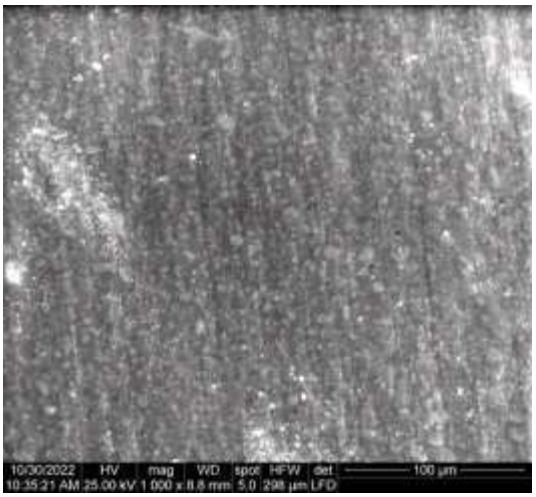

Figure (15): SEM photomicrograph (x1000) of nanofilled composite subjected heavy then intermediate in dry condition without coolant

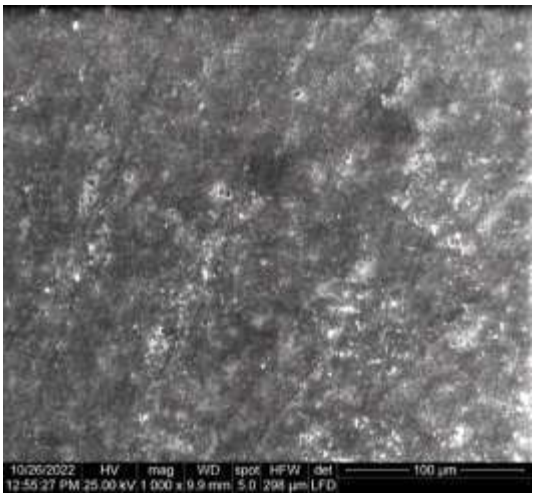

Figure (16): SEM photomicrograph (x1000) of nanohybrid composite subjected heavy then intermediate in dry condition without coolant

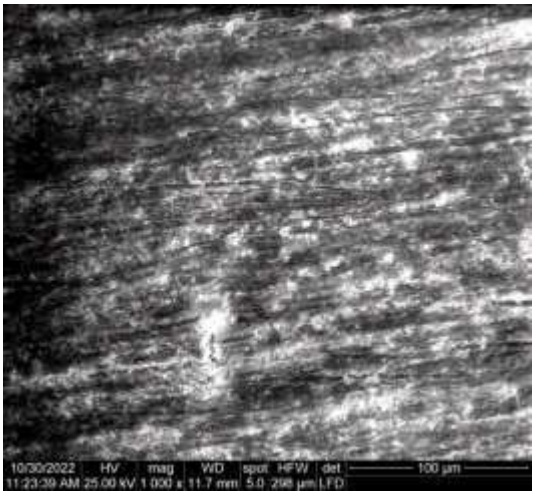

Figure (17): SEM photomicrograph (x1000) of nanofilled composite subjected to intermediate then light pressure in wet condition with coolant

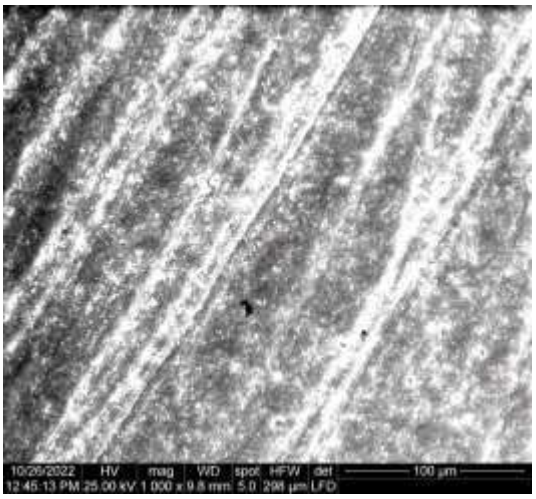

Figure (18): SEM photomicrograph (x1000) of nanohybrid composite subjected to intermediate then light pressure in wet condition with coolant

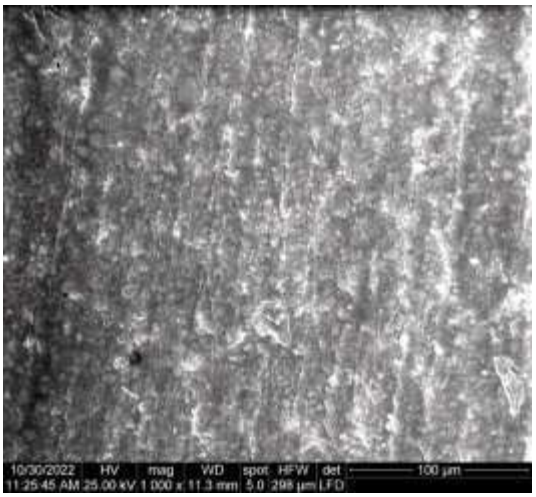

Figure (19): SEM photomicrograph (x1000) of nanofilled composite subjected to heavy then intermediate then light pressure in wet condition with coolant

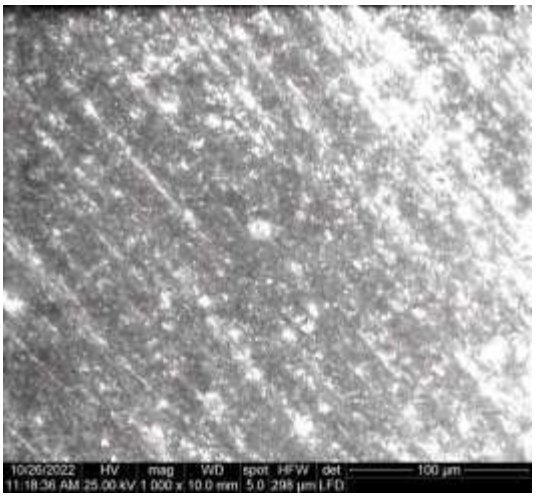

Figure (20): SEM photomicrograph (x1000) of nanohybrid composite subjected to heavy then intermediate then light pressure in wet condition with coolant

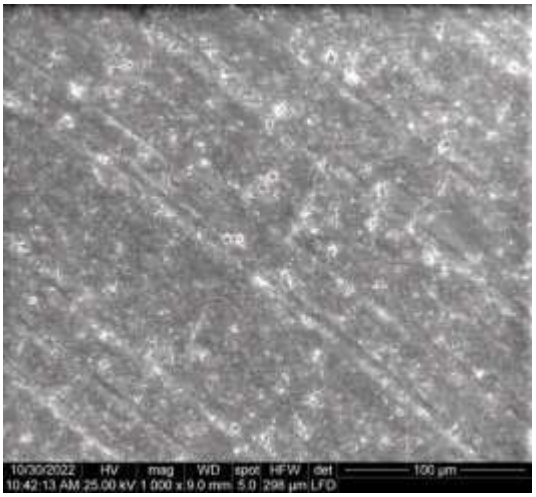

Figure (21): SEM photomicrograph (x1000) of nanofilled composite subjected to heavy force then light force in wet condition with coolant

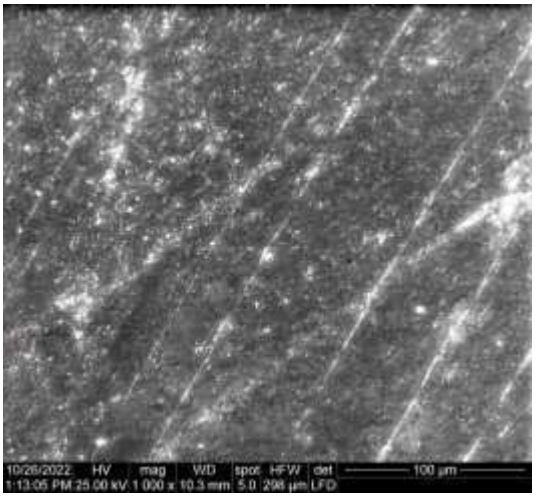

Figure (22): SEM photomicrograph (x1000) of nanohybrid composite subjected to heavy force then light force in wet condition with coolant

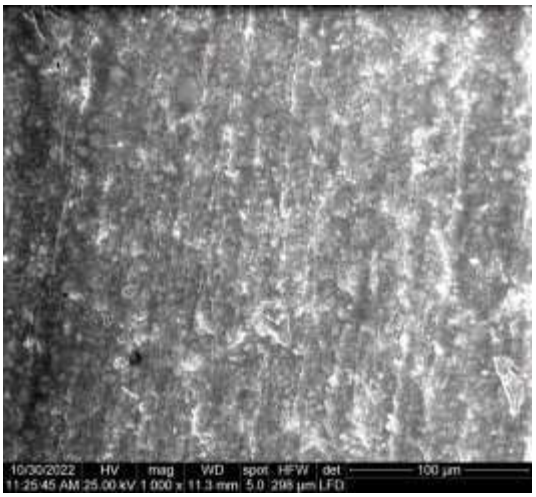

Figure (23): SEM photomicrograph (x1000) of nanofilled composite subjected heavy then intermediate in wet condition with coolant

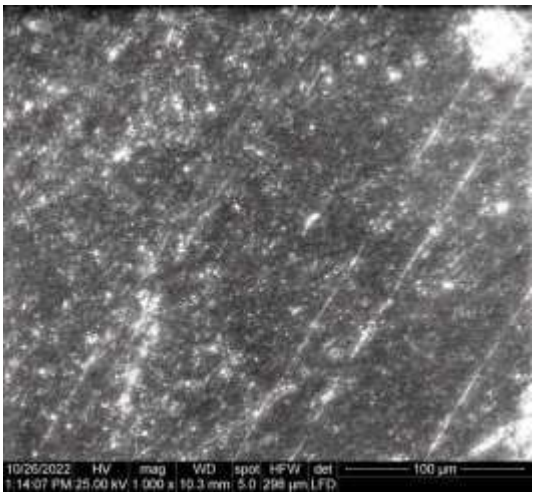

Figure (24): SEM photomicrograph (x1000) of nanohybrid composite subjected heavy then intermediate in wet condition with coolant

Discussion:

The surface texture of dental materials has a major influence on plaque accumulation, discoloration, wear and the aesthetical appearance of both direct and indirect restorations [22]. Furthermore, a smooth surface adds to the patient's comfort, as already a change of surface roughness in the order of 0.3 mm can be detected by the tip of the patient's tongue [25]. Increasing roughness is correlated with increased deposition of plaque [26] and staining [27]. Furthermore, an increased surface roughness accelerates the wear of dental materials. In order to resolve this problem, referring to standard operating procedure, ***finishing and polishing*** should be done after every treatment using a composite resin. Polishing is done to produce good physical properties with a smooth and shiny surface so that an esthetic restoration of good quality can be achieved [28]. The effectivity of polishing is affected by a few factors, one of which is the materials used and the polishing protocol [29] ***The polishability*** of dental materials in relation to polishing systems is normally tested in vitro on flat specimens using dental handpieces, a defined rotation speed and a predefined polishing time. Mostly, ***the press-on force*** is not controlled during the polishing procedures and this issue is not even mentioned in the material and method or the discussion section of the studies. However, there are no systematic studies evaluating the roughness and gloss of dental materials and polishing results as a function of different press- on forces. The polishing process is a very dynamic task. The polisher is constantly moving on the tooth surface. The forces acting on them are also subjected to constant fluctuations. In this study, all polishing procedures were applied by the same operator according to their corresponding manufacturers recommendations in order to achieve predictable results. Moreover, the speed and motion used during the polishing were fixed, guided by the range of their manufacturers, to reduce the variability for all polishing protocols [30,31,32]. The press-on force during the polishing procedure in this study was controlled using a sensitive digital kitchen scale to keep it at the assigned pressure according to the assigned study subgroups [33]. In addition, rehearsal on the applied pressure was done by the operator prior to the experiment with other composite discs samples mounted on the digital scale, which were disregarded and not included in the experimental samples, to insure the standardization of each stroke within the range of light to heavy pressure (30-300 grams) during the polishing procedure. Besides the press-on force of polishing, ***the surface condition (dryness***

and wetness) is considered to be of great importance. The polishing can be done either in dry or wet condition. The dry protocol can cause a better view and administration of the work area, but it generates a lot of heat, which can affect the restoration properties. On the other hand, wet polishing protocol used to decrease the temperature in order to prevent the damages caused by heat [(34)]. There is no consensus on which condition provides the best surfaces roughness. That is why the present study was to evaluate the effect of dry and wet polishing on the surface roughness of the used resin composites. ***Regarding the effect of resin composite type,*** Nano-hybrid composite (9.20±1.53) had a significantly higher value than Nano-filled composite (6.78±1.89). This could be due to the difference in filler technology between nanofilled composite that provide smoother surface in comparison to nanohybrid composite. Nanohybrid composite has larger and irregular filler size. The larger and irregular fillers tend to be more protrusive after the curing process and detach easily after finishing and polishing leaving rough surface. When the larger filler detached from the matrix, it would create a large hole on the surface and increase the surface roughness. Consequently, it was concluded that the larger the filler size, the higher the surface roughness after the polishing procedure. Larger and irregular filler size were obtained by grinding larger particles and causing a lot of space between fillers, that is why manufacturers added nanomer and nanocluster inside to fill the space in the nanofilled composite. In addition, the used nanohybrid composite uses PEGDMA as a main matrix with more double bonds than Bis-EMA 6 and UDMA, making the curing process less adequate than the used nanofilled composite. An inadequate curing process would create fewer polymers and a poor bond between the filler and the matrix [(35)]. On the contrary, nanofilled composite resin with nanomer and nanocluster particles might produce few defects and scratches as a result of friction from the finishing instrument [(36)]. During the polishing procedure, nanomer and nanocluster particles were abraded easily along with the resin matrix. The interparticle nanomer bond which constructs nanoclusters would detach, easily providing a smoother surface[(37)]. Furthermore, nanomer of the nanofilled composite was added with silane on its surface so that it would create a strong bond with the matrix during curing. This was supported by the matrix system which contains more Bis-EMA 6 and UDMA with less double bonds, increasing the degree of resin matrix polymerization. These results were in agreement with studies like Da Costa's that proved that nanofilled composite resin surface roughness was better than nanohybrid resin after polishing [(38)]. Moreover, these results were in accordance with other studies

conducted by Khorgami [39] and Endo [40]. Khorgami stated that the average Z350 XT composite filler size was smaller because it comprised spherical shaped nano sized particles (nanomer) combined with nanocluster particles made from the sintering process. The sintering process on Filtek Z350 XT was not as adequate as the first generation of nanofilled resin; therefore, the interparticle nano bond was more easily detached [39]. Furthermore, Endo stated that the spherical nanomer made from turning liquid into solid caused more filler [40]. Additionally, more load would cause the composite resin to be easily polished since more filler particles were in contact with the polishing instrument to minimalize excessive abrasion to the resin matrix [36]. On the contrary, other studies have proved that nanohybrid surface roughness after polishing was better than that of nanofilled resin [41]. ***Endo*** [40] also reported rougher surface was obtained after finishing and polishing in the nanofilled composite. Endo suggested that it would be better for the finishing procedure to be carried out by aggressive tool as 600-grit SiC paper or carbide bur before polishing [40]. ***Concerning the effect of pressure exerted during the polishing procedure,*** there was a significant difference between different groups ($p<0.001$). The highest value was found in IL (Intermediate then light pressure) (10.38±1.14), followed by HIL (heavy then Intermediate then light pressure) (8.51±1.55), then control group (7.54±1.21), and HI (heavy then intermediate pressure) (6.81±1.54), while the lowest value was found in HL (heavy then light pressure) (6.47±1.89). Post hoc pairwise comparisons showed IL to have significantly higher value than other groups. In addition, they showed HIL to have significantly higher value than HL and HI groups. In addition, the HIL group (heavy then Intermediate then light pressure) has significantly higher value than HL (heavy then light pressure) and HI (heavy then intermediate pressure) groups. This can be attributed to the effect of friction between the polishing tool and the composite surface that might smoothen the outer surface of the composite by the effect of heat production. As polishing procedure has a micro-grinding effect on the material surface causing material removal through abrasive wear, ductile flow and some degree of micro-fracturing. Additionally, application of heavy pressure obtains better control of the polishing tip and tactile sense to obtain smoother surface with the impregnated abrasive particles in the polishing system used. Moreover, the used polishing system was relatively not resilient; so, the pressure was transmitted to the polished surface that maximize the polishing effect of the tool on the composite surface. Rubber discs are stiffer and do not compensate for higher pressure when compared to flexible discs which bend and

counteract the increase in pressure. Another attribution could be the shape of the polishing tool used. Disc polishing tip with its flat and wide contact area with the flat surface of the specimens emphasized the effect of the press-on force and improved the balanced control of the tool over the specimens. Oppositely, light and medium pressure with the low-speed handpiece might affect the control of the polishing tip causing eccentric movements resulted in scratches and rougher surface of the specimens. Our results were in accordance with ***Heintze et al 2019*** [(42)], they used single step polishing system as this study and their conclusion was that the press-on forces during polishing varied significantly between dentists and within the same dentist when testing this variable among ten dentists. They used single step polishing system and the press-on force exceeded 2N during a considerable polishing. Another variable that should be considered during polishing is the shape of polishing tool which is highly dependent on the operator preference. These results were in disagreement with ***Lehmann et al 2021*** [(31)], as they concluded that the higher-pressure force during polishing may generate greater roughness of the composite material. This might be due to difference in the methodology of the study as they used microfilled composites and multi-step finishing and polishing discs. Moreover, ***Yu et al 2023***, [(43)] concluded that for optimal smoothness and gloss, materials must be polished using a 1.0 to 1.5 N force. They also used multi-step finishing and polishing discs and different restorative materials as CAD/CAM composite blocks. ***Concerning the combined press-on force***, groups with heavy pressure combined with intermediate and light pressure showed better surface roughness (6.81±1.54 and 6.47±1.89) than those without heavy pressure (10.38±1.14). This might be due to the dominating effect of the high pressure over the other pressures. Absence of the high force may lead to rougher surface due to loss of control of the polishing tools that increases surface scratches and roughness. Moreover, lack of full control on the low-speed handpiece accentuates the effect of eccentricity even it was very little in the handpiece. ***Regarding effect of surface condition (dryness/wetness),*** Wet polishing (8.52±2.06) had a significantly higher value than dry polishing (7.56±2.23). This could be explained by the temperature increase at the surface with coolant absence due to frictional forces causing localized softening and melting. This may lead to smearing of the resin over any exposed particles, making the particle-like appearance not so noticeable, and the surface smoother. These results were in agreements with many studies as Dodge et al [(44)], Cardoso et al [(45)], and Jones et al [(46)]. On the other hand, other studies revealed that dry finishing and polishing is less successful and

obtain higher surface roughness [47–48]. They attributed their results to the fact that the abrasive particles separated from the polishing tool may be embedded into the composite's surface. Furthermore, accumulation of separated particles on the surface of polishing tools can decrease its efficiency when attempting to smooth the surface [44]. In addition, the heat generated during dry finishing and polishing is high and can degrade the filler/matrix bond resulting in separation of filler particles from the matrix and subsequently increase the surface roughness [49]. Thus, the null hypothesis of this study should be rejected as there was significant difference between different polishing pressures as well as the surface condition (either dry or wet) for both the nano-filled and nano hybrid composites. Finally, the present study had several limitations. First, only one polishing system was assessed. Further studies incorporating different polishing systems as well as polishing pastes are needed. Moreover, the used specimens were flat that might simulate the clinical situations regarding anterior restorations but not the same for posterior restorations with occlusal anatomy that affect the control and forces of polishing. Polishing of fissures and cusps, the polishing force decomposes less linearly. Part of the filling is subjected to pressure from the vertical direction, but the slopes of the cusps are under pressure from the force's horizontal or oblique direction. Furthermore, using polishing pastes may enhance the results and needs to be investigated. Moreover, clinical trials are needed to assess the clinical inference regarding plaque accumulation and aesthetic appearance would be desirable.

Conclusions:

Under the limitations of the current study the following conclusions were derived:

1. The surface roughness of resin composite after polishing is highly affected by the type of composite used.

2. One step polishing system is considered as an effective polishing tool for nano-filled and nano-hybrid composites.

3. Press-on force during polishing procedure as well as surface condition (either dry or wet) have a profound effect on the surface roughness of nano-filled and nano-hybrid resin composites.

4. Heavy pressure in combination with dry surface is considered the most efficient polishing protocol to minimize the surface roughness of nano-filled and nano-hybrid resin composite with one step polishing system.

Recommendations:

1. Randomized controlled clinical trials (RCTs) should be carried out to confirm our findings.
2. Further Long-term evaluation must be done to confirm the color stability of the specimens after polishing.
3. Using different polishing systems and protocols to reach a standardized methodology for the polishing protocol of resin composite restorations.

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