Surface Roughness of Nano-Hybrid Universal Composite Restorative Materials After Different Finishing and Polishing Protocols

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Objectives: The study aims to assess and compare the surface roughness of three universal composite restorative materials after using two different protocols for finishing and polishing.
Materials and methods: Three types of nano-hybrid universal resin composite were used: Beautifil II (SHOFU), Filtek Z250 XT (3M), and Tetric N-Ceram (Ivoclar Vivadent). Thirty specimens were prepared of each type of composite and divided into three subgroups: control (polymerized against a celluloid strip with no polishing), polished with Enhance finishing system (Dentsply), and OptiDisc polishing discs (Kerr). Surface roughness (Ra) was evaluated using the atomic force microscope (AFM).
Results: The celluloid strip achieved the smoothest finish, followed by OptiDisc polishing discs, while the Enhance finishing system produced the least smooth surface. The differences ranged from statistically significant ($p \leq 0.05$) to highly significant ($p \leq 0.001$). In all finishing and polishing methods used in this research, Beautifil II presented the highest levels of Ra, followed by Tetric N-Ceram and Filtek Z250 XT respectively with statistically highly significant differences ($p \leq 0.001$).
Conclusion: OptiDisc polishing discs produced a smoother composite surface than the Enhance finishing system. Beautifil II presented higher surface roughness than Tetric N-Ceram and Filtek Z250 XT, respectively.

Keywords: finishing and polishing, nano-hybrid composite, surface roughness.

Introduction

Universal composites are gaining popularity nowadays since many general dentists prefer to obtain one kit for both posterior and anterior restorations. These composites are supposed to merge the strength and high mechanical properties of posterior composites with the optical esthetic values of anterior composites. The goal is to provide an esthetic and functional restoration, yet simple at a reasonable chair time and cost.

Polishing means making the surface smoother using abrasive tools in a particular sequence. Polishing of composite restoration is a fundamental final step that contributes to the success of treatment as it makes the restoration surface smooth, shiny, and easily cleaned by the patient.1,2 This, in turn, can increase the durability of the restoration, decrease the possibility of secondary caries, and enhance the health of the gingiva and periodontal tissues.3

Many variable products dedicated to finishing and polishing composites are available in the market. Many manufacturers advertise different composite polishing systems ranging from burs, strips, disks, cups, points, and brushes. The concept and steps of most of these systems are consistent, including the succession from coarse to finer abrasives. Some researchers4 have shown that one-step polishing protocols can give comparable results to multi-step systems.

Measurement of surface roughness means measuring variations in the height of a physical surface at a micro- or nanoscale.5 Atomic force microscopy (AFM) is a popular technique for measuring surface roughness as it offers a total 3-dimensional surface imaging with nanoscale resolution.6

Table 1. Details of resin-based composites used in the present study.

Material	Manufacturer	Filler composition	Filler loading	Filler particle size	Resin type
Beautifil II	Shofu Inc., Japan.	Derived from surface pre-reacted Glass Ionomer technology	83.3% by weight	10- 4000 nm	Bis-GMA and TEGDMA
Filtek Z250 XT	3M ESPE, St Paul, MN, USA	Surface-modified zirconia/silica and Non-agglomerated Surface-modified silica particles	82% by weight	20-3000 nm	BIS-GMA, UDMA, BIS-EMA, PEGDMA and TEGDMA
Tetric N-Ceram	Ivoclar Vivadent AG, Schaan/Liechtenstein	Barium glass, ytterbium trifluoride, mixed oxide and copolymers	80-81% by weight	Between 40 and 3000 nm	Bis-GMA, UDMA and Bis-EMA

MATERIALS AND METHODS

Preparation of composite resin specimens

The materials used in this study were 3 types of light cure nano-hybrid universal resin composites: Beautifil II (Shofu, Kyoto, Japan), Filtek Z250 XT (3M ESPE, USA), and Tetric N-Ceram (Ivoclar-Vivadent, Schaan, Liechtenstein), and two types of composite finishing and polishing systems; Enhance finishing system (Dentsply Sirona, USA), and OptiDisc polishing discs (Kerr). The compositions of the three composites are listed in Table 1.

All steps of preparing the specimens, finishing, and polishing were done by one operator to decrease variables. A total of 90 specimens (30 of each composite type) were prepared. Each specimen (4 mm in height and 4 mm in diameter) was prepared by packing the composite into a ready-made plastic mould used for testing the depth of curing (Fig. 1), then covered by a celluloid strip and pressed against a microscopic glass slide.7,8 The composites were cured according to manufacturer instructions using LED curing unit9 (Demi Ultra, Kerr dental, USA) (Fig. 2) with an intensity of more than 800mW/cm2, as measured with a radiometer (Model 100, Demetron Corp., Danbury, CT, USA) (Fig. 3). The intensity of the LED curing unit was measured after every 10 usages to ensure that the output was constant.

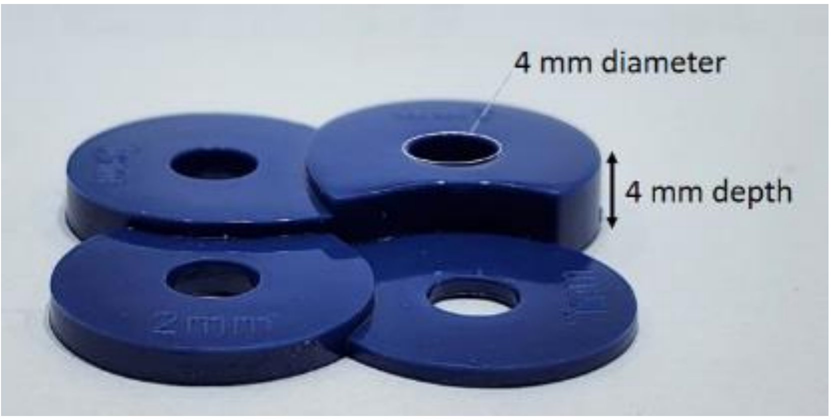

Figure. 1. Plastic mould used to make composite specimens.

Figure. 2. LED curing unit, Demi Ultra, Kerr dental, USA.

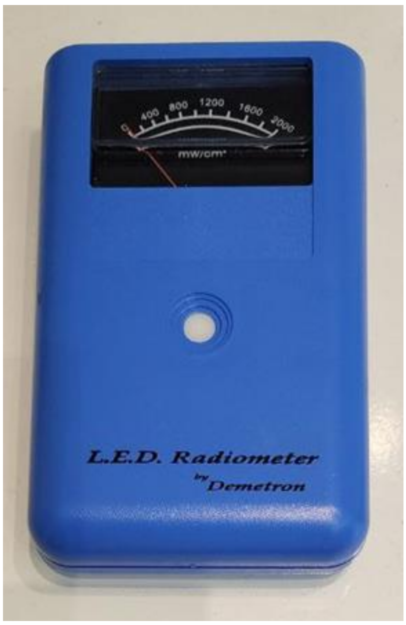

Figure. 3. LED radiometer, Demetron Corp., USA

After complete polymerization, the composite specimen was extruded from the mould. The neglected side was marked and then stored, according to the designed groups, in a labelled container filled with distilled water at 37° C for 24 h. A metal dressing tweezers were used to handle the specimens applied to the sides of the cylinder to avoid any damage or contamination to the test surface.

Finishing and polishing

The 30 specimens of each composite group were divided randomly into three subgroups, 10 specimens in each subgroup. One subgroup was polished using the Enhance finishing system (Dentsply), the second subgroup was polished using OptiDisc polishing discs (Kerr), while the third subgroup was left unpolished as a control. A summary of the methods of surface treatment used in each of the 9 subgroups is detailed in Table 2. Specimens were handled using mosquito forceps (Hartman, Mosquito Forceps Extra Delicate, Straight, Indian Surgicals, New Delhi) during surface finishing and polishing.

Table 2. Classifying study subgroups according to polishing systems.

Group	Composite	Polishing system
A1	Beautifil II	Control
A2	Beautifil II	Enhance
A3	Beautifil II	OptiDisc
B1	Filtek Z250 XT	Control
B2	Filtek Z250 XT	Enhance
B3	Filtek Z250 XT	OptiDisc
C1	Tetric N-Ceram	Control
C2	Tetric N-Ceram	Enhance
C3	Tetric N-Ceram	OptiDisc

Finishing and polishing of composite specimens were done according to the instructions of the manufacturer. Enhance Finisher discs were inserted into a conventional speed contra-angled handpiece and started finishing and polishing. Moderate to light, intermittent pressure was used in a buffing motion for 1 minute without water (manufacturer instructions).

OptiDisc polishing discs inserted into a conventional speed contra-angled handpiece were used sequentially from extra-coarse to extra-fine using light pressure. Each disc was applied for 15 seconds (total time 1 minute) with water rinse after each disc to wash debris. Enhance Finisher discs and OptiDisc polishing discs were single-use, and each composite specimen was rinsed thoroughly under cold, running water before being stored again in a water-filled tube.

Surface roughness measurement

An atomic force microscope (AFM) (AA3000 Scanning Probe Microscope, Angstrom Advanced Inc., Boston, USA) (Fig. 4) was used to measure the average Ra. Each specimen was scanned, and the surface roughness average was measured in nanometer (nm) units.

Figure. 4. Scanning Probe Microscope, Angstrom Advanced Inc., Boston, USA

Analysis

The data were statistically analyzed using the Statistical Package for Social Science (SPSS) version 23 computer program. The surface roughness means of each group were tested using the Tukey HSD test with 5% significance if the data were normally distributed and homogeneous. Results were significantly different with $p \leq 0.05$.

RESULTS

The average Ra of each material against the celluloid strip (control) and after various finishing and polishing procedures are displayed in Table 3 and Fig. 5. These results revealed that for the 3 composites, the smoothest finish was achieved by the celluloid strip, followed by OptiDisc polishing discs while Enhance finishing system produced the least smooth surface. The differences were statistically highly significant ($p \leq 0.001$) except for Filtek Z250 XT groups, where the difference between the control group and OptiDisc group was significant, and for Tetric N-Ceram groups, where the difference between the OptiDisc group and Enhance group was significant ($p \leq 0.05$) (Table 4).

Table 3. Descriptive statistics and ANOVA results for the composites.

Materials	Groups	Descriptive statistics					Difference	
		N	Mean	S.D.	Min.	Max.	F-test	p-value
Beautifil II	Control	10	7	0.110	6.85	7.21	73.321	0.000
	Optidisc	10	7.357	0.192	7.1	7.68		
	Enhance	10	7.857	0.164	7.61	8.11		
Filtek Z250 XT	Control	10	2.846	0.174	2.56	3.11	157.898	0.000
	Optidisc	10	3.085	0.181	2.81	3.3		
	Enhance	10	4.408	0.267	4.02	4.77		
Tetric N-Ceram	Control	10	3.237	0.145	3.04	3.53	86.073	0.000
	Optidisc	10	3.791	0.139	3.52	3.92		
	Enhance	10	4.008	0.121	3.87	4.24		

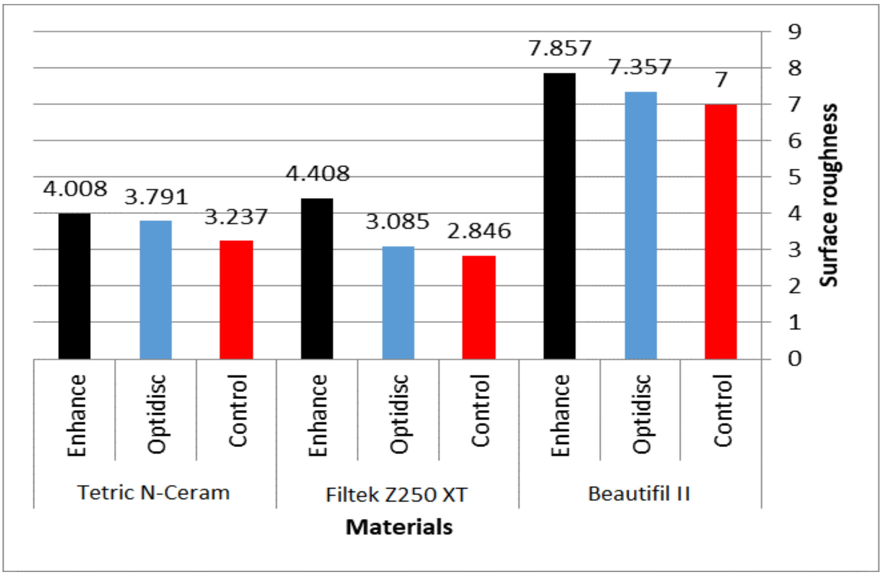

Figure 5. The average Ra of each material against the celluloid strip (control) and after various finishing and polishing procedures.

Table 4. Tukey HSD test for the composites

Materials	Groups		Mean difference	p-value
Beautifil II	Control	Optidisc	-0.357	0.000
		Enhance	-0.857	0.000
	Optidisc	Enhance	-0.500	0.000
Filtek Z250 XT	Control	Optidisc	-0.239	0.045
		Enhance	-1.562	0.000
	Optidisc	Enhance	-1.323	0.000
Tetric N-Ceram	Control	Optidisc	-0.554	0.000
		Enhance	-0.771	0.000
	Optidisc	Enhance	-0.217	0.004

Table 5. Descriptive statistics and ANOVA results for the surface treatment methods.

Groups	Materials	Descriptive statistics					Difference	
		N	Mean	S.D.	Min.	Max.	F-test	p-value
Control	Beautifil II	10	7	0.110	6.85	7.21	2489.432	0.000
	Filtek Z250 XT	10	2.846	0.174	2.56	3.11		
	Tetric N-Ceram	10	3.237	0.145	3.04	3.53		
Optidisc	Beautifil II	10	7.357	0.192	7.1	7.68	1766.030	0.000
	Filtek Z250 XT	10	3.085	0.181	2.81	3.3		
	Tetric N-Ceram	10	3.791	0.139	3.52	3.92		
Enhance	Beautifil II	10	7.857	0.164	7.61	8.11	1189.740	0.000
	Filtek Z250 XT	10	4.408	0.267	4.02	4.77		
	Tetric N-Ceram	10	4.008	0.121	3.87	4.24		

Table 6. Tukey HSD test for the surface treatment methods.

Groups	Materials		Mean difference	p-value
Control	Beautifil II	Filtek Z250 XT	4.154	0.000
		Tetric N-Ceram	3.763	0.000
	Filtek Z250 XT	Tetric N-Ceram	-0.391	0.000
Optidisc	Beautifil II	Filtek Z250 XT	4.272	0.000
		Tetric N-Ceram	3.566	0.000
	Filtek Z250 XT	Tetric N-Ceram	-0.706	0.000
Enhance	Beautifil II	Filtek Z250 XT	3.449	0.000
		Tetric N-Ceram	3.849	0.000
	Filtek Z250 XT	Tetric N-Ceram	0.400	0.000

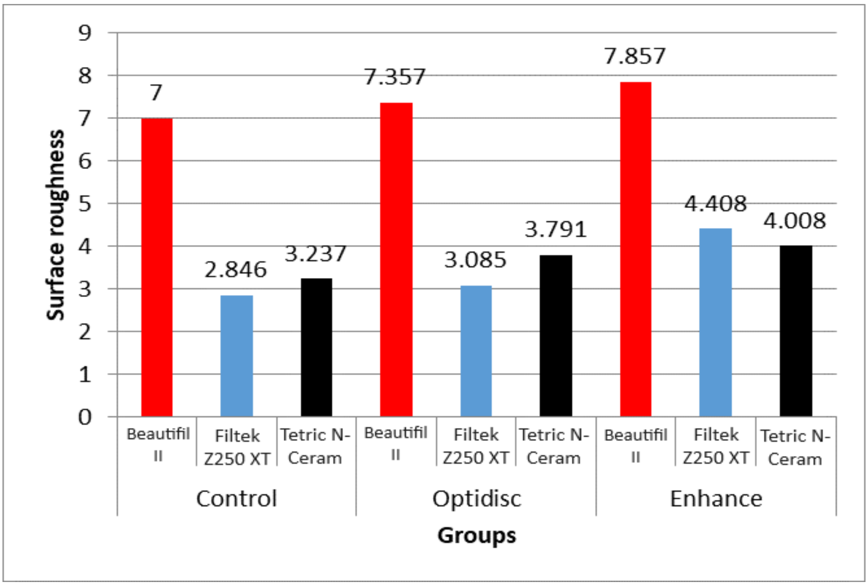

Figure 6. The average Ra after each finishing and polishing procedures for the different composites used in this study.

In all finishing and polishing methods used in this research, Beautifil II presented the highest levels of Ra, followed by Tetric N-Ceram and Filtek Z250 XT respectively with statistically highly significant differences ($p \leq 0.001$) (Tables 5,6 and Fig. 6)

Figures 7 shows the profilometric image of the composite after finishing and polishing as shown by Scanning Probe Microscope.

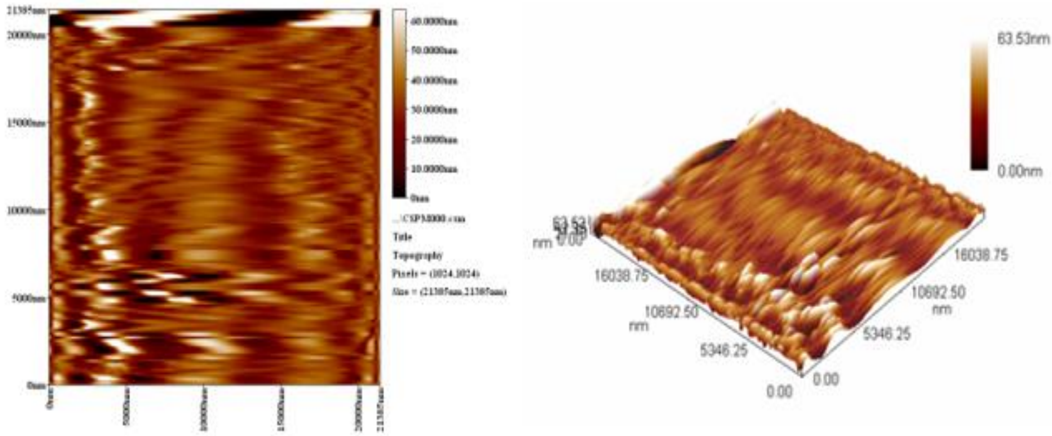

Figure 7. Scanning probe microscope imager surface roughness analysis.

DISCUSSION

Nano-hybrid universal resin composites were used in the present study because they are commonly used by dental practitioners for tooth restoration. One of the crucial properties of composite restorative materials is their polishability. High-quality finishing and polishing is a contributing factor to the success of composite restoration by decreasing plaque retention and margin discoloration, thus improving the aesthetics and longevity of these restorations. The polishability of a composite restoration depends on factors like the type, size, and amount of the filler particles, in addition to the accessibility of the surface(s) to be polished.10

There is wide acceptance that the smoothest composite restoration surface is obtained by well-adapted matrix strip.11-13 This was true for the three types of composite materials used in the present study as the control groups showed the lowest surface roughness values. It is very common that even the smooth composite surface formed by the matrix strip needs finishing and polishing to eliminate the resin rich layer and the flash excess.13

The Filtek Z250 XT specimens in the control group were smoother than the corresponding Tetric N-Ceram specimens, while the Beautifil II specimens presented the highest roughness values.

The filler loading of the three materials is too close (Table 1). It has been suggested that the size of the largest filler particles has a greater influence on surface roughness of composite restoration than the average filler particle size because dislodgement of these filler particles during finishing and polishing procedures will result in higher Ra values.14 This might explain the higher values of surface roughness obtained by the Beautifil II specimens.

Beautifil II belongs to a group of hybrid restorative materials made of pre-reacted glass ionomer fillers incorporated into a resin-based composite known as giomers, which are fluoride-releasing.15,16 Being a fluoride-releasing restorative material, Beautifil II must permit a certain degree of water diffusion,17 which causes a higher level of water sorption when compared to conventional nanohybrid composites.18 This is another factor that can explain the higher surface roughness presented by Beautifil II.

The filler hybridization technology of Filtek™ Z250 XT, which includes the addition of proprietary nanoparticles and nanoclusters bound in the resin matrix, might explain the lower values of surface roughness obtained for these composite specimens.

To be efficient, the finishing and polishing systems must contain abrasive particles, which are reasonably harder than the filler particles. If not, the finishing and polishing system will affect only the soft resin matrix.19,20 It is widely accepted that flexible polishing discs impregnated with aluminum oxide particles are the best tools for providing low surface roughness on composite surfaces.21,22 The results of the current study came in agreement with this. The samples polished with Optidisc showed lower surface roughness than those polished with Enhance.

AFM, a scanner-tipped microscope, was used in the current study because it is a more up-to-date method for evaluating surface roughness that has been considered a new technique in dental materials research. AFM has been reported to be the most effective method of providing three-dimensional detailed topographic images of surface roughness in nanometer scale. 23,24

CONFLICTS OF INTEREST

The authors have no conflicts of interest related to this research.

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