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Research Article

Surface Roughness Evaluation of Nano Composites with Different Polishing Techniques: (*In-Vitro* Study)

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Abstract

Background and Objective: The purpose of this study was to evaluate the surface roughness of Nano resin composites with different polishing techniques (*in-vitro* study).

Method: 120 composite specimens with a 6 mm diameter and a thickness of 3 mm were fabricated from the nanofilled Filtek Z350 XT (C1) and the nanohybrid Filtek Z250 XT (C2) and equally divided into two main groups (n = 60), 20 specimens of each composite were polished with PoGo single step micro-polishers (P1), Sof-Lex multiple steps polishing system (P2) and polyester strip was used as the control group (P0), (n = 20), a profilometer was used to measure the surface roughness value after specimens' polishing (Ra), the data were statistically analyzed using Repeated measures Analysis of Variance (ANOVA) and Bonferroni's post-hoc test ($P \leq 0.05$) was used for pair-wise comparisons when ANOVA test is significant.

Results: There was a statistically significant difference between mean Ra of different polishing systems (P-value = 0.001, Effect size = 0.269), no statistically significant difference between PoGo discs and Sof-Lex discs; both showed statistically significantly higher mean Ra than Polyester strip.

Conclusion: 1. The nanofilled Filtek Z350 XT resin composite is a good choice material for the clinical use. 2. the one-step PoGo micro-polisher produced better surface quality in terms of roughness than the multiple steps Sof-Lex polishing system.

Keywords: Resin Composite; Surface Roughness

Introduction

Beauty and natural tooth appearance of resin composite together with their conservative approach are the main reasons for the increasing demands for its use since their introduction in the late 1950's. Resin composite is a material that is made of an inorganic filler phase and an organic matrix phase with a coupling agent that bonds the filler to the matrix [70].

Composites were traditionally classified depending upon their filler size into macrofilled, microfilled and hybrid [12]. Since the introduction of nanotechnology, a new classification for resin composites had been attempted to be classified as nanofilled and nanohybrids [49]. Nanofilled contains only nanoscale particles (20-75 nm) [12], which are made of nearly uniform nanometric particles and create nanoclusters as secondarily formed fillers while nanohybrids are made of particles of various sizes, from the micrometric to nanometric scale [23]. The nanomer and nanocluster filler particles in the nanofill type provide surface smoothness, high polish retain ability and superior gloss as well as adequate mechanical properties [2,12]. The clinical success of composite restorations is related to surface smoothness, thus, finishing and polishing is of paramount importance for the success and longevity of these restorations [2,29].

Increased surface roughness allows accumulation of biofilm leading to the development of gingivitis and discoloration of the restoration [18]. It is dependent on the type of the composite material and polishing system used [17]. Finishing procedure removes scratches created by instruments and provides smooth surface with particle size of more than 25µ whereas polishing creates an enamel-like luster to the restoration and increases the surface energy of the restoration with particle size lesser than 25 µm [2].

Diamond or multi-fluted tungsten carbide burs are used for gross finishing followed by polishing using polishing wheels and discs with flexible or semi flexible abrasives coated with aluminum oxide (Al_2O_3) abrasive or fine diamond particles. Polishing devices are available including Al_2O_3 impregnated Sof-Lex wheels and diamond impregnated rubber PoGo polishing discs, which operate as multi-step and single step polishing systems simultaneously. Multi-step polishing system use medium (40 µm), fine (24 µm) and ultra-fine (8 µm) grit sequence in while PoGo product rubber diamond polisher uses a single step [2,20,23,29].

Therefore, it seems worthwhile to evaluate the surface roughness of the Nano resin composites with different polishing techniques. The study was carried out under the following regards, Comparing the surface roughness of two different types of resin composite (Filtek Z350 XT nanofilled and Filtek Z250 XT nanohybrid) and comparing the surface roughness of two different types of polishing system (PoGo single step and Sof-Lex multiple steps).

The following hypothesizes were tested:

- There would be no difference in surface roughness values between nanofilled and nanohybrid resin restoratives.
- There would be no difference between the single step and multiple steps polishing systems.

Materials and Methods

Two widely used commercial resin composites (Table 1) were evaluated in this study. A total of 120 resin composite disks with a thickness of 3 mm and 6 mm in diameter were fabricated using a special cylindrical split Teflon mold in order to standardize specimens' dimension. The composite was inserted into the mold in two incremental layers using OptraSculpt (Ivoclar Vivadent, Schaan, Liechtenstein) modeling instrument. Teflon mold contained uncured composite was covered on both sides with a transparent polyester strip then held between two microscopic glass slides gently pressed together to remove excess material. An axial load of 500 g was applied on the top of microscopic glass slide for 20 sec to promote smoothness, removing voids and extrude any excess of material [44]. Using light emitting diode (Elipar curing unite, 3m ESPE St. Paul, USA (wavelength: 430 - 480 nm, light intensity: 1200 mW/cm^2), (LED) light curing unit, the first inserted resin composite increment was light-cured for 20 sec following manufacturer instructions. Then, the second inserted resin composite increment had been light-cured for 20 sec through the polyester matrix strip and the microscopic glass slide. Additional 20 sec light-curing on both sides of the composite disc specimen were done after removing the polyester matrix strips and the microscopic glass slides to insure proper curing. The light intensity of the curing unit was varified regularly every 5 exposures by means of a digital dental radiometer (Ivoclar Vivadent, Schaan, Liechtenstein). Standardization of the distance between light source and specimen was obtained by the thickness of the glass slide (1 mm) and polyester matrix strip, which gave smooth surfaces for the composite specimens [1]. After light-curing, the cured composite specimens were then removed from the Teflon mold and checked by using hand held magnifying glass lens (Jinhua Top Optical Instrument Co., Ltd, China) X5 for detecting any surface defect, crack or/and air bubbles, which if present the specimen was discarded. The non-irradiated surface of the cured composite specimen was marked. Then, the cured composite specimen was picked up by tweezer, which was applied to the sides of the cylinder to protect the flat polyester-formed surface of the cured composite specimen from any damage or contamination.

The cured composite specimens were inserted into the second Teflon mold (Figure 1) of 2 mm thickness making it possible to polish the cured composite specimens on a tight-fixed base. Thus, the residual thickness can be controlled [23]. The cured composite

Brand name	Specification	Composition	Manufacturer (Batch No.)
Filtek™ Z350XT Universal Restorative Body Shade: A2	Nanofilled composite	Matrix: Bis-GMA[1], UDMA[2], TEGDMA[3], PEGDMA[4] and Bis- EMA[5] resins. Filler: Combination of a non- agglomerated/non-aggregated 20 nm silica filler, a non- agglomerated/non-aggregated 4 - 11 nm zirconia filler and an aggregated zirconia/silica cluster filler (compromised of 20 nm silica and 4 - 11 nm zirconia particles. Filler loading: 63.3% by volume.	3M ESPE, St. Paul, MN, USA (NA44144)
Filtek™ Z250XT Universal Restorative Shade: A2	Nanohybrid composite	Matrix: Bis-GMA, UDMA, Bis- EMA, PEGDMA and TEGDMA resins. Fillers: Combination of surface modified zirconia/silica. The inorganic filler loading is 81.8% by weight (67.8% by volume) with a particle size of 20 nm for the silica and approximately 0.1 - 10 µm for the zirconia/silica. Filler loading: 67.8% by volume.	3M ESPE, St. Paul, MN, USA (NA60349)

Table 1: Brand name, specification, composition and manufacturer of resin composite.

[1]Bisphenol-A-glycol-dimethacrylate.

[2]Urethane-dimethacrylate.

[3]Tri-ethylene-glycol-dimethacrylate.

[4]Polyethylene glycol dimethacrylate.

[5]Bisphenol-A-polyethylene-glycol-diether-dimethacrylate.

Figure 1: The specimens were inserted into the second Teflon mold, marked on the side to facilitate the polishing procedures.

surfaces had been marked from their side to ensure that all polishing took place in the same direction i.e., parallel to the surface [20]. According to manufacturer instructions, the cured composite specimens were polished with three different polishing techniques (Table 2), (n = 20) the first group (P1) the pogo single step micro polishers, The PoGo polishers were manufactured in different shapes including cups, points or discs. In this study, disc shape polishers were used in order to obtain a direct contact with the surfaces of specimens [31]. Although the manufacturer recommends pre-treatment with Enhance system to obtain favorable results, some investigators have used this system as a one-step method without any pre-treatment and reported no beneficial results on the surface quality with the pre-treatment step [22,66]. Therefore, PoGo was used as a one-step method in the present study.

Material		Product Specifications	Composition	Manufacturer (Batch No.)
Transparent Polyester strip		Transparent rectangle-shaped universal strip.	Flexible polyester used for contouring and polishing of resin composite restorations (length: 100 mm, width: 8 mm, thickness: 0.05 mm).	Kerr-Hawe, Bioggio, Switzerland (40611)
PoGo discs micro-polishers (One step)		Pre-mounted, single use diamond impregnated cured urethane dimethacrylate resin polishing devices.	Polymerized urethane dimethacylate resin, fine diamond powder, silicon oxide, plastic latch-type mandrel.	Dentsply Caulk, Milford, Delaware, USA (662010Y)
Sof-Lex polishing system (Multi-step)	Sof-Lex extra-thin discs	Medium-grit flexible discs for contouring and polishing.	Aluminum oxide extra thin flexible disc (diameter: 12.7 mm, thickness: 0.5 inches).	3M ESPE, St. Paul, MN, USA (4673856)
	Sof-Lex spiral wheels	Fine grit (beige) pre-polishing spiral wheel.	Aluminum oxide impregnated in a thermoplastic elastomer (diameter: 12.7 mm, thickness: 0.13 inches).	3M ESPE, St. Paul, MN, USA (NA46599)
		Ultra fine grit (pink) for final polishing.	Aluminum oxide impregnated in a thermoplastic elastomer (diameter: 12.7 mm, thickness: 0.13 inches).	3M ESPE, St. Paul, MN, USA (NA46599)

Table 2: Specification, composition and manufacturer of polishing system.

The flat broad surface of the one step PoGo polishing system that uses diamond micro-polisher disc were used (Figure 2). These discs are indicated for single use. Thus, one disc was used for each

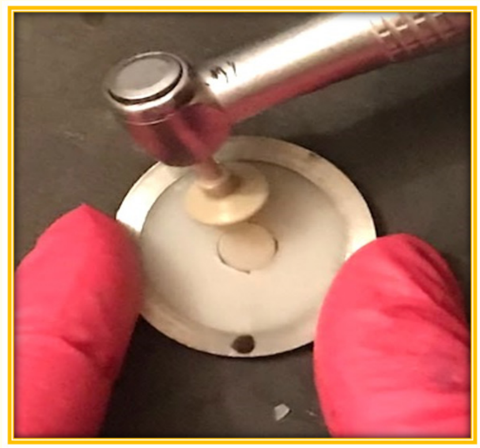

Figure 2: Polishing the specimen with PoGo micro-polisher disc.

specimen. The discs were attached to a slow-speed micro-motor Micromotor handpiece; Strong, South Korea (20.000 - 40.000rpm) handpiece NSK Ti-Max Electric Handpiece, Japan. The speed was adjusted at 10,000 rpm for the initial 15 sec followed by 15 sec at 20,000 rpm for each specimen [27].

Unlike to any other rotary instrument, the PoGo polishers are designed for use without water, which may generate heat with prolonged contact, thus, they were first applied with a light and intermittent pressure in buffing motion to increase the surface luster.

In the Sof-Lex system, the manufacturer strictly recommends the use of Sof-Lex extra thin disc prior to the use of spirals in accordance with [41], who found the use of Sof-Lex extra thin disc prior to the use of Sof-Lex spirals had produced smoother surface than using spirals alone, therefore, The second group of the cured composite specimens were polished with Sof-Lex contouring and polishing system (P2) following the protocol recommended by the manufacturer; medium grit Sof-Lex extra thin contouring disc (orange) was first used followed by the Sof-Lex spiral wheels fine grit (beige) pre polishing disc and ultra fine polishing disc (pink)for the final surface luster.

For optimum results, the spiral wheels were used on wet surfaces with moderate pressure. The spiral wheels were immersed in water before polishing the specimens as well as the surface of the specimens had been wetted with a microbrush. The specimen was rinsed and dried by a microbrush between the successive discs in the same specimen in order to eliminate any created debris from instruments side [41].

Abrasive Sof-Lex disc in the kit was attached by a metal hub to an autoclavable metal mandrel. The specimens were contoured and polished with medium, fine, and ultra fine discs by using linear movements with a slow-speed micro-motor handpiece (Figure 3-5). For each resin composite specimen, the medium grit discs were used for a gross contouring at medium speed of 10,000 rpm for 15 sec without water spray then the specimens were rinsed to remove any material's powder and dried with microbrush while the fine grit Sof-Lex and the ultra-fine grit spiral wheels were used at a high speed of 20,000 rpm for 15 sec [10].

The Sof-Lex extra thin discs are single use, thus, a new polishing disc was used for each specimen and was discarded after each use. On the other hand, the Sof-Lex spiral wheels are multiuse, thus, they were replaced each five specimens [23]. The third group (P0) were left without surface treatment, just curing under the polyester strip and were used as a control group. Another parameter of importance was the standardization of the force applied on the surface during polishing. In the present study, to minimize the variation in the force applied, single operator used a light force with a constant movement of repetitive stroking action was applied in order to prevent the heat build-up and the formation of grooves [76].

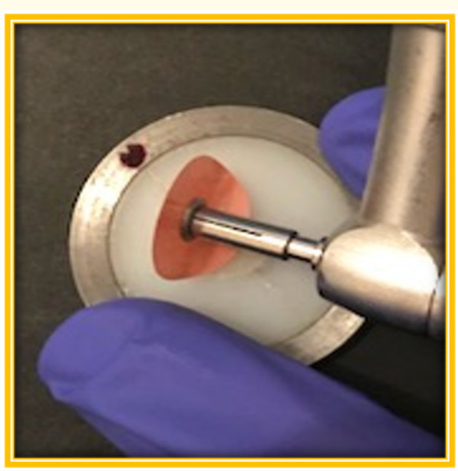

Figure 3: Contouring the specimen with a Sof-Lex extra-thin disc (Orange).

Figure 4: Pre-polishing the specimen with the Sof-Lex spiral wheel fine (beige).

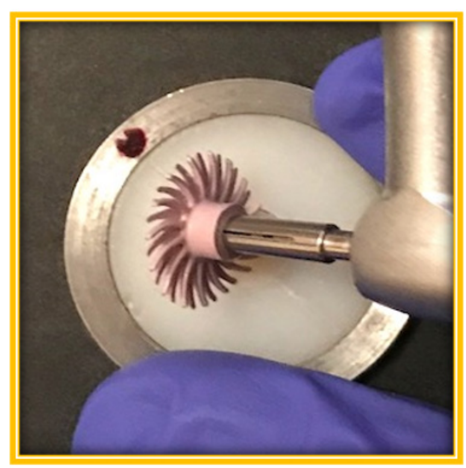

Figure 5: Polishing the specimen with the Sof-Lex ultra fine (Pink).

The polishing time was standardized to avoid bias. In the current study, the time of polishing with each instrument was standardized at 30 sec because the most relevant research used 20 - 30 sec per polisher [76]. To avoid bias in the results of the present study, all the polishing systems had been undertaken by using the same slow-speed dental handpiece during all phases of the polishing procedure at a maximum speed of 20,000 rpm [69].

After polishing, the specimens were cleaned in an ultrasonic bath at 35°C for 3 min to remove any debris then dried with absorbent paper and absolute ethanol (90%) using a microbrush [15].

The composite specimens had their thickness measured in triplicates with a digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, Japan). Specimens that varied more than 0.05 mm from the ideal thickness (3 mm) were discarded [44].

Surface roughness measurements (Ra)

The average surface roughness (Ra) was measured after specimens polishing four times each with a cut-off value of 0.8 mm, a transverse length of 0.8 mm and a stylus speed of 0.1 mm/sec near the center of each specimen using a profilometer (Mitutoyo SJ-201 Surf tests, Japan).

Statistical analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values.

Repeated measures Analysis of Variance (ANOVA) was used to study the effect of composite type, polishing system, tooth brush type, brushing and their interactions on mean Ra.

Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Version 23.0. Armonk, NY: IBM Corp Statistics for Windows.

Results

Effect of composite type regardless of other variables

Regardless of polishing system; Filtek Z350 XT showed statistically significantly lower mean Ra than Filtek Z250 (P-value = 0.008, Effect size = 0.136) (Table 3 and figure 6).

Filtek Z350 XT		Filtek Z250 XT		P-value	Effect size (Partial eta squared)
Mean	SD	Mean	SD		
0.7118	0.2039	0.8279	0.385	0.008*	0.136

Table 3: The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between Ra of the two composite types regardless of other variables.

*: Significant at P ≤ 0.05.

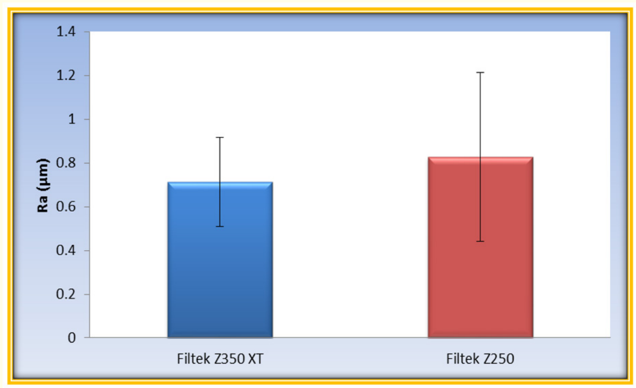

Figure 6: Bar chart representing mean and standard deviation values for Ra of the two composite types regardless of other variables.

Effect of polishing system regardless of other variables

Regardless of composite type, there was a statistically significant difference between mean Ra of different polishing systems (P-value = 0.001, Effect size = 0.269). Pair-wise comparisons revealed that, there was no statistically significant difference between PoGo discs and Sof-Lex discs; both showed statistically significantly higher mean Ra than Polyester strip (Table 4 and figure 7).

Discussion

In esthetic dentistry, restorative materials should duplicate the appearance of a natural tooth. A resin composite restoration can be unpredictable by the naked eye when its surface closely resembles the surrounding enamel surface. Thus, highly finished and polished restorations should produce an enamel-like surface texture and

PoGo		Sof-Lex		Polyester strip		P-value	Effect size (Partial eta squared)
Mean	SD	Mean	SD	Mean	SD		
0.8026 ^{A}	0.309	0.8583 ^{A}	0.2406	0.6486 ^{B}	0.3464	0.001*	0.269

Table 4: The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between Ra values of different polishing systems regardless of other variables

*: Significant at P ≤ 0.05, Different superscripts are statistically significantly different.

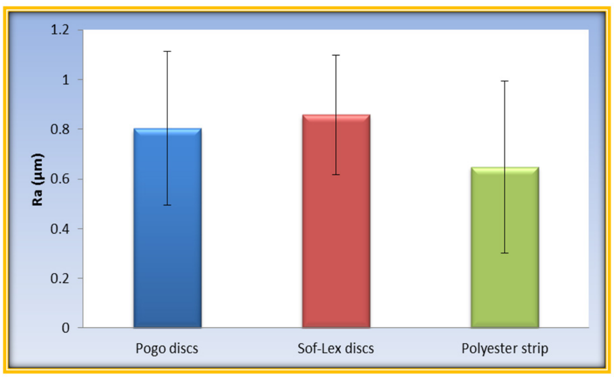

Figure 7: Bar chart representing mean and standard deviation values for Ra of different polishing systems regardless of other variables.

gloss. The clinical significance of surface roughness is related to decrease esthetic appearance of the restoration and discoloration. The biological consequences of the rough surface are the affection of gingival and periodontal health and the development of secondary caries due to increased plaque accumulation [27].

Therefore, the aim of the present study was to evaluate the surface roughness of two resin composites (Filtek Z350 XT nanofilled and Filtek Z250 XT nanohybrid) with different polishing techniques (PoGo single step and Sof-Lex multiple steps).

The commonly used nanofilled Filtek Z350 XT and nanohybrid Filtek Z250 XT resin composites were chosen in the present study because of the great advantages in their material compositions relating to the use of nanotechnology [20,33]. The application of nanotechnology to composite research has been of great benefit, due to reduced dimension of the particles and wider distribution; an increased filler load can be achieved, which results in high surface polish and better handling property [12,27].

In the current study, a polyester matrix strip was used to produce standardized specimens. After photo-polymerization, the specimens that received no polishing served as controls and were compared with groups treated with different polishing systems. Such specimens, cured under matrix strips, have also been used as controls in several studies [21,25]. However, it is not always possible to use this method because of the anatomical complexity of the tooth [13].

Two polishing systems were used in the current study; PoGo single step polishers and Sof-Lex multiple steps contouring and polishing system because they reduce the clinical time and appear to be as effective as multi-step systems for finishing and polishing dental composites. The obvious advantage of the one-step system is the convenience and efficiency of producing a very smooth surface without having to switch to finer polishing items or having to wash and dry between each step to ensure removal of the larger abrasives from the previous step [5].

Surface roughness

Although a threshold for unacceptable surface roughness has not yet been agreed on, it was reported that, surface roughness above 0.2 µm results in an increase of plaque accumulation, higher risk for caries and periodontal inflammation, compromising esthetics and longevity of the restoration [26].

However, [53] reported no difference in plaque accumulation throughout the roughness range of 0.7 - 1.4 µm. Thus, the clinical acceptable threshold level of the surface roughness in present study was situated at .8 µm. Since most treated surfaces presented surface roughness values in the range of 0.2 - 1.4 μm, the effect of the polishing systems on the finished surface of resin composites investigated is clinically relevant.

Generally, surface roughness of resin composites depends on several intrinsic and extrinsic factors. Intrinsic factors include: type of material, type of filler, shape, size and distribution of filler particles, degree of polymerization, resin matrix composition and durability of filler/matrix bond. Extrinsic factors are related to the method of polishing and include the flexibility of polishing tool, hardness of abrasive particles, geometrical shape and chemical structure of polishing tool, polishing time, applied force and its method of application [36,46].

Effect of composite type

Filtek Z350 XT composite showed statistically significantly lower surface roughness (0.71 μm) than Filtek Z250 XT composite (0.82 μm) (Table 3 and figure 6). Thus, the first null hypothesis that, there would be no difference in surface roughness values between nanofilled and nanohybrid composites was rejected.

This result could be attributed to different fillers' composition, size and loading of both tested materials. During the polishing procedure, in Filtek Z350 XT, nanomer and nanocluster particles were abraded easily along with the resin matrix. The nanomer bond which constructs nanoclusters would detach, providing a smoother surface. Also, nanomer was added with silane on its surface, which creates a strong bond with the matrix during curing. The matrix system contains more Bis-GMA and UDMA with less double bonds, increasing the degree of polymerization [33,43].

While in Filtek Z250 XT resin composite, larger and irregular filler size was obtained by grinding larger particles and causing a lot of space between fillers. The larger filler would appear protrusive on the surface during curing. Pressure would gather more on the irregular filler and increase the chance of the filler detaching from the resin surface. When the larger filler detached from the matrix, it would create a large hole on the surface and increase surface roughness [33].

Additionally, Filtek Z250 XT resin composite still uses PEGDMA as a main matrix with more double bonds than Bis-GMA and UDMA, making the curing process less adequate than Filtek Z350 XT resin composite [33].

This result is in a wide agreement with those reported by [14,20,42,60] who explained difference in surface roughness between Filtek Z350 XT and Filtek Z250 XT resin composites on the basis of differences in their chemical composition; nanofilled Filtek Z350 XT resin composite contains nanoparticles with an average size of 11 nm while nanohybrid Filtek Z250 XT resin composite has an average particle size of 0.6 μm.

On the other hand, this finding is in contrast with [53], who found that, Teric N-Ceram, which has been classified as nanohybrid composite as Z250 XT showed lower surface roughness compared to Filtek Z350 XT resin composite. This contradictory could be explained by difference in the brand of the nanohybrid composites used, which may have different fillers and matrix. Moreover, both studies have different methodologies; the surface of composite specimens had pre-finished with 1200 grit sand paper for 30 sec.

Effect of polishing system

There was no statistically significant difference between PoGo (0.80 μm) and Sof-Lex (0.85 μm) polishing systems, both showed statistically significantly higher surface roughness than polyester strip (0.64 μm) (Table 3 and figure 6). Thus, the second hypothesis, that there would be no difference in surface roughness between the single step and multiple steps polishing systems was accepted.

These findings might be due to the polyester strip worked as a prohibition to format any oxygen inhibition layer over the surface of the uncured resin composite [2,20,60].

These findings are in wide agreement with those reported by [14,20,23,40] who found that, the smoothest surface obtainable on a composite restoration was that formed by a well-applied polyester strip, assuming the matrix was not allowed to move during the polymerization of the surface layer of the composite. The smooth surface formed by the matrix, which may include some imperfections, air inclusions and folds, tends to be rich in resin, but free of any air-inhibited composite. However, this surface has a resin-rich layer and presents a lower hardness. To prevent wear and discoloration, it is suggested to finish and polish this surface [36,55].

The similarity in the results of surface roughness for PoGo and Sof-Lex polishing systems were similar to those reported by [9,20], who found no difference between PoGo and Sof-Lex polishing systems, which might be attributed to that, for a composite polishing system to be effective, the abrasive particles must be relatively harder than the fillers, if not, the polishing agent will only remove the soft resin matrix and leave the filler particles protruding from the surface [27].

Thus, it is believed that, the aluminum oxide abrasives in the Sof-Lex system and the diamond abrasives in the PoGo are higher in hardness than the most filler particles in resin composite used, which allow them to abrade the matrix and the filler particles equally promoting smooth surface for both resin restoratives [2,20,53].

Contradictory results were obtained by [48], who found that, Sof-Lex spiral wheels created significantly smoother surfaces than PoGo micro-polisher. This may be explained by grounding the top surfaces of the composite discs with 600-grit silicon carbide paper for 20 sec.

Though there was no significant difference between the PoGo and Sof-Lex polishing systems the average mean roughness of PoGo system was lower than the Sof-Lex system, the excellent polishing ability of PoGo disc may be attributed to the fact that, the flexible PoGo disc contained fine diamond particles [20,53], which has harder diamond particles (7000 KHN) compared to aluminum oxide (2100 KHN) in Sof-Lex polishing system [27,51,53,55]. Moreover, a study by [58] demonstrated that, the Sof-Lex system created a more abrasive surface because it consists of three gradual files, starting from 98 μm and progressing to 2 um to 5 μm, to first contour and then polish the surface, moving from grit disc to another might cause scratches, grooves and cracks due to heat build-up resulting in more roughness [9,42,65]. Furthermore, [28] measured the temperature of dry polishing and found that, Sof-Lex spirals resulted in higher temperature than PoGo. The heat build-up can lead to the formation of grooves, which may result to higher surface roughness for Sof-Lex system [27].

On the other hand, the results of the current study are in disagreement with those obtained by [2], who found no significant difference between both polishing systems although the mean roughness values in PoGo micro-polisher were higher than the Sof-Lex polishing system. This might be due to variation in methodology, as the top surface of each sample was pre-roughened using 120-grit size sand paper.

Conclusion

Within the limitations of this study, the following conclusions can be drawn:

1. The nanofilled Filtek Z350 XT resin composite is a good choice material for the clinical use because it has better surface polishability.
2. The one-step PoGo micro-polisher produced better surface quality in terms of roughness than the multiple steps Sof-Lex polishing system.

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