Influence of Polishing Procedures on Properties of Nano-Composite Resins

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Abstract: Objectives: This study aimed to evaluate the effects of different techniques of polishing on the surface roughness and surface micro-hardness of two types of composites. **Materials and Methods:** One hundred twenty samples were prepared in disc-shaped stainless steel molds with a uniform size of 6 mm in diameter and 2 mm in thickness. The samples were divided according to the materials used into two groups for each material (Clearfil Majesty ES2 and Micro-hybrid composite Amelogen plus [A2]). Each group was subdivided into subgroups according to polishing instruments: Group I(control group) (Mylar strip) with no finishing or polishing; Group II, polishing with Sof-lex Pop-on discs; and Group III, polishing with rubber-polishing cups–Flexicups. In addition, each subgroup was again divided into two groups according to measurements of surface roughness and microhardness (n=10 in each). Restorative materials were handled according to the manufacturers' instructions. The molds were placed on flat glass plates covered with Mylar strips and then were filled with restorative materials. The samples were photo-activated for 40 sec, transparent matrices were removed immediately after light-polymerization, and the specimens surfaces for groups II and III were finished with ultrafine diamond finishing burs. After finishing, the group II specimens were polished using –Sof-Lex aluminum-oxide discs, and in group III, the specimens were polished using Flexicups rubber-polishing cups with polishing paste, strictly following the manufacturer's instructions. All of the groups were stored in saline for 24 hr. All of the specimens were equally subdivided for the surface roughness and microhardness tests. The data were analyzed using one-way ANOVA and Duncan's multiple range test. **Results:** The Mylar strip (control) group exhibited significantly lower roughness and microhardness values than the polishing systems ($p<0.05$). Flexicups showed significantly higher roughness values than the Sof-Lex system ($p<0.05$). Clearfil Majesty ES-2 exhibited statistically significantly higher microhardness values compared to Amelogen Plus. **Conclusions:** The control group had the lowest surface roughness and microhardness values compared to the polishing groups. Rubber-polishing cups had higher surface roughness than Soflex discs.
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1. Introduction

The property of surface smoothness is extremely important for the clinical success of restorations, Joniot et al, (2000). There is consensus in the literature, with regard to finishing and polishing aesthetic restorative materials, that finishing and polishing are necessary (Ozgunaltay et al., 2003; Brbosa et al., 2005). It is difficult to obtain restorations with perfect shapes and outlines and without excesses; thus, finishing and polishing are necessary, Joao et al.,(2010).

The proper finishing and polishing of dental restoratives are critical clinical procedures, and they are very important for the aesthetics and longevity of restorations. Residual surface roughness of restorations can influence dental bio-film retention, resulting in superficial staining, gingival inflammation and secondary caries, thus affecting the clinical performance of restorations (Yap et al., 1997; Hoelscher etal.,1998; Setcos etal., 1999; Reis etal., 2002). However, a highly polished surface of composites is difficult to achieve because of factors such as different amounts of filler particles, the sizes of the particles and differences in hardness between the filler particles and matrix of the resin composite. Traditionally, it has been believed that the polishing ability of composites varied depending on the particle size, and microfilled resin composites were more easily polished than hybrid types.

Finishing is defined as the gross contouring or reduction of a restoration to obtain ideal anatomy. Polishing refers to the reduction of roughness and scratches created by finishing instruments, Yap et al.,(1997).

Novel resin composites have improved filler technology, modifications in organic matrices and a greater degree of polymerization which improve their mechanical and physical properties. One of the most significant advances in the last few years has been resin composites containing nano-particles, Joao et al.,(2010).

Different methods can be used for the finishing and polishing of resin composite restorations, Setcos et al.,(1999). However, there is no consensus regarding which material and technique provides the smoothest surfaces for resin composites. Surface roughness is a major contributor to extrinsic discoloration of resin composite restorations. This property is closely related to the organic matrix, the inorganic filler composition of the composite, the finishing and polishing procedures (Ozgunaltay et al., 2003; Brbosa et al., 2005).

In this study we evaluated the effects of different techniques of polishing on the surface roughness and surface micro-hardness of two types of composites.

2. Materials and Methods

2.1. Materials

Two commercial materials, Clearfil Majesty ES2 nano-hybrid composite and Amelogen Plus (A2) micro-hybrid composite were used. The commercial names, compositions and manufacturers of all of the materials used in this study are listed in Table (1).

A Cromalux 7050 light curing unit (Mega-PHYSIK GmbH & Co KG, Megadenta, Germany) at 400 mW/cm2 was used in this study.

Table 1: The commercial names, compositions and manufacturers of the materials used

Materials	Manufacturer	Composition
Clearfil Majesty ES-2	Kurary Noritake Dental, Inc.	Silanated barium glass filler Pre-polymerized organic filler Bis-GMA — dimethacrylate Camphorquinone Filler (78% w, 66% v)
Amelogen plus (A2)	Ultradent Inc., South Jordan, UT, USA	Microhybrid Matrix*:* Bis-GMA and diluents Filler*:* silicone dioxide, silicone, silicate particles (76% w, 61% v)
Ultrafine finishing diamond burrs	859-018-10-UF, Diatech Dental	
Sof-Lex discs Al_2O_3 flexible discs 29 μm(M) 14 μm(F) 5 μm (SF)	3M ESPE ,Dental Products, St. Paul, MN, USA	
Flexicups Rubber-polishing cups	Cosmedent, Chicago, IL, USA	

2.2 Methods

One hundred and twenty samples were prepared in disc-shaped stainless steel molds with a uniform size of 6 mm in diameter and 2 mm in thickness. The samples were divided according to the materials used into two groups of 60 samples for each material, and each group was then subdivided into subgroups according to the polishing instruments with 20 samples in each subgroup:

Group I(control group)(Mylar strip) with no finishing and polishing

Group II, polishing with Sof-lex Pop-on discs; and *Group III*, polishing with Flexicups rubber-polishing cups.

A single operator prepared the samples. Each subgroup was divided into two groups according to measurements of surface roughness and microhardness (n=10).

Restorative materials were handled according to the manufacturers' instructions. The molds were placed on flat glass plates covered with Mylar strips and then were filled with restorative materials.

The materials were covered with Mylar strips, and a microscope slide was pressed against the molds to adapt the materials completely to the inner portions of the molds. The excess material was removed, and the samples were photo-activated for 40 sec at the top surface units, transparent matrices were removed immediately after light-polymerization. The specimens surfaces in groups II and III were finished with an ultrafine diamond finishing burrs (859-018-10-UF, Diatech Dental), which were used with a high-speed hand-piece and a water-coolant spray. Each bur was applied using light hand pressure in multiple directions for 20 s and was discarded after 3 times being used. After finishing the group II specimens were polished using Sof-Lex Pop On XT aluminum-oxide discs. Group III specimens were polished using Flexicups rubber-polishing cups with polishing paste (Enamelize, Cosmedent), strictly following the manufacturer's instructions. Each disc and rubber-polishing cup was discarded after use. All of the groups were stored in saline for 24 hr. All of the specimens were equally subdivided for the surface roughness and micro-hardness tests.

2.2.1 Surface roughness evaluation

The specimens were photographed using a USB digital microscope with a built-in camera *(Scope*

Capture Digital Microscope, Guangdong, China), connected to an IBM-compatible personal computer using a fixed magnification of 50X. The images were recorded at a resolution of 1280 × 1024 pixels per image. The digital microscopic images were cropped to 350 x 400 pixels using Microsoft Office Picture Manager Software, to specify/standardize the area of roughness measurement. The cropped images were analyzed using WSxM software, Horcas et al.,(2007). Within the WSxM software, all of the limits, sizes, frames and measured parameters were expressed in pixels. Therefore, system calibration was performed to convert pixels into absolute real-world units. Calibration was performed by comparing an object of known size (a ruler in this study) with a scale generated by the software.

Subsequently, 3D images of the surface profile of the specimens were created. Three 3D images were collected for each specimen, both in the central area and on the sides at area of 10 µm × 10 µm. WSxM software was used to calculate the average of surface roughness (R_a) of the average height of every specimen, expressed in micrometers, which can be assumed as a reliable index of surface roughness, Kakaboura et al.,(2007).

2.2.2. Vickers hardness measurements

The surface hardness of the specimens was determined using a Digital Display Vickers Micro-hardness Tester (Model HVS-50, LaizhouHuayin Testing Instrument Co., Ltd., China) with a Vickers diamond indenter and a 20X objective lens. A load of 200 g was applied to the surface of the specimens for 15 seconds. Three indentations were equally placed over a circle of 1 mm in diameter at the middle third of the specimens. The diagonal lengths of the indentations were measured by a built-in scaled micrometer, and the Vickers values were converted into micro-hardness values.

2.2.3. Micro-hardness calculation

Micro-hardness was obtained using the following equation:

HV=1.854 P/d2

where:

HV is Vickers hardness in Kgf/mm^2;

P is the load in Kgf;

d is the average diagonal lengths in mm.

2.2.4. Statistics analysis

The data were analyzed using one-way ANOVA at a significance level of 0.05 for both the surface roughness and microhardness tests, followed by Duncan's multiple range tests, using SAS software.

3. Results

The average surface roughness values and standard deviation produced by the Mylar strips, Sof-Lex discs and Flexicups rubber-polishing cups on the two resin-based composites are listed in Table 2 and Figure 1.

The Mylar strips (control group) exhibited significantly lower roughness values (smoothest surface) than the polishing systems ($p<0.05$).

In the Clearfil Majesty ES-2 and Amelogen Plus (A2) groups, Flexicups showed significantly higher roughness values than the Sof-Lex system ($p<0.05$).

Table 2: Mean Values and Standard Deviations of Groups for Surface Roughness (Ra)

Materials	Mylar strips (control group)	Soflex discs	Flexicups
Clearfil Majesty ES-2	0.03 ± 0.01	0.095 ± 0.028	0.12 ± 0.06
Amelogen Plus (A2)	0.056 ± 0.026	0.17 ± 0.02	0.20 ± 0.02

The average surface microhardness values and standard deviations produced by the Mylar strips, Sof-Lex discs and Flexicups rubber-polishing cups in the two resin-based composites are listed in Table(3).

According to the microhardness values, no statistically significant differences were observed between the polishing systems with the Sof-Lex discs and Flexicups rubber-polishing cups for the two resin-based composite groups ($p>0.05$). However, the Mylar strips created surfaces that exhibited statistically significantly lower microhardness values, compared with all of the polishing systems for the two resin composites tested ($p<0.05$). In contrast, Clearfil Majesty ES-2 exhibited statistically significantly higher microhardness values compared to Amelogen Plus with all of the polishing systems.

Table 3: Mean Values and Standard Deviations of Groups for Microhardness (VHN)

Materials	Mylar strips (control group)	Soflex discs	Flexicups
Clearfil Majesty ES-2	78.76 ± 0.65	87.24 ± 4.35	89.73 ± 4.74
Amelogen Plus (A2)	65.14 ± 0.40	76.67 ± 2.98	77.12 ± 3.81

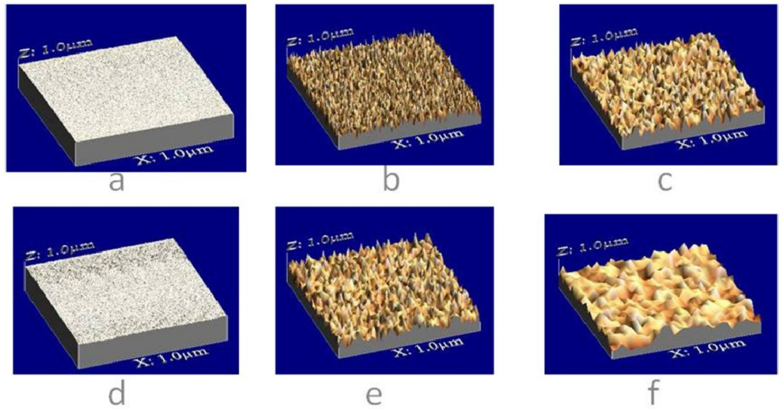

Fig.(1) 3D image of the surface roughness of the specimens,
Clearfil ES2 a- control b- soflex disc c- Flexicups
Amelogen d-control e- soflex disc f- Flexicups

4.Discussion

The current study examined the effect of different techniques of polishing on the surface roughness and surface micro-hardness of two nano-hybrid composites: Clearfil Majesty ES2 and Micro-hybrid composite Amelogen Plus (A2).

Regarding surface roughness, the results from the current study showed that the control group (Mylar strips) exhibited significantly lower roughness values (smoothest surface) than the Soflex discs or Flexicups polishing systems ($p<0.05$). This finding was in agreement with other studies that showed that Mylar strip groups exhibited significantly lower roughness values (smoothest surface) than other polishing systems ($p<0.05$) (Woolford.,1988; Tate., 1996; Yap et al., 1997; Yap & Mok., 2002; Yap et al.,2004;Korkmaz et al.,2oo8;Dutta et al.,2012).

The results also showed significantly lower roughness values for Sof-Lex Al_2O_3 flexible discs than for Flexicups in the two composite resins: Clearfil Majesty ES-2 and Amelogen Plus ($p<0.05$). These findings are in agreement with the results obtained by other researchers (Berastegui et al., 1992; Toledano et al., 1994; Luet al., 2003) which showed that flexible aluminum oxide discs are the best instruments for providing low roughness on composite surfaces. Van and Ruyter (1987) showed that the capability of aluminum oxide discs to produce smooth surfaces was related to their ability to cut filler particles and matrix equally. Their efficacy, however, depended on the anatomical form and accessibility of the restoration.

Moreover, other studies have reported that flexible aluminum oxide discs are the best instruments for generating low roughness in resin surfaces. (Lu et al., 2003;T¨urk¨un et al.,2003 and Venturini et al.,2006) demonstrated that aluminum oxide discs were capable of providing smooth surfaces and this fact was related to their ability to reduce fillers and matrix evenly.

Özgünaltay et al., (2003) reported that aluminum oxide disks provided the smoothest surfaces on resin restoration related to their tendency to abrade filler particles and resin matrix equally, without dislodging the filler particles or gouging into the material.

Microhardness testing showed that it provides information regarding the mechanical properties of the material, Braem et al.,(1989). A positive correlation has been determined between the hardness and inorganic filler content of composites, Boyer et al., (1982). Increased organic filler levels result in increased hardness values, Chung (1999). In this study, the Clearfil Majesty ES-2 nanohybrid composite, which had the highest filler content (78% by weight), showed significantly higher microhardness than Amelogen Plus.

Composites with harder filler particles exhibited higher surface roughness values; however, the bond of the filler particles to the polymer matrix affected their hardness values (Craig 1997; Korkmaz et al., 2008).

However, the Mylar strip-created surfaces exhibited statistically significant lower microhardness values compared with all of the polishing systems for the two resin composites tested.

Although the surface obtained with Mylar strips was perfectly smooth, it is rich in organic binder resin. Therefore, removal of the outermost resin by finishing-polishing procedures would tend to produce a harder, more wear-resistant and hence, more aesthetically stable surface Jung et al.,(2007). In this study, the Mylar strip-created surface exhibited statistically lower microhardness values than all of the polishing systems.

Conclusions

Under the conditions of this study:

1- The smoothest surfaces were produced in the control group (Mylar strips) among the two composite resin materials tested.

2- Flexicup rubber-polishing cups had higher surface roughness than Soflex discs**.**

3- Composite Clearfil Majesty ES-2 had higher microhardness than Amelogen Plus.

4- The control group (Mylar strips) had lower microhardness than the polishing systems.

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