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EFFECT OF DIFFERENT POLISHING SYSTEMS ON PROPERTIES OF CONTEMPORARY COMPOSITE RESINS

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ABSTRACT

Objectives: This study aimed to evaluate the effects of different polishing systems on the surface roughness and surface micro-hardness of three types of composites.

Materials and Methods: One hundred and eighty samples were prepared in disc-shaped stainless steel molds with a uniform size of 6 mm in diameter and 4 mm in thickness. The samples were divided according to the materials used into three 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's strip) with no finishing and polishing. *Group II*, polishing with Spiral polishing wheels and *Group III*, polishing with Sof-lex Pop-on discs. 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's strips and then were filled with restorative materials. The materials were covered with Mylar's strips, and a glass slide was pressed against the mold 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 using high intensity Elipar TM LED light curing unit, all samples were light cured following the manufacturers' instructions. The specimens' surfaces in groups II and III were finished with an ultrafine diamond finishing. After finishing the group II specimens were polished using Spiral polishing wheel. Group III specimens were polished using Sof-Lex Pop-on discs, 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 both the surface roughness and micro-hardness test. 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 Tukey,s post hoc test, using SAS software.

Results: Comparing between the three polishing techniques, the Mylar's strips (control group) exhibited significantly lower roughness values (smoothest surface) than the polishing systems ($p < 0.0001$). Nanocomposite had the lowest surface roughness comparing to other materials. Comparing between the three materials, the greatest microhardness mean value was recorded with Sonic bulkfill, using Mylar's strips or Spiral wheel or Solfex disc polishing techniques($p < 0.0001$).

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Conclusions: The control group had the lowest surface roughness and microhardness values compared to the polishing groups. No significant difference on surface roughness between Spiral wheel disc values and Soflex disc. The lowest surface roughness material was Nano-composite in each of the used techniques and Sonic bulkfill had the highest mic-ohardness than bulkfill and nanocomposite

INTRODUCTION

The ultimate goal of using a dental restorative material is to restore the biological, functional, and aesthetic properties of healthy tooth structure [1]. Due to increasing restorative esthetic demand of the patient and newer improvement of composite, its clinical use has expanded considerably over the years, regardless of the cavity type and location. Application of nanotechnology in composites with nano-particles and nano-clusters have been introduced [2,3]. Recently bulk fill resin composite materials are being introduced into dentistry with an increasing number and different applications. All of them share the same claim of being able to be properly cured as on bulk up to 4 mm thickness [4]. This has the advantage of reducing the chair time and making the resin composite restoration procedure simple compared to incremental placement [5]. Changing materials composition can change its surface properties. A smooth surface restoration is crucial for esthetic and biological success of the restoration. Rough surfaces have unpleasant optical properties and are more susceptible to stain, plaque and bacterial retention [6]. The surface roughness of a restorative material influences the aesthetic appearance of a restoration in terms of brightness and texture [7]. An increased surface roughness allows for the accumulation of plaque, increasing the occurrence of recurrent caries [8]. The step of finishing and polishing composite restorations aims to provide adequate occlusal anatomy, remove small excesses and get a smooth, flawless surface that allows for adequate light reflection [9]. The surface roughness depends on various factors, such as: the amount and size of the filler particles and the type of resin matrix of composite restoration, also the type and particle size of the abrasives [10,11]. The mechanical properties of a composite, such as hardness and flexural strength, are fundamental to the material in resisting masticatory forces and providing greater longevity. The microhardness of a composite is directly related to the depth of cure of the restorative material. A lower microhardness of a resin composite indicates that the material is more susceptible to scratches and surface defects that can reduce the materials flexural strength and cause premature failure of the restoration [12,13]. Thus, the purpose of this current study is to evaluate the effect of different polishing systems on the surface roughness and microhardness of Sonic bulkfill, Filtek bukfill and Nano-composite Z350.

MATERIALS AND METHODS

Materials

Three commercial materials, Sonic bulkfill, Filtek bulkfill (posterior type) and Nanocomposite were used, all of them had shad A2. The commercial names, compositions and manufacturers of all of the materials used in this study are listed in Table (1).

Methods

One hundred and eighty samples were prepared in disc-shaped stainless steel molds with a uniform size of 6 mm in diameter and 4 mm in thickness. The samples were divided according to the materials used into three groups of 60 samples for each material, and each group was then subdivided into three subgroups according to the polishing

TABLE (1) The commercial names, compositions and manufacturers of the materials used

Materials	Manufacturer	Composition
Sonic bulkfill	Kerr Corporation,Orange, CA, USA	(1-methylethylidene) bis (4, 1-phenyleneoxy-2, 1-ethanediyloxy-2, 1-ethanediyl) bismethacrylate. (1-methylethylidene) bis [4, 1-phenyleneoxy (2-hydroxy-3, 1-propanediyl)] bismethacrylate. 2, 2'-rthylenedioxydiethyl dimethacrylate. Glass, oxide, and Silicon dioxide.
Filtek Bulk Fill,	3M ESPE, St. Paul,USA	AUDMA, UDMA, and 1, 12-dodecane-DMA. Non-agglomerated/non-aggregated 20nm silica filler, a Non agglomerated/ nonaggregated 4 to 11 nm zirconia filler, an aggregated zirconia/silica cluster filler (20nm silica and 4 to 11 nm zirconia particles), and a ytterbium trifluoride filler consisting of agglomerate 100 nm particles.
Filtek Z350	3M ESPE, St. Paul, MN, USA	Nanocomposite Bis-GMA, UDMA, TEGDMA, Bis-EMA, discrete nonagglomerated and nonaggregated silica and zirconia fillers of 20 nm and 4-11 nm in size
Ultrafine finishing diamond stones	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, St. Paul, MN, USA	
Spiral polishing wheels	3M ESPE, St. Paul, MN, USA	

instruments with 20 samples in each:

Group I, (control group)(Mylar's strip transparent non glazed) with no finishing and polishing.

Group II, polishing with Spiral polishing wheels. and *Group III*, polishing with Sof-lex Pop-on discs.

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's strips and then were filled with restorative materials. The materials were covered with Mylar's strips, and a glass slide was pressed against the mold 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 using high intensity Elipar TM LED light curing unit (3M ESPE), all samples were light cured following the manufacturers' instructions and, transparent Mylar's strips were removed immediately after light polymerization and the surface facing the light-curing unit was marked with a small dot using a permanent pen.

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 three times being used. Then the group II specimens were polished using Spiral polishing wheel (3M ESPE). Group III specimens were polished using descending 29 μm(M) 14 μm(F) 5 μm (SF) Sof-Lex Pop On XT aluminum-oxide discs, strictly following the manufacturer's instructions. Each disc and spiral wheels was discarded after use. All of the groups were stored in saline for 24 hr. All of the specimens in each subgroup were equally subdivided for both the surface roughness and micro-hardness tests.

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 (Ra) 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).

Vickers hardness measurements

The surface hardness of the specimens was determined using a Digital Display Vickers Microhardness Tester (Model HVS-50, Laizhou Huayin 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.

Micro-hardness was obtained using the following equation:

HV=1.854 P/d2

where:

HV is Vickers hardness in Kgf/mm2;

P is the load in Kgf;

d is the average diagonal lengths in mm.

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 Tukey's post hoc test, using SAS software.

RESULTS

I- Surface roughness Ra (um)

Comparing between the three polishing techniques, the mylar strip (control group) exhibited significantly lower roughness values (smoothest surface) than the polishing systems ($p < 0.0001$)

Comparing between the three materials using the same polishing technique, the highest mean value was recorded in bulkfill, while the lowest mean was recorded in Nanocomposite in each of the used techniques (mylar's strip, spiral wheel disc and Soflex disc). ANOVA difference revealed that the difference was statistically significant (P<0.0001),

No significant difference between Spiral wheel disc values and soflex disc

Two ways analysis of variance, revealed that the interaction of variables resulted in a significant difference between groups (p <0.0001), (Table 2, Fig.1,2,3)

II- Microhardness (HV)

Comparing between the three materials, the greatest mean value was recorded with Sonic bulkfill, using Myler strip or spiral wheel or Solfex disc polishing techniques. ANOVA difference revealed that the difference was statistically significant (P<0.0001), (Table 3)

Comparing different polishing techniques within the same material, One way analysis of variance (ANOVA) revealed a significantly higher value using Spiral wheel in Sonic Bulkfill (p=0.0037) and Bulkfill (p<0.0001). Moreover, in Nanocomposite Z350, a significantly higher mean value was recorded in Soflex disc subgroup, followed by spiral wheel, with the least value in Mylar's strip (p <0.0001), (Table 3, Fig. 2)

Two ways analysis of variance, revealed that the interaction of variables resulted in a significant difference between groups (p <0.0001), (Table 3)

TABLE (2) Surface roughness Ra (um) in different groups

		Mylar's strip	Spiral wheel	Soflex disc	F value	P^1 value
Nano composite Z350	Mean	0.012^{Cc}	0.222^{Cb}	0.231^{Ca}	20731	<0.0001*
	Std Dev	0.004	0.000	0.001		
	Min	0.007	0.221	0.229		
	Max	0.018	0.222	0.231		
Filtek Bulkfill	Mean	0.095^{Ac}	0.235^{Ab}	0.255^{Aa}	76000	<0.0001*
	Std Dev	0.001	0.001	0.003		
	Min	0.097	0.237	0.249		
	Max	0.094	0.234	0.257		
Sonic Bulkfill	Mean	0.059^{Bc}	0.230^{Bb}	$0.244^{B a}$	53051	<0.0001*
	Std Dev	0.002	0.001	0.001		
	Min	0.056	0.229	0.240		
	Max	0.061	0.233	0.247		
F value		2474	645	786	F= 51061 P^3<0.0001*	
P^2 value		<0.0001*	<0.0001*	<0.0001*		

Significance level p<0.05, *significant

TABLE (3) Microhardness (HV) in different groups

		Mylar's strip	Spiral wheel	Soflex disc	F value	P[1] value
Sonic Bulkfill	Mean	94.64^{Ac}	124.39^{Aa}	111.26^{Ab}	6.91	0.0037*
	Std Dev	2.77	22.89	20.81		
	Min	91.15	94.06	93.03		
	Max	101.09	148.74	142.90		
Filtek Bulkfill	Mean	91.74^{A}	106.13^{B}	98.65^{B}	15.53	<0.0001*
	Std Dev	4.89	4.57	7.43		
	Min	87.48	99.69	89.98		
	Max	101.11	111.88	111.75		
Nano composite Z350	Mean	61.17^{B}	78.89^{C}	83.24^{C}	40.1	<0.0001*
	Std Dev	9.20	0.83	4.11		
	Min	42.74	77.58	78.05		
	Max	69.07	79.60	87.44		
F value		88.73	26	11.69	F= 61.07	
P[2] value		<0.0001*	<0.0001*	0.0002*	P[3]<0.0001*	

Significance level p<0.05, *significant, ns= non significant

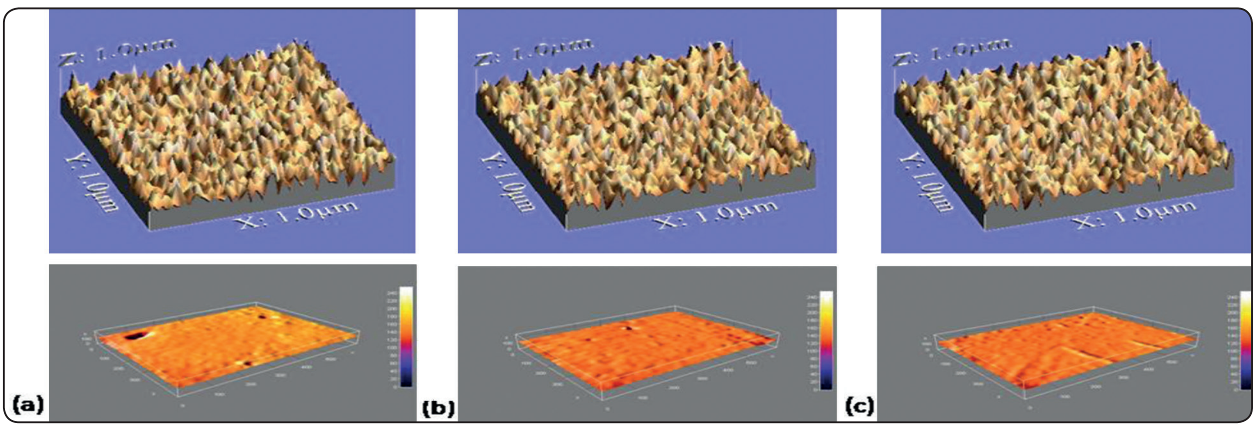

Fig. (1) 3D image of the surface roughness of the specimens, control (mylar strip) a) Sonicbulkfill. b) Bulkfill c) nanocomposite

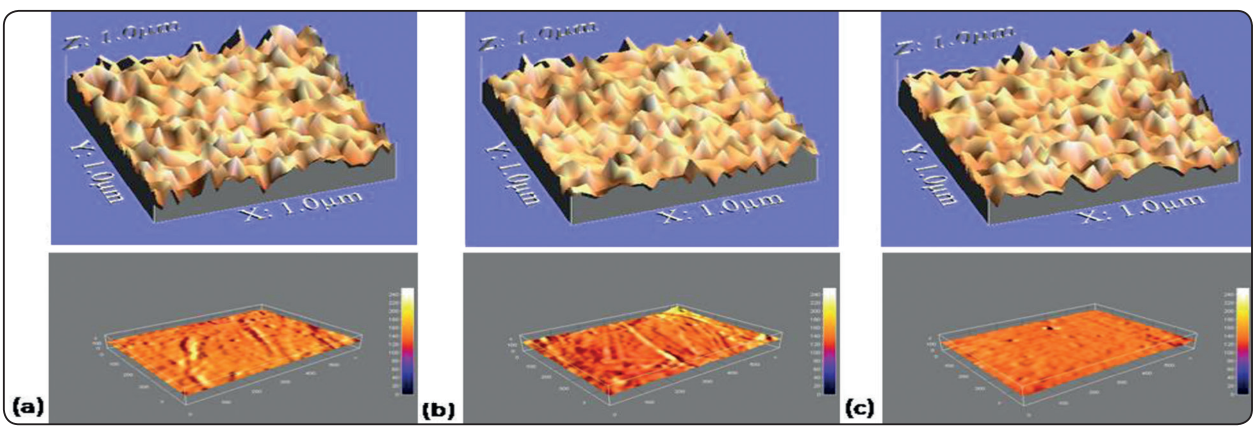

Fig. (2) 3D image of the surface roughness of the specimens polished by Spiral wheel a) Sonicbulkfill . b) Bulkfill c) nanocomposite

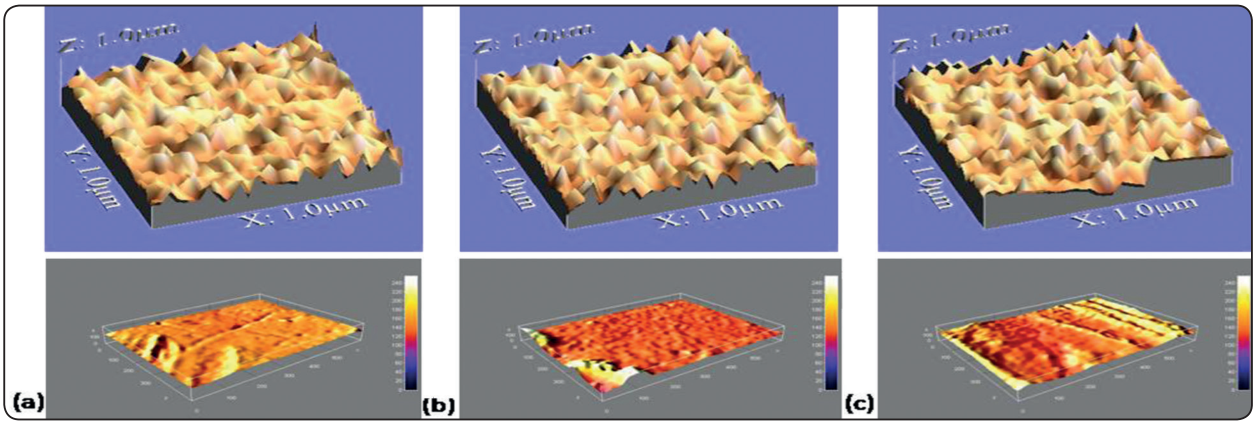

Fig. (3) 3D image of the surface roughness of the specimens polished by Soflex disc. a) Sonicbulkfill . b) Bulkfill c) nanocomposite

DISCUSIONS

Finishing and polishing of resin composite restorations are critical steps to enhance the esthetics and longevity of restored teeth.[14-15] Poorly polished restorations are susceptible to surface discoloration, plaque buildup, gingival irritation, and recurrent caries.[16] The surface quality of resin composite restorations is associated with the polishing quality along with its inborn physical properties like volume, hardness, quantity of filler particles and organization of the resin matrix.[17] The current study examined , the effect of different polishing systems on the surface roughness and microhardness of Sonic bulkfill, Filtek bukfill and Nano-composite Z350.

As regards surface roughness results from the current study were showed that control group (the mylar's strip) exhibited significantly lower roughness values (smoothest surface) than spiral wheel disc and soflex disc ($P<0.0001$). This finding is in agreement with other studies that showed that mylar's strip group exhibited significantly lower roughness values (smoothest surface) than the other polishing systems ($P<0.0001$). Didem et al., 2016[18]; Korkmaz et al.,2008[19]; Dutta S et al., 2012[20]; Yap et al., 1997[21]; Erdemir., 2012[22]; Uppal.,2013[23]; Yap & Mok., 2002[24]; Yap et al., 2004[25] ; Hassan et al.,2015[26]. Also, resin composite surface untouched with any cutting instruments or any finishing and polishing systems had filler particles that were not abraded away from the resin matrix, which finally led to the creation of the smoothest surface of the tested resin composites [27]. However, the smoothest surface of resin composite is achieved under Mylar's strip, but this surface cannot be maintained clinically because no flat tooth surface exists; otherwise, the complex tooth morphology will necessitate the clinician to make finishing and polishing for the restoration to reassemble the tooth complex morphology[28]. Moreover, control group (Mylar's strip) the resulting surface is polymer-rich and makes the restoration relatively unstable. Furthermore, this resin-rich surface should be removed since it can easily wear in the oral environment. In addition, the oral environment will be exposed to inorganic filler content if no polishing procedure is carried out. Therefore, this layer is often clinically abolishing during removal of excess material or contouring of the restoration after placement, making the efficiency of finishing and polishing procedures an important factor in the clinical success of composite resin restorations [18].

No significant difference between Spiral wheel disc values and soflex disc due to both of them contain aluminum oxide particles which promote homogenous abrasion of fillers and resin matrix[1], moreover Spiral wheel its abrasive particles are embedded throughout the wheels, so dentists can angle them to effectively polish with any side-top, bottom or edge. This flexibility makes it easier to work intra-orally, especially on challenging posterior teeth. Additionally, the flexibility of the wheels makes them kinder to gingival tissues compared with other types of rotary tools [15].

The current study were showed that the lowest surface roughness material was Nanocomposite in each of the used techniques (Mylar's strip, spiral wheel disc and Soflex disc).

The surface roughness of composite resins is influenced by filler size, hardness and amount, as well as the flexibility of the material used for polishing, hardness of the abrasive particles and grit size.[29] Nano-filled materials in dentistry are developed as a result of the combination of nano-sized particles with a conventional resin matrix. This technology not only improves the mechanical properties of conventional composite resins but also enhances esthetics by increasing polishing capacity and durability. The manufacturers claim that nano-filled composites have the strength of the hybrids and the polish of microfills.[30] Nano-particles are comprised of a polysiloxane backbone and may be best described as inorganic-organic hybrid particles. Methacrylic groups are attached to this backbone via Silicone-carbon-bonds. The inorganic Silicone component provides strength, while the organic part makes the particles compatible and polymerizable with the resin matrix.[18]

However Kumari et al, reported that Nanotechnology applied to resin composites is aimed toward the production of composites resins with improved mechanical and esthetic characteristics attributed to the reduced size and wide distribution of the fillers. These nano-filled composites also possess differences in their organic formulations, which may lead to distinct mechanical performance. The reduced size and wide distribution of the nano-fillers may increase filler load, consequently, improve the mechanical properties of these new materials, such as their polymerization shrinkage, tensile strength, compressive strength, resistance to fracture, and reduced wear. It has been observed that nano composites promote translucency and polish, and retain that polish similar to microfilled composites but with physical properties and wear resistance equivalent to those of hybrid or universal composites.[31]

Moreover they reported that the Filtek Z350 nanocomposite consists of both nanoparticles and nanocluster fillers 82% by wt. Nanoparticles are discrete nonagglomerated and nonaggregated silica and zirconia fillers of 20 nm and4-11 nm in size. The nanocluster particles increase filler loading, physical properties and polish retention of the nanocomposite. the reason for less abrasion of Z350 is because of uniform distribution of pre-cured silica particles in the organic matrix. Z350 exhibited least roughness when compared to other posterior composites.[31]

When comparing the resin composites, the Nanocomposite (Z350) exhibited the lowest Ra value, followed by the Sonic bulkfill, while the Bulkfill recorded the highest Ra value. This finding is in agreement with other studies that showed that Surface roughness was related to material composition rather than the polishing system[32]. This result is in accordance with other studies, they suggested that the filler particle size affects the surface roughness. The larger the filler particle size, the rougher would be the resin composite surface [28-33].

Microhardness is defined as the blocking resistance that prevents the creation of permanent deformation and hardness is the most important feature contributes the success of clinical utilizations. A high microhardness value eventuates increasing the scratch and abrasion resistance, meanwhile prevents the material easily deformed against various forces [34].

Sonic fill bulk fill resin composite had the highest surface microhardness compare to bulkfill and nanocomposite. This might be due to compositional differences in the filler type and amount. In agreement with our study, Czasch P and Ilie N found that there was a statistically significant difference in the mechanical properties and degree of cure between two bulk fill materials (SDR and Venus bulk fill) regardless of irradiation times and materials thicknesses used [35]. Flury et al found that increasing the increment thickness will result in decrease in the Vickers microhardness values for the conventional resin composites but remained constant for the bulk fill resin composites [36]. Moreover This result is in agreement with a study by Alrahlahet el al who used Vickers hardness profile to determine the post-cure depth of cure of five different bulk fill composite materials and found that the results were statistically significantly different [4].

The current study recorded that Mylar's strip group for all materials used had the lowest micro-hardness value, this in agreement with other studies that reported that Mylar strip produced perfectly smooth restoration surface, although it is rich in the resin organic binder. Finishing and polishing in such a case results in harder, more wear resistant and esthetically pleasing surface which is attributed to the removal of the superficial resin layer [18-37-38].

CONCLUSIONS

Within the limitations of the current study, it could be concluded that:

1. The smoothest surfaces were produced in the control group (Mylar's strips) among the three composite resin materials tested.
2. No significant difference between Spiral wheel disc surface roughness values and soflex disc.
3. The lowest surface roughness material was Nanocomposite in each of the used techniques (Mylar's strip, spiral wheel disc and Soflex disc). It also had the lowest micro-hardness value.
4. Sonic bulkfill had the highest mic-ohardness than bulkfill and nanocomposite
5. Control group (Mylar's strips) had the lowest microhardness than polishing systems.

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