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Compression of Surface Roughness of Different Bulk-Fill Composite Materials Using One-Step Polishing Systems (An In-Vitro Study)

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Abstract: Surface qualities for resin composite restorations are important factors for any successful restoration. Thus, finishing and polishing procedures are paramount to achieving acceptable aesthetics and guaranteeing the longevity of composite restorations. This in-vitro study aimed to evaluate the influence of a one-step polishing system on the surface roughness of three bulk-fill composite resin materials. This article provides a new view into the effects of finishing and polishing on bulk-fill composites, which has received very little research. Hence, this in-vitro study was conducted to extensively evaluate the impact one-step polishing technique has upon the three bulk-fill composite resin materials' surface roughness. A total of thirty discs were prepared from three commercial resin composite [Filtek One Bulk-Fill (3M), Tetric EvoCeram Bulk-Fill (Ivoclar Vivadent), and Ecosite Bulk-Fill(DMG)] using a stainless-steel flat washer. The composite material was condensed within a mold and cured with light Intensity 1000 mw/cm for 20 seconds. All specimens were divided into three groups (n = 10): (1) EvoCeram, (2) Ecosite group, and (3) Filtek group. A single operator polished all specimens. The top surface of each sample was finished with a fine-grit tungsten carbide bur (X-mas Tree with Safe End, NTI-Kahla GmbH, and Germany) for 30 seconds. Then all specimens were polished for 30 seconds by using the OneGloss one-step polishing system. A calibrated mechanical profilometer was used to measure the Ra for each material. The lowest roughness value (0.19) was observed for the composite resin Tetric EvoCeram (Ivoclar). One-way ANOVA and LSD test showed significant differences among and between all experimental groups. Therefore, Tetric EvoCeram had the only clinically acceptable Ra values.

Keywords: restoration, surface roughness, bulk-fill composite material, one-step polishing system.

使用一步拋光系統壓縮不同填充複合材料的表面粗糙度（體外研究）

摘要：樹脂複合修復體的表面質量是任何成功修復的重要因素。因此，修整和拋光程序對於獲得可接受的美學效果和保證複合修復體的使用壽命至關重要。這項體外研究旨在評估一步拋光系統對三種散裝複合樹脂材料表面粗糙度的影響。本文提供了一種新的觀點，即精加工和拋光對散裝複合材料的影響，這方面的研究很少。因此，進行這項體外研究以廣泛評估一步拋光技術對三種散裝複合樹脂材料表面粗糙度的影響。使用不銹鋼平墊圈，由三種商業樹脂複合材料[飛達一號批量填充、特立克埃沃赛拉姆批量填充和生態網站批量填充]製備了總共30個圓盤。複合材料在模具內濃縮並用光強度為1000兆瓦/厘米的光固化20秒。所有標本分為三組（n=10）：（埃沃赛拉姆，生態網站組，和菲爾泰克組。一個操作員拋光所有樣品。每個樣品的頂面用細粒碳化鎢車針（帶安全端的聖誕樹、新技術卡拉和德國）打磨30秒。然後使用一種光澤一步拋光系統

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將所有樣品拋光30秒。使用校準的機械輪廓儀測量每種材料的拉。複合樹脂特立克埃沃賽拉姆的粗糙度值最低(0.19)。單向方差分析和最小顯著性差異檢驗檢驗顯示所有實驗組之間和之間存在顯著差異。因此，特立克埃沃賽拉姆具有唯一臨床可接受的拉值。

关键词：修復，表面粗糙度，散裝複合材料，一步拋光系統。

1. Introduction

In order to have a successful resin composite restoration, surface qualities are reflected as key factors. Plaque buildup and staining surface caused by the rough surface of composite restoration could cause the failure of the restoration [1]. The cumulative demands for esthetic restoration of posterior teeth prompted an increase in the utilization of resin composite material instead of amalgam material. In comparison with other materials, composite resin material has more advantages. For example, better esthetic, minimal tooth preparation, mercury-free, and reinforcement of remaining tooth structure [2].

The surface quality is affected by several factors, such as the composition of restorative material, finishing and polishing instruments, and operator’s skill throughout the procedure [3]. Since its introduction, no material has been as modified and improved as composite resin [4]. One of the components of this material, which relates to surface smoothness, is its filler, i.e., the inorganic particles, and the factors involved are the type of particle, its size, and quantity [5]. The advance of nanotechnology to attain filler particles is one of the major advances in composite resins [6]. To improve composite resins without altering their physical qualities, smaller particles were created [7]. Polymerization shrinkage was reduced, strength and elasticity were increased, and polishing was improved due to this advancement [8]. Extrinsic elements such as food, alcohol, and smoking habits also play a role. Extensive discoloration can adversely affect the look of the restoration and is considered an aesthetic failure [9].

As a result, finishing and polishing techniques are critical not only for achieving acceptable aesthetics but also for ensuring the composite restoration's lifespan [10]. A novel type of resin composites, bulk-fill composites, was introduced to solve limited curing depth in large and deep cavities [11], time-consuming procedures, and other polymerization disadvantages [12]. This new material, which has a higher translucency, has the advantage of being applied in a 4 mm thickness increment in one simple process. Due to variations in the composition related to filler size, distribution, and initiators, the negative effect of polymerization shrinkage is avoided, and the degree of conversion may also be improved. Due to changes in composition and filler content, bulk-fill resin composites have varied optical characteristics [13]. Their surface roughness should be affected by these changes. There are numerous finishing and polishing technologies available today. While the effects of finishing and polishing on the roughness and gloss of "conventional" hybrid and nanohybrid materials have been extensively studied [14], little information on the effects of finishing and polishing procedures on bulk-fill materials has been gathered thus far. As a result, the goal of this in-vitro study was to evaluate the influence of a one-step polishing system on the surface roughness of three bulk-fill composite resin materials.

2. Materials and Methods

In the present study, three types of bulk-fill composite materials were used: Filtek One Bulk-Fill restorative shade A2 (3M, Minnesota, USA), Tetric EvoCeram Bulk-Fill shade IVA (Ivoclar Vivadent, Schaan, Liechtenstein), and Ecosite Bulk-Fill shade universal (DMG, Hamburg, Germany) (Fig. 1). Detailed information on the composition of each material is listed in Table 1.

Fig. 1 Flow chart for research methodology

Table 1 Summary of the bulk-fill resin composite products used in the study

Products	Monomer compositions	Filler wt.% / vol%	Filler type & particle size
Tetric EvoCeram Bulk-Fill shade IVA (Ivoclar Vivadent, Schaan, Liechtenstein) (TBF)	Bis-GMA, Bis-EMA, UDMA	81 wt. 61 vol.	Barium aluminum silicate glass (0.4 µm & 0.7µm) Isofiller (pre-polymer) Ytterbium fluoride (200 nm) Mixed oxide (160 nm)
Ecosite Bulk-Fill shade universal (DMG, Hamburg, Germany) (EBF)	Bis-GMA	82% wt. 65% vol.	Barium glass (0.02 and 0.7 µm)
Filtek One Bulk-Fill Restorative shade A2 (3M, Minnesota, USA), (FBF)	AFM, AUDMA, UDMA, DDDMA	76.5 wt. 58.5 vol.	Non-agglomerated Silica (20 nm) Non-agglomerated Zirconia (4–11 nm) Aggregated zirconia/silica (20 nm/4–11 nm) Agglomerate Trifluoride ytterbium (100 nm)

2.1. Specimen Preparation

A total of thirty discs, ten per group, were prepared from three commercial resin composite using a ready-made stainless-steel flat washer (10 mm diameter, 2 mm thickness) (Fig. 2). The composite material was condensed within the mold then covered with a celluloid strep in order to produce a flat smooth surface and to prevent the formation of an oxygen-inhibited layer on the surface of the samples [15] and cured with O-Light Curing Light unit (Woodpecker, Guilin, China) with light intensity 1000 mW/cm^2 for 20 Second. The distance between the light source and the material was zero mm. Specimens were examined for obvious voids by using a metallographic microscope (ME 600 Eclipse, Nikon-Kogaku, Tokyo, Japan). All specimens were divided into three groups (n = 10): (1) Evoceram group, (2) Ecosite group, and (3) Filtek group (Fig. 3). The samples were placed in a dark dry-storage area for 24 h in an incubator at 37°C [16].

Fig. 1 Types of bulk-fill composite materials

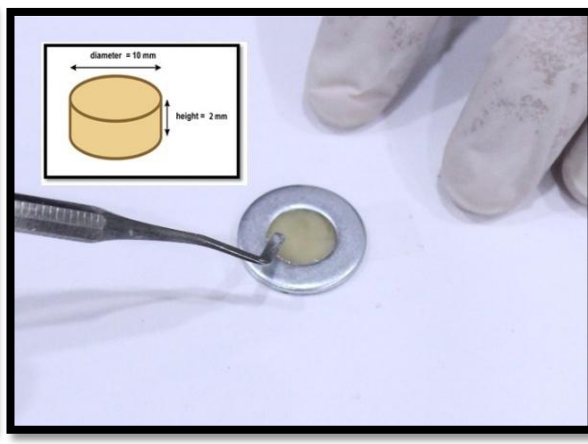

Fig. 2 Steel mold used for discs preparation

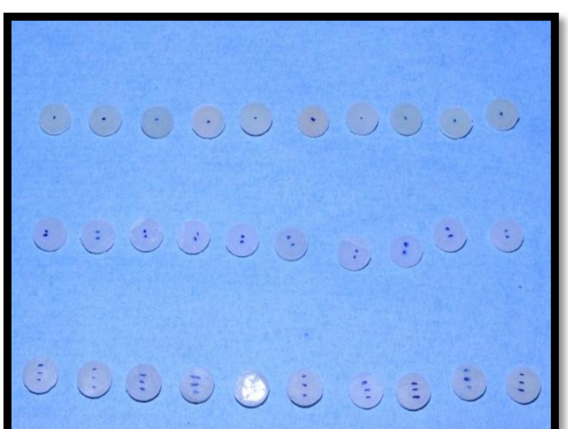

Fig. 3 Specimens group

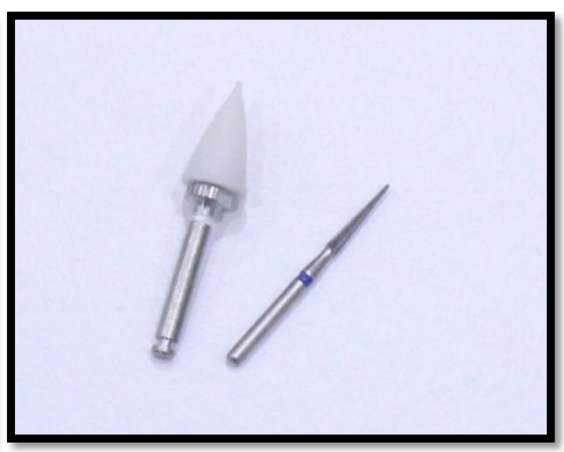

Fig. 4 Finishing & polishing bur

2.2. Finishing and Polishing Procedures

A single operator polished all specimens. The top surface of each sample was finished with a fine-grit tungsten carbide bur (X-mas Tree with Safe End, NTI-Kahla GmbH, Germany) for 30 seconds with a recommended speed of 20000 under constant cooling water. Then, all specimens were polished for 30 seconds at a rotation speed of 10,000/min with intermittent water spray by using a one-step polishing system (OneGloss, Shofu, Menlo Park, CA) (Fig. 4), the polishing head of this system consists of three different types of material which includes Synthetic rubber (Polyvinylsiloxane), Alumina grit (Al2O3) and Silicon oxide (SiO2). Specimens were then stored in a dry-storage area at 37°C for 24 hours. According to DIN 4768 [17], a calibrated, mechanical profilometer (Fig. 5) was used to measure the Ra for each material, and six measurements in the center of each sample at crossing directions were performed.

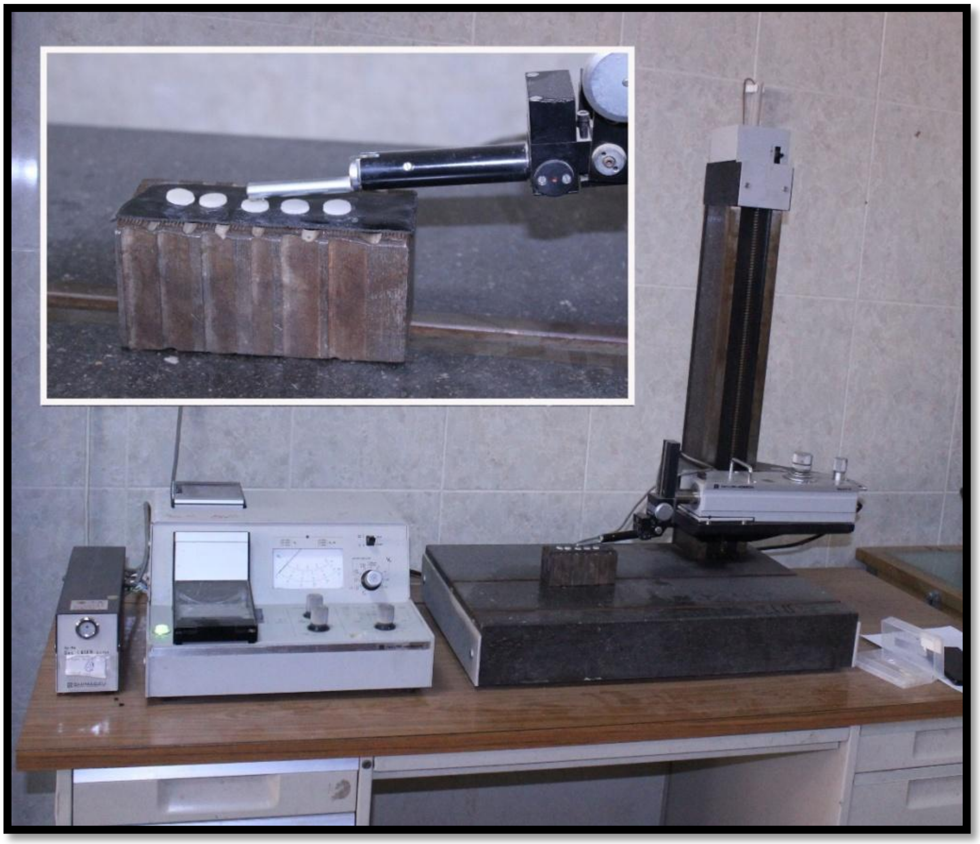

Fig. 5 Profilometer

3. Results

The descriptive statistics in Table 2 showed the highest Ra value, which was 0.38 for Filtek One (3M) composite resin, while the lowest rough value was (0.19), which was seen in Tetric EvoCeram (Ivoclar) composite resin, as shown in Fig. 6.

Table 2 Descriptive statistics

Materials	N	Minimum	Maximum	Mean	Std. Deviation
(TBF) Tetric EvoCeram (ivoclar)	10	.15	.25	.1910	.03178
(FBF) Filtek One (3M)	10	.31	.44	.3810	.03755
(EBF) Ecosite Bulk-Fill (DMG)	10	.20	.30	.26	.037

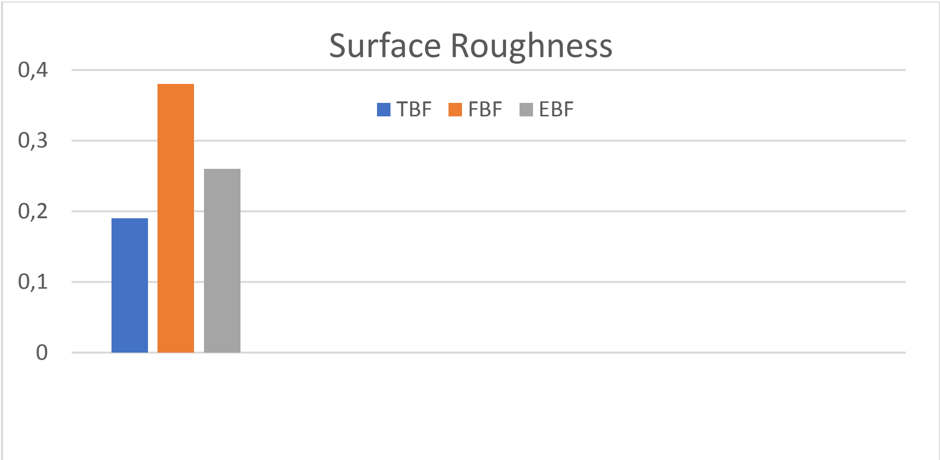

Fig. 6 Line chart of compressive strength of all groups

For further analysis, one-way ANOVA test was used to determine any statistical differences among groups. They showed significant differences among all experimental groups (Table 3).

Table 3 One-way ANOVA test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.184	2	.092	77.661	.000
Within Groups	.032	27	.001		
Total	.216	29			

For determining the statistical difference between each two experimental groups LSD test was used, it was shown that there were significant differences in Ra value between every two groups, as seen in (Table 4).

Table 4 LSD test

(I) Factor	(J) Factor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
TBF	EBF	-.07200*	.01539	.000	-.1036	-.0404
	FBF	-.19000*	.01539	.000	-.2216	-.1584
EBF	TBF	.07200*	.01539	.000	.0404	.1036
	FBF	-.11800*	.01539	.000	-.1496	-.0864
FBF	TBF	.19000*	.01539	.000	.1584	.2216
	EBF	.11800*	.01539	.000	.0864	.1496

* The mean difference is significant at the 0.05 level.

4. Discussion

Combining various intrinsic and extrinsic elements determines the surface roughness and gloss of any resin composite material. Intrinsic factors are related to the material itself, such as the resin matrix, the filler (type and size), and the binding strength at the filler/resin interface [18]. The type of polishing technique employed and the light-curing method are extrinsic factors. For all of the materials examined in this study, the polishing system and light-curing process were standardized. Profilometers have been used to assess surface roughness better to understand the surface texture of dental materials. SEM can be used to illustrate contour changes that the profilometer would miss, but it has limitations in that it cannot characterize three-dimensional surface topography. AFM has recently been utilized to obtain three-dimensional detailed topographical images of surface roughness in dentistry [19]. For the present study, the surface roughness values of each specimen were measured using a profilometer because of practical usage, cheap cost, and obtaining numerical values.

Filtek One, Ecosite, and Tetric EvoCeram were chosen because they have various filler and resin matrix compositions. In addition to differences in the resin matrix, they differ primarily in their inorganic component. The type of inorganic filler, particle size, and quantity of filler loading vary greatly among these materials, and these aspects influence their polishability [20]. This study found a considerable difference amongst bulk-fill materials, with TBF having the lowest Ra value, FBF having the highest Ra value, and EBF having an intermediate value.

Previous research has revealed that due to changes in chemical composition, TBF has a higher Vickers microhardness. Alterations centered upon switching the resin's backbone to a photoinitiator (Ivocerin, Ivoclar Vivadent) of higher efficiency and raising the substance's translucency and the insertion of smaller-sized spherical fillers. Due to the size and shape of the fillers, these changes result in a deeper and more efficient degree of polymerizing and higher polishing performance [12]. The roughest surface was formed by FBF, which might be explained by the changes made to the FBF matrix content. Two novel monomers (DDDMA and UDMA) and two low-viscosity monomers (DDDMA and UDMA) were introduced (AUDMA and AFM). DDMA and UDMA reduce reactive groups in the material to moderate the shrinkage, while AUDMA and AFM react with any methacrylate. This mechanism relaxes the developing material, relieving stress. According to previous research, UDMA elution on Filtek bulk-fill was significantly higher, and the degree of cure was lower than other bulk-fill composites [21]. These characteristics could lead to increased abrasion of the matrices during polishing and the exposure of surface fillers, resulting in increased roughness [22].

The resin matrix composition has a considerable impact on Ra and gloss. Bis-GMA is the foundation of TBF and EBF. Both resins' backbones are rigid [23], explaining why TBF and EBF were smoother than FBF. After polishing, the resin may not have been completely removed, leaving less filler exposed, resulting in a lower Ra and higher gloss value. In addition, the higher degree of monomer conversion in TBF could contribute to the low roughness rating; this has been shown to affect surface roughness [24]. TBF also incorporates "pre-polymers," a pre-cured composite consisting of an organic matrix and inorganic fillers crushed to generate filler particles with specified grain size[25]. The pre-polymers are blended with additional filler and monomer to create the finished composite material. The degree of monomer conversion may be increased by pre-curing these pre-polymers, resulting in lower roughness values. TBF is based on Bis-GMA, which has a high molecule size and chemical structure, resulting in stronger and stiffer resins [26]. FBF and TBF both had the highest gloss, but there was no significant difference in the appearance of polished surfaces or surface gloss.

According to a previous study, high-fill RBCs exhibit higher SR values than low-fill RBCs [27], which agrees with the present study in which there was a significant difference between Ra of TBF and EBF? Variations in Ra between TBF and EBF could be related to the fact that TBF had relatively lower filler content by weight (81%) than EBF, which had 82% filler content by weight. OneGloss (Shofu) produced the smooth surface in all restorative resin composite groups tested regarding the surface roughness of the different restorative resin composites investigated in this study. Backing material flexibility where the abrasive is placed, the hardness of the abrasive, the geometry of the instrument, and how the instruments are utilized are all factors that influence the efficiency of abrasive systems [28]. To be effective, the abrasive particles in a composite finishing system must be tougher than the filler materials, otherwise, polishing would only remove the soft matrix while the filler particles would pass through the surface [29].

The findings of the profilometer analysis in our study vary from 0.15 to 0.44 μm, and any surface with a Ra value of more than 0.2 μm is clinically undesirable because it increases the likelihood of bacterial adhesion and recurrent caries formation [30]. Therefore, according to the findings, the Tetric EvoCeram had the only clinically acceptable values because the mean Ra values of Tetric EvoCeram, Ecosite, and Filtek were (0.19 μm, 0.26 μm, and 0.38 μm) respectively.

A few limitations of the current study include the sample's flat surface, which does not exist within clinical repairs, limitations correlated to the in vitro research, and the lack of a clinical setting as there might be modifications in the in vivo outcomes. The Ra of the different groups in this study was evaluated and compared after roughening the samples. Moreover, for research in the future, it is recommended to perform the first Ra as it provides a better assessment. Additional studies are needed to determine the long-term toughness of these materials. It should include more research utilizing other accessible processes with greater sample size. In order to learn about the way these resins and polishing methods will operate in clinical settings, more research using materials formed in the teeth to imitate concave and convex teeth is needed. Moreover, additional research should include more investigation utilizing other available methods, such as SEM or AFM, because the profilometers were designed to evaluate surface roughness, yet, this technique is restrictive because it specifically produces statistical or quantitative findings.

5. Conclusion

According to the results obtained in this in-vitro study and within its limitations, there was a statistically significant correlation between the surface roughness of different groups. Tetric EvoCeram had the lowest surface roughness and an acceptable clinical Ra value. Moreover, bulk-fill resin mixtures contain many optical features caused by variations in composition and filler substance. These adjustments should have an impact on their surface roughness.

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