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Avaliação da rugosidade superficial de resinas compostas após polimento

Evaluation of surface roughness of composite resins after polishing

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RESUMO

Objetivos. O objetivo deste estudo foi avaliar a rugosidade superficial em diferentes resinas compostas após o uso de um sistema de polimento.

Métodos. Realizaram-se dez amostras em forma de disco de quatro resinas compostas nano-híbridas (Zirconfill®; Filtek ™ Supreme XTE; Brilliant EverGlow ™ e Ceram.X® Duo) e uma nanoparticulada (Harmonize ™) para cada um dos cinco grupos, usando um molde de silicone (6 mm de diâmetro e 1,5 mm de espessura) e perfazendo um total de cinquenta discos (n=10). Ambas as superfícies de cada amostra foram inicialmente preparadas com uma lixa de grão 600 (WSFlex 16®, Hermes Schleifmittel GmbH, Hamburg, Germany) com água corrente. Apenas uma superfície de cada amostra foi submetida ao sistema de polimento Enhance® e PoGo® (formato de disco) montado num contra-ângulo na peça com rotação ajustada a 7000 rpm. Após o polimento, a rugosidade da superfície foi avaliada (Sa-µm) para todas as amostras com um perfilómetro ótico 3D sem contato (S neox® 3D, Sensofar, Stuttgart, Alemanha). A análise estatística foi realizada com o IBM® SPSS® Statistics versão 23. A avaliação das diferenças entre cada par de amostras foi corrigida pelo método de Bonferroni. O nível de significância foi estabelecido em 0,05 para todas as análises.

Resultados. A resina composta Brilliant EverGlow™ obteve menores valores de rugosidade superficial; Harmonize ™, Filtek ™ Supreme XTE e Ceram.X® Duo apresentaram valores intermédios e Zirconfill® apresentou o maior valor de rugosidade superficial. Houve diferença estatisticamente significativa entre a rugosidade superficial das diferentes resinas compostas estudadas ($p < 0,05$).

Conclusão. Dentro das limitações do presente estudo, a rugosidade superficial (Sa) foi dependente do material e a capacidade de polimento dos compósitos foi significativamente diferente quando o sistema Enhance® e PoGo® foi usado.

Palavras-chave: rugosidade superficial, resina composta, acabamento, polimento, nanocompósito, perfilómetro, microscopia eletrónica de varrimento

ABSTRACT

Objectives. The purpose of this study was to evaluate surface roughness in different resin-based composites after using one polishing system.

Methods. Ten disk-shaped specimens of nanohybrid (Zirconfill®; Filtek™ Supreme XTE; Brilliant EverGlow™ and Ceram.X® Duo) and nanofilled composite (Harmonize™) were prepared for each of the five resin composite groups using a silicon mold (6 mm in diameter and 1,5 mm in thickness), and a total of fifty discs were obtained (n=10). Both surfaces of each specimen were firstly grinded with a 600-grit SiC paper (WSFlex 16®, Hermes Schleifmittel GmbH, Hamburg, Germany) in a moistened environment. Then, only one surface of each sample was subjected to an Enhance® and PoGo® polishing system (disc shape) in slow-speed handpiece with rotation set at 7000 rpm. After polishing the surface roughness was evaluated (Sa-µm value) for all samples with a non-contact 3D optical profilometer (S neox® 3D, Sensofar, Stuttgart, Germany). Statistical analysis was performed with the IBM® SPSS® Statistics Version 23. The evaluation of differences between each pair of groups was corrected by the Bonferroni method. The level of significance was established at 0.05 for all analysis.

Results. Brilliant EverGlow™ obtained the lowest roughness values; Harmonize ™, Filtek™ Supreme XTE and Ceram.X® Duo presented intermediate values and Zirconfill® showed the highest surface roughness value. There were statistically significant differences between the surface roughness of the different composite resins studied ($p<0.05$).

Conclusion. Within the limitations of the present study, surface roughness (Sa) was material-dependent and the polishability of the composites was significantly different when the Enhance® and PoGo® system was used.

Keywords: surface roughness, composite resin, finishing, polishing, nanocomposite, profilometer, scanning electron microscopy

INTRODUCTION

Resin-based composites have been increasingly used for a range of applications in dentistry due to their versatility on restorative procedures and because they provide good aesthetic properties, ease of handling and long-lasting clinical performance. (1-5) They also provide acceptable resistance and biocompatibility. (4-6) However, surface and optical characteristics, such as colour stability, surface gloss, and smoothness, can influence clinical success and longevity of these restorations. (7)

Composite resins are usually classified according to the average particle size, content and distribution, and filler type. (4, 8-11) They have a polymeric matrix organic (dimethacrylate), a silane bonding agent, filler particles, and modulators of polymerization reaction. The predominant monomer used is a high viscosity dimethacrylate: bisphenol-A glycidyldimethacrylate (bis-GMA). To reduce viscosity, this monomer is usually mixed with other monomers with lower molecular weight such as triethyleneglycol-dimethacrylate (TEGDMA) and urethane dimethacrylate (UDMA). (2, 10, 12)

The organic and inorganic matrix presents different hardness and, consequently, has different wear profiles. (1, 9, 13, 14)

The evolution of composite resins intends to reduce and eliminate their critical disadvantages such as polymerization contraction, fatigue, occlusal wear, organic particles degradation, surface roughness, interdental contacts and fractures. (13) These materials have progressed from macrofills (particle size between 10-50 µm, which had good strength but were difficult to polish and to obtain a smooth surface) to microfills (particle size between 0,01-0,04 µm, making them highly polishable). (10, 14, 15) Later, small hybrid particles (0,6-1 µm) were developed to be introduced in conventional composites. These hybrids progressed to microhybrids materials (0,01 µm – 3 µm) to provide a material with higher mechanical properties combined with superior polishability and luster. These are considered universal composites, as they can be used for most clinical applications. (1, 10, 14)

Newer materials have been introduced in the market, such as nanoceramic and nanofilled composites (1-100 nm) (6, 10, 14) and these are designed to provide maximum aesthetics, as well as good mechanical properties, allowing them to be used for both posterior and anterior restorations. (9, 12) Most manufacturers now include more nanoparticles and pre-polymerized agglomerates of resin in their microhybrid resins, similar to microfilled composites, naming this group as nanohybrids (0,4-5 µm). These resin composites are the most noteworthy because have excellent optical and mechanic properties. (5, 10, 14, 15)

Surface roughness is an extremely important property for the clinical success of composite restorations. (4, 6, 12, 16, 17) It refers to the finer irregularities of the surface texture. (18) On the composite resin surface, the roughness depends on the chemical composition and mechanical characteristics of these materials, which is determined by the size, shape, and percentage of inorganic filler particles. (3, 5, 6, 13, 19)

Distinct particle sizes of composites will determine the surface roughness and gloss; and the bigger the particle size, the greater the roughness. (5, 13, 18, 20, 21) As the size of filler particles is decreased and the percentage by weight is increased, the aesthetic properties and polishing capacity of a material improve. (1, 22)

Optimum aesthetics and low plaque accumulation are achieved through the smoothness of the surface restoration. A smooth surface has always been the major objective of composite restorations, not only for aesthetic reasons but also regarding better oral health. If the surface is rough, it may lead to a decreased in gloss and an increased in discoloration of the material surface. (5, 12, 14, 18) As bacterial plaque retention occurs preferentially on rough surfaces, when infiltrated bacteria on such surfaces, they are more protected against shear forces from brushing, muscle action, and salivary flow. (19, 23) It has been reported that a material incapable of attaining and/or maintaining a Ra value below 0.2 µm *in vitro* would be susceptible to an increase in plaque accumulation and higher risk for caries and periodontal inflammation, however most patients could detect rough surfaces only when the Ra values were above 0.3 µm. (23) Restorations poorly-polished may even cause irritation to tongue, lips, and oral mucosa and it can be a matter of concern to patients. (1, 3, 4, 14, 16, 23, 24) On the other hand, a recent systematic review reports that the bacterial adhesion does not seem to be related to a pre-established roughness threshold. (19)

External or internal factors can influence the discoloration of composite restorations and these represent a problem to treatment success. The physicochemical characteristics of the resin structure and the surface irregularities can cause internal colour changes, retentions of biofilm or superficial stains. Various techniques and materials are frequently used for finishing and polishing composite restorations. They have different abrasives and according to their size and hardness attains different degrees of surface roughness. (5, 14-16, 24) These systems influence the surface roughness, the gloss, and maintenance of the colour of restorations. (3, 12, 15, 19, 25-27)

It is well known that polishing and finishing procedures improve the aesthetic properties and clinical stability of resin composites and can also be determinant for discoloration resistance of these materials. (21, 22, 25, 28, 29) A visibly polished surface significantly reduces the risk of initial bacterial adhesion and subsequent colonization.(19) Simultaneously, it is expected a decrease in periodontal disease, marginal discoloration and the progression of secondary caries specifically promoted by *Streptococcus mutans* and *Streptococcus sobrinus*. (3, 4, 6, 12, 13, 20, 22, 27, 28)

However, the question about the best techniques or materials should be used still remains, because different polishing systems yield distinct results on resin composite surfaces. (1, 6, 12, 20-22) Resin matrix and inorganic filler differ in hardness and do not wear out uniformly, hence the abrasive particles of the polishing materials must present hardness superior to that of the inorganic particles of the composite, to avoid excessive wear of the organic matrix. In addition, the surface geometry and proper operatory handling also influence composite polishing. (13, 21, 27)

In dental practice, professionals sometimes need to perform adjustments of the restoration and they resort to the use of finishing procedures with fine-grit diamond burs that change the surface topography and causing an increase in surface roughness. (17, 19) The difference between finishing and polishing procedures is that the first is the gross contouring procedure that aims to create an adequate anatomy and remove excess of restorative material; the second increases the lustre and brightness of restoration, decreases surface roughness and minimizes the scratches produced by the finishing instruments. (4, 13, 14, 17, 29) Composites are finished and polished to establish a functional occlusal relation and a contour that is physiologically in accordance with supporting tissues, with an higher gloss to give the desired appearance of natural tooth structure that patients demand. (20) Immediate polishing produces a rougher surface in comparison with that produced by polishing after 24 hours or 7 days.(6) However, immediate polishing is recommended, since this procedure reduces the number of clinical sessions and brings more comfort and satisfaction to the patient. (20) To minimize the roughness after finishing procedures, many polishing kits were created to eliminate the grooves and achieve a smoother surface. Rubber wheels, sandpaper discs and wheels with diamond paste are usually used. (17, 19)

Information is scarce about how to finish and polish nanostructured resin composites. (29) With the development of nanocomposites, update on the best polishing system to use and their relation with bacterial adhesion is required. (29) However, it is know that finishing and polishing procedures change the surface characteristics of restorations with time, which can lead to increased or decreased the formation of biofilm. (19)

The effect of the polishing systems on the surface roughness of composites has been reported to be material-dependent, and the effectiveness of these systems was mostly product-dependent. (14, 19) Thus, the aim of this study was to evaluate surface roughness of different resin-based composites after using one polishing system.

The null hypothesis is that there is no difference on surface roughness in resin-based composites after using one polishing system.

Keywords: surface roughness, composite resin, finishing, polishing, nanocomposite, profilometer, scanning electron microscopy

MATERIAL AND METHODS

Preparation of composite resin specimens

The composite materials tested in the current study were Zirconfill® (TECHnew, RJ, Brasil), Filtek™ Supreme XTE (3M ESPE, St Paul, MN, USA), Brilliant EverGlow™ (Coltène, Whaledent, Altstätten), Harmonize™ (KERR, Orange, CA, USA) and Ceram.X® Duo (Dentsply, Middle East & Africa). (Table I)

Ten disk-shaped specimens were prepared for each of six resin composite groups using a silicon mold (6 mm in diameter and 1,5 mm in thickness), and a total of fifty discs were obtained (n=10). The composite resin was condensed in a single increment and the upper and bottom surfaces of the mold were covered by glass slides where the material was compressed under pressure to produce a smooth surface and reducing the incorporation of pores into the formed resin disc. (Figure 1)

The specimens were polymerized using a light-emitting diode curing unit (SPEC 3 Coltène LED, Whaledent, Cuyahoga Falls, OH, U.S.A, 1600 mW/cm^2) from both sides for 20 seconds each.

Both surfaces of each specimen were firstly grinded with 600-grit SiC sandpaper (WSFlex 16®, Hermes Schleifmittel GmbH, Hamburg, Germany) in a moistened environment for 10 seconds to reach a standard surface roughness level prior to the finishing and polishing procedures. They were rinsed thoroughly with water after that process. The specimens were handled using tweezers, applied to the sides of the cylinder to protect the flat surface of the composite from any damage or contamination.

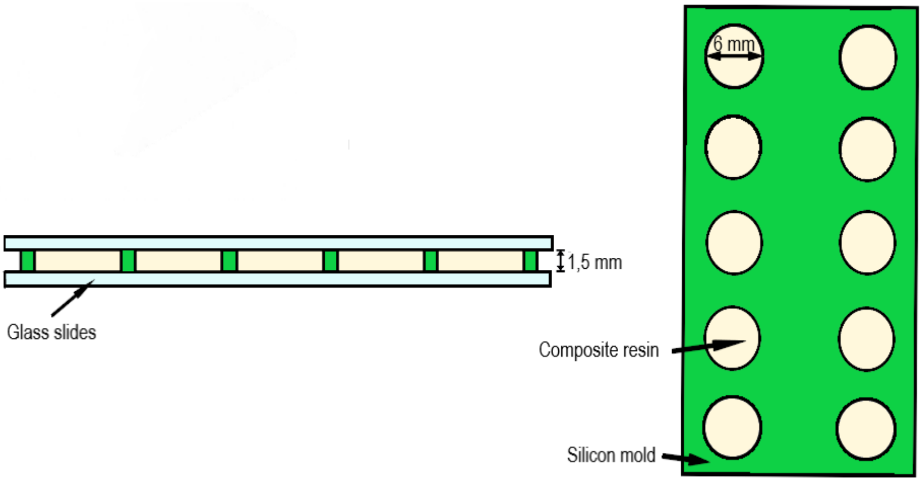


Figure 1: Schematic illustration of the preparation of composite resins samples

Finishing and polishing

The order of the groups to be submitted to the finishing/polishing procedures was chosen randomly. (Table I) A slow-speed handpiece (NSK S Max M25L) was placed in individualized support in paralellometer to standardize the pressure and keep the position perpendicular and constant on the surface of specimens (figure 2). The specimen preparation, finishing, and polishing procedures were carried out by the same operator.

One surface of each sample was submitted to Discs of Enhance® Finishing System and Discs of PoGo® Polishing System (Dentsply, Sirona). Enhance® and PoGo® systems have been developed to be used in the final polishing of compomer and composite restorations with micro-matrix, micro-hybrid, hybrid, microfill or restorative compomer, producing a smooth surface and high brightness. They are pre-mounted, single-use, of diamond rubber impregnated cured urethane dimethacrylate resin (information by manufacturer's) (Table II)

The specimens were primarily dry-polished, according to the manufacturer's instructions, for 30 seconds with Enhance® disc points at 7000 rpm 1:1, rinsed with distilled water to remove debris during 5 s, and then air-dried. The specimens were then dry-polished with PoGo® disc points at 7000 rpm 1:1 for 30 s, rinsed with distilled water, and then air-dried. New polishing tools were used to polish each specimen and discarded after each use. After this process, the samples were stored in distilled water. Subsequently they were placed in an ultrasonic bath for 5 minutes to eliminate the debris caused by the finishing procedures.

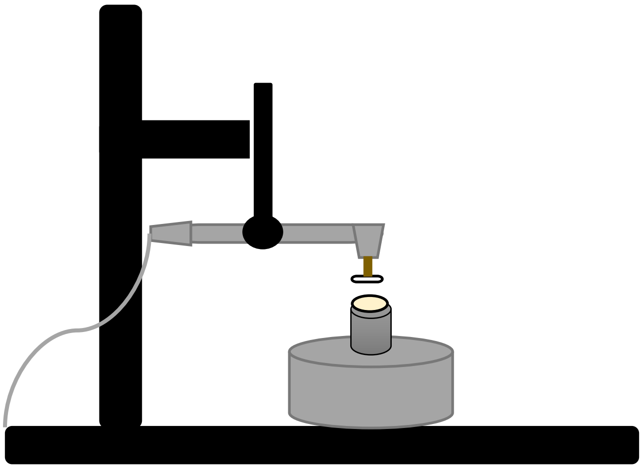


Figure 2: Schematic illustration of finishing and polishing procedures.

Surface roughness

A non-contact three-dimensional optical profilometer (S neox® 3D, Sensofar, Stuttgart, Germany) was used to measure the surface roughness in Sa (3D - µm) which is a 3D parameter expanded from Ra (2D - µm) parameter. Sa (µm) expresses the mean of the absolute values of roughness in the measured area. The 3D optical profilometer creates measurements at defined positions and full 3D volumetric measurements. This device also expresses the values of the highest peak (Sp) and the lowest peak (valley) (Sv) of the surface. This profilometer has a high-accuracy rotational module and a high-resolution translation platform with advanced inspection and analysis capabilities and uses a high-resolution CCD sensor with 1360×1024 pixels that are combinate with high-resolution displays of 2560×1440. This dispositive have 3 LEDs (red, green and blue) which illuminate the surface during measurement. A high-resolution color image (sharp, vivid and realistic) is obtain from composition of three monochromatic images. This approach are high fidelity because provides a real pixel-to-pixel color information, great color and saturation. In this study, an overview of the surface was made on the centre of the discs with amplification 10x, in an area of 6,49x7,26 mm^2 with 4 columns and 6 lines (Figure 2a).

For the analysis of the roughness, 4 images with the amplification of 100x were obtained in confocal mode of each sample in an area of 175.4x132,1 μm^2 and the mean was calculated (Figure 2b). In total, 50 images general and 200 imagens amplificated was obtained.

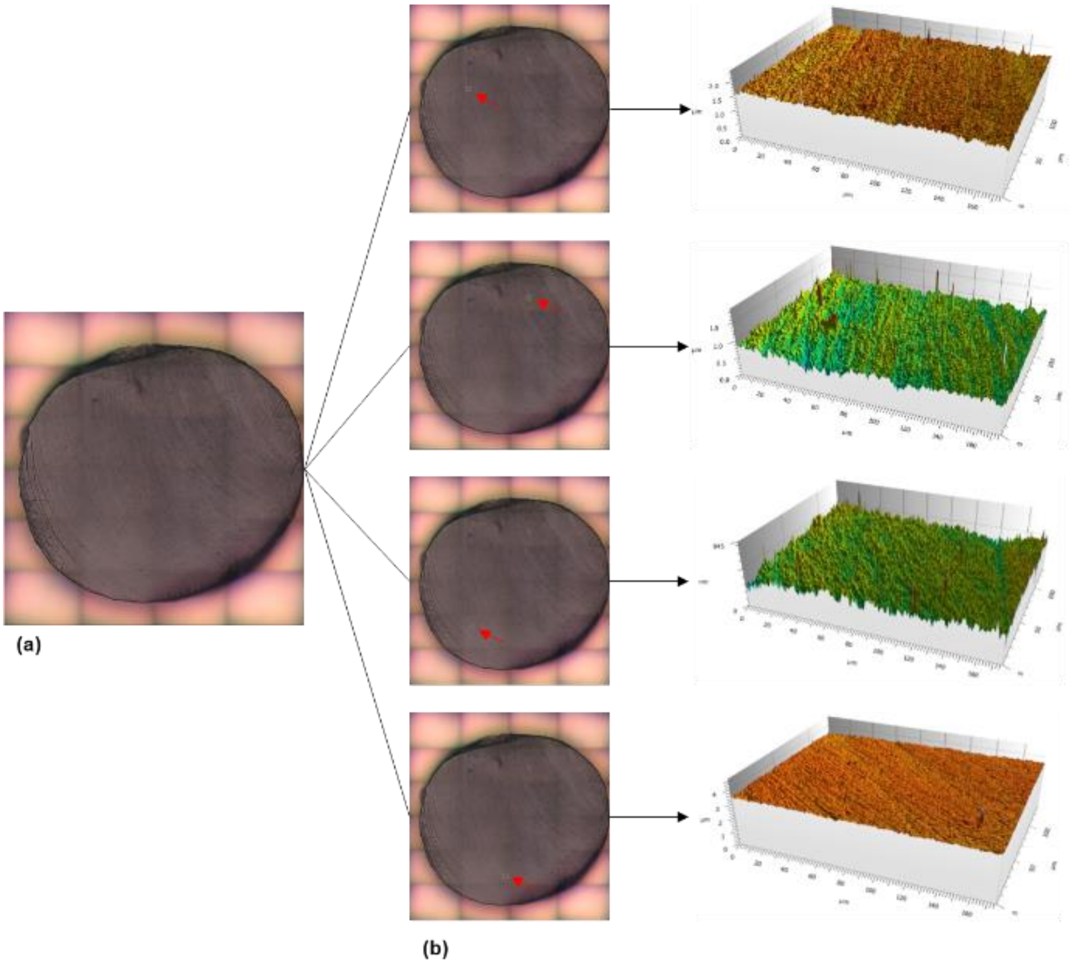


Figure 3: Schematic illustration of the acquisition of images from the profilometer. **(a)** general view with magnification 10x in an area of 6.49x7.26 mm^2; **(b)** random choice of 4 sites on the sample surface with 100x amplification in an area of 175.4x132.1 μm^2

Surface morphology

After finishing and polishing procedures, one representative sample of each group of composite resins was chosen for qualitative analysis. The samples were dehydrated using increasing ethanol sequences and immersed for 2 minutes in each solution (60%, 80%, 90%, 100%) in ultrasound cycles. Samples were placed on metal stubs, sputter coating with gold and palladium, and examined under a Scanning Electron Microscopy (Hitachi S-4100, Hitachi High Technology Corp., Tokyo, Japan) with an accelerating voltage of 25kV, for surface morphology of composites evaluation. The pictures were obtained with 5x, 2500x and 5000x amplifications and compared with previous images of each material to characterize the inorganic filler of each material.

Statistical analysis

A statistical analysis programme IBM® SPSS® Statistics Version 23 was used to calculate the mean and standard deviation. A non-parametric test Kruskal-Wallis was used to evaluate the null hypothesis and the level of significance. Pairwise comparisons were performed with Bonferroni corrections. The level of significance was set at 0.05 for all analysis.

Table I: Finishing/polishing systems used in this study.

Material	**Composition***		**Particle size***	**Manufacturer**	**Lot**
	Matrix	**Abrasives**			
Enhance®	Polymerized Urethane Dimethacrylate Resin and Silicon Dioxide	Aluminum Oxide	40 µm	Dentsply Caulk, USA	624045
PoGo®	Polymerized Urethane Dimethacrylate Resin and Silicon Dioxide	Fine Diamond Powder	7 µm	Dentsply Caulk, USA	662010

*Information provided by manufacturers

Table II- The composite resin materials used in this study.

Group	Resin Composite (shade)	Resin type	Filler type composition*	Filler weight (%)	Matrix*	Manufacturer	Lot/ Validity
1	**Zirconfill®** (A2)	Nanohybrid	Diatomite; Silica; Mixed Oxide of Zirconia and Silica; Barium glass	80%	Bis-GMA; Bis-EMA; TEGMA; UDMA	TECHnew, RJ, Brasil	16003/ 2019-02
2	**Filtek™ Supreme XTE** (A2)	Nanohybrid	Aggregated zirconia/silica cluster filler (0.6-10 μm); Silica (20 nm); Zirconia (4-11 nm)	78,5%	Bis-GMA; Bis-EMA; UDMA; TEGDMA	3M ESPE, St Paul, MN, USA	N843006/ 2019-10
3	**Brilliant EverGlow™** (A2)	Nanohybrid	Pre-polymerized filler with glass and nano-silica; colloidal nano-silica aggregated and barium glass non-aggregated (20-1500 nm)	79%	Bis-GMA; Bis-EMA; TEGDMA	Coltène, Whaledent, Altstätten	H31783/ 2018-09
4	**Harmonize™** (A2)	Nanofilled	Silica; Zirconia; Barium Glass (400 nm)	81%	Bis-GMA; Bis-EMA; TEGDMA	KERR, Orange, CA, USA	6280026/ 2019-09
5	**Ceram.X® Duo** (E2)	Nanohybrid	Barium-aluminium-borosilicate glass; silicon dioxide	72-73%	Polysiloxane methacrylate modified; Di-metacrylate	Dentsply, Middle East & Africa	0784/ 2018-04

*Information provided by the manufacturers. Bis-GMA: bisfenol-A glycidyl dimetacrylate; Bis-EMA: bisfenol-A ethoxylated dimetacrylate; UDMA: urethane dimetacrylate; TEGDMA: triethylene glycol dimethacrylate; TEGMA: triethylene glycol monomethacrylate

RESULTS

The results of roughness obtained for each composite resin studied are presented in Table III:

Table III: Statistics descriptive.

Composite resin	**Sa (µm) ± standard deviation**	**Sp (µm) ± standard deviation**	**Sv (µm) ± standard deviation**
1. Zirconfill®	0,126±0,020$_{a}$	1,530±0,180$_{b}$	2,163±0,439$_{dg}$
2. Filtek™ Supreme XTE	0,082±0,057	1,278±1,067	2,094±0,525$_{cfg}$
3. Brilliant EverGlow™	0,049±0,019$_{a}$	0,880±0,236	0,775±0,522$_{f}$
4. Harmonize™	0,076±0,016	1,079±0,473	2,260 ±0,7120$_{e}$
5. Ceram.X® Duo	0,070±0,013	0,799±0,290$_{b}$	0,714±0,285$_{cde}$
P	**0,001**	**0,024**	**<0,001**
Groups with same letter presents statistically significant differences (P<0,05)			

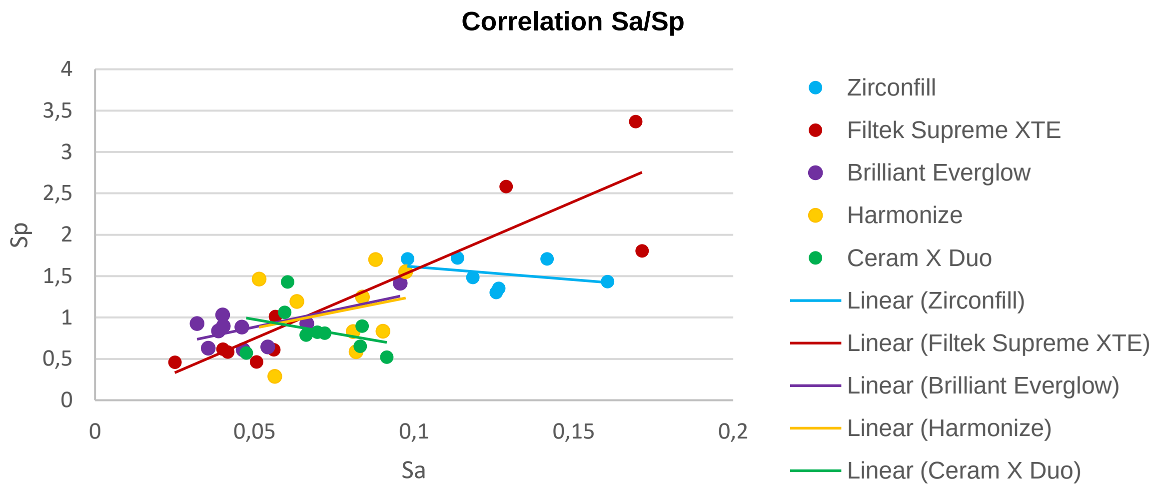
Statistical analysis was performed using non-parametric tests. The Kruskal-Wallis test indicates that for the 3 variables (Sa, Sp, Sv) there are statistically significant differences. Pairwise comparisons were performed with Bonferroni correction. There are differences between pairs of groups: Sa between groups 1 and 3 (P <0,001); Sp between groups 1 and 5 (P = 0.012); Sv between groups 2 and 5 (P = 0,008), 1 and 5 (P = 0,007), 4 and 5 (P = 0,001), 2 and 3 (P = 0,010), 1 and 3 (P =0,008), 3 and 4 (P = 0,002).

According to the results obtained, the null hypothesis formulated is rejected. There were statistically significant differences between the surface roughness of the different composite resins studied.

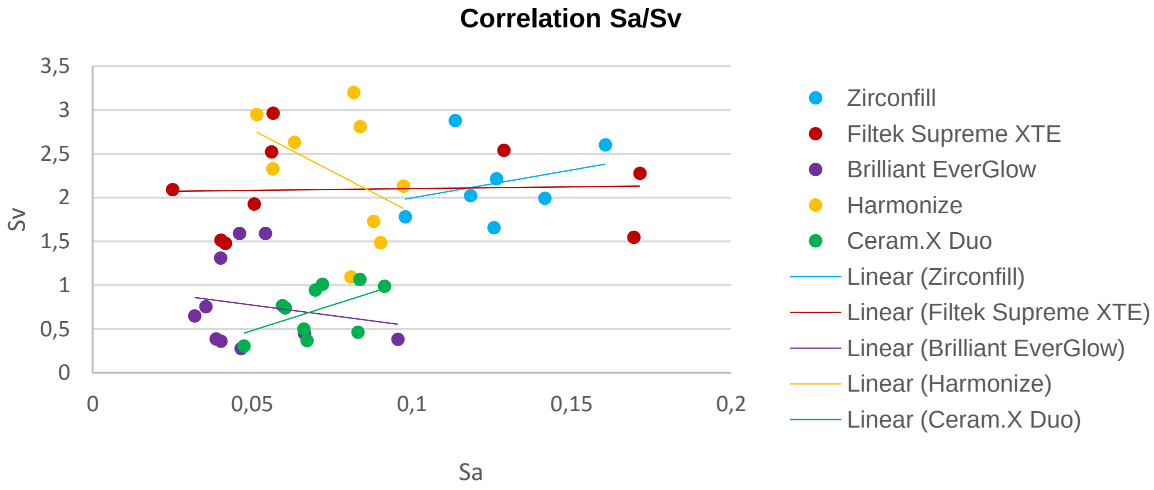
Table IV: Pearson correlation

Composite resin	**Sa/Sp**	**Sa/Sv**	**Sp/Sv**
1. Zirconfill®	0,033 P=0,867	0,263 P=0,177	-0,173 P=0,379
2. Filtek™ Supreme XTE	**0,678*** **P< 0,001**	0,121 P= 0,482	0,047 P= 0,786
3. Brilliant EverGlow™	0,107 P= 0,512	-0,044 P= 0,787	-0,086 P= 0,598
4. Harmonize™	0,082 P= 0,634	0,064 P= 0,711	0,105 P= 0,541
5. Ceram.X® Duo	0,034 P= 0,835	-0,127 P= 0,434	-0,220 P= 0,173

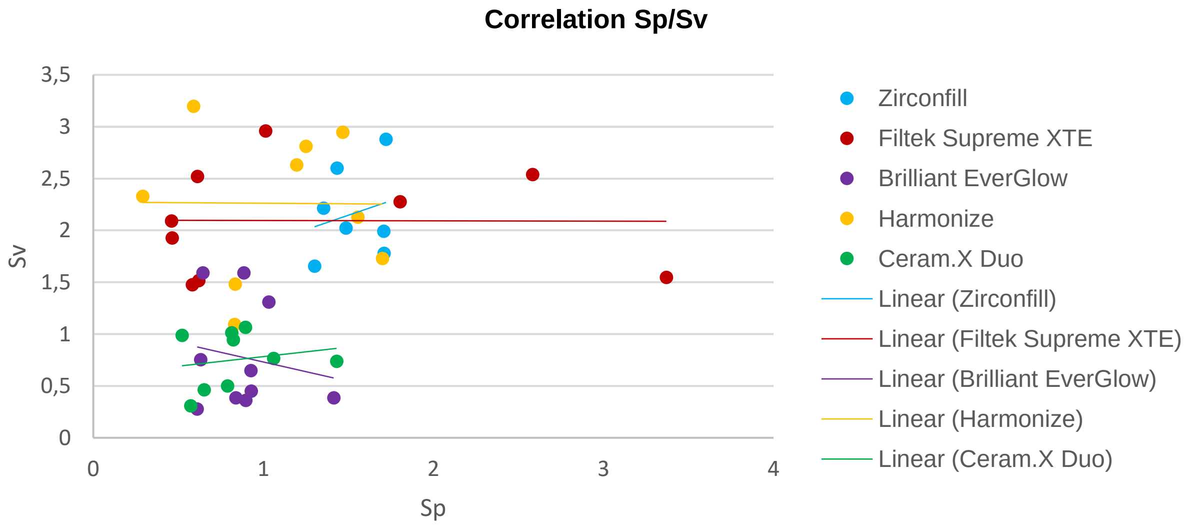
*Correlation is significant at the 0.01 level



Graphic 1: Pearson Correlation between Sa and Sp. Very strong positive correlation in Filtek Supreme XTE.



Graphic 2: Pearson Correlation between Sa and Sv



Graphic 3: Pearson Correlation between Sp and Sv

There is a positive correlation in group 2 (Filtek™ Supreme XTE) between the values of Sa and Sp (P<0,001), which indicates that the average surface roughness of this composite resin is more related to the higher peaks (Sp). For the other groups, there is no correlation between the values, which indicates that the average roughness arises from a random pattern.

The graphics show the correlation between the different parameters Sa/Sp (graphic 1), Sa/Sv (graphic 2) and Sp/Sv (graphic 3).

In the following images (figure 4 to 8) can be observed the three-dimensional images obtained through the optical profilometry of the representative sample of each group of composite resins studied.

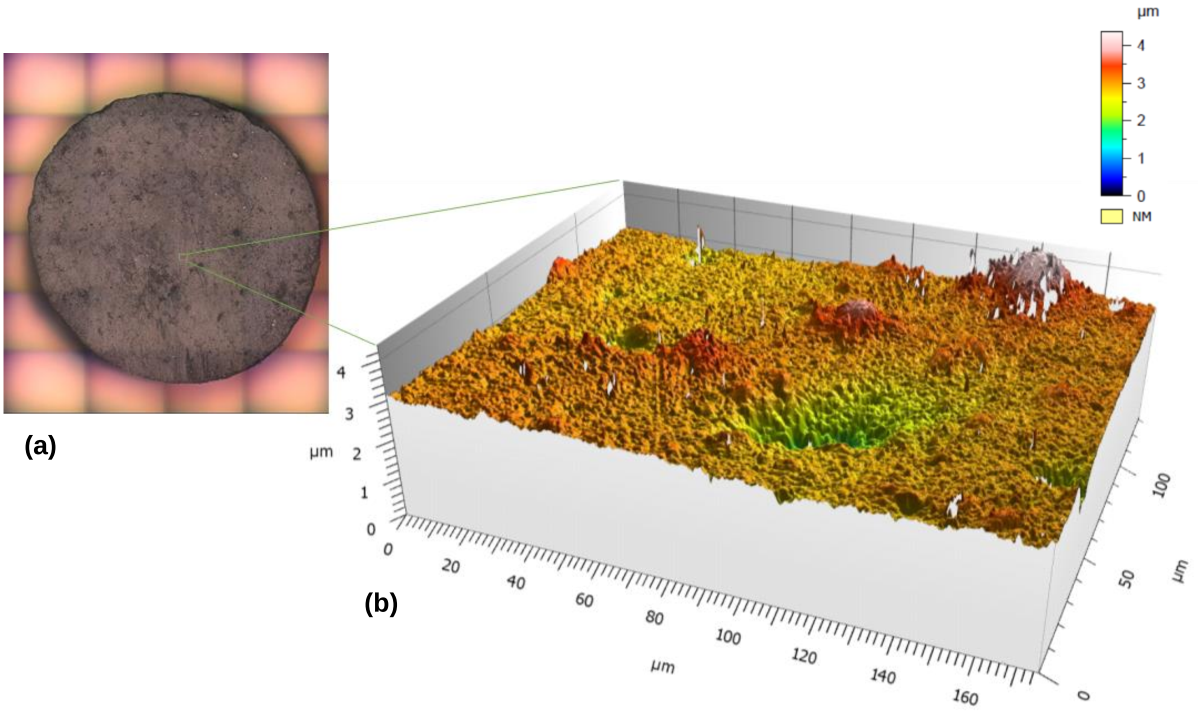


Figure 4: Three-dimensional image of surface roughness of Zirconfill® (group 1). **(a)** General overview; **(b)** Surface of representative sample.

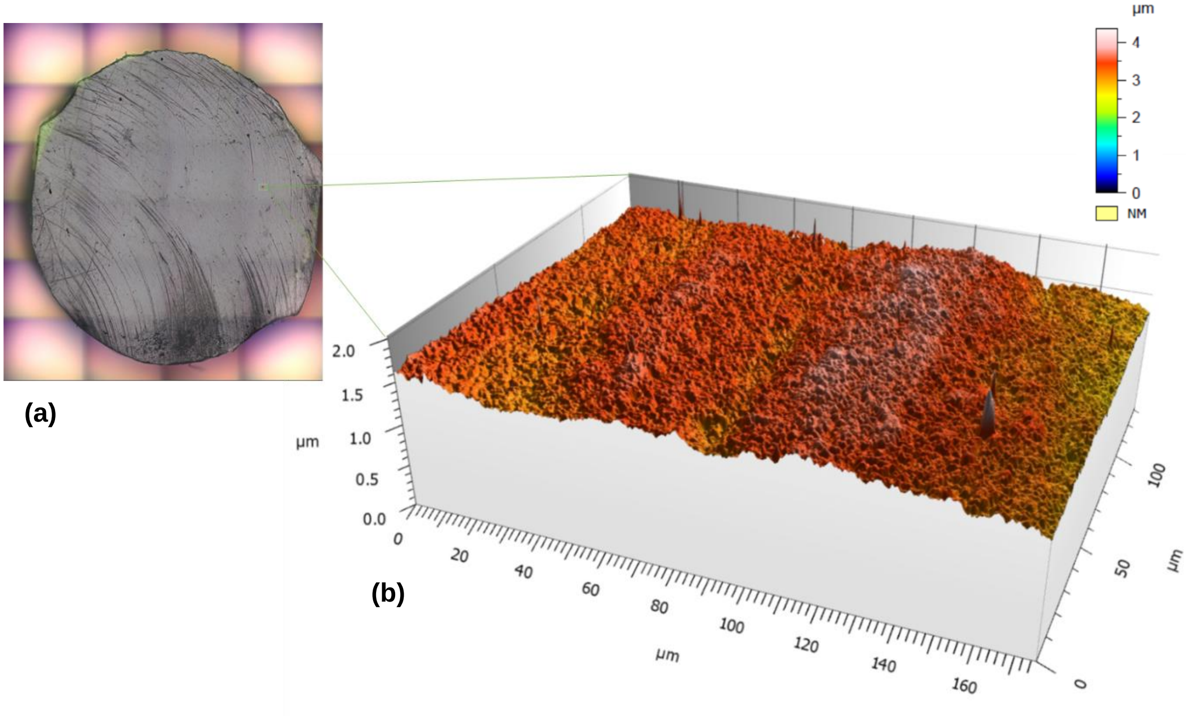


Figure 5: Three-dimensional image of surface roughness of Filtek™ Supreme XTE (group 2). **(a)** General overview; **(b)** Surface of representative sample.

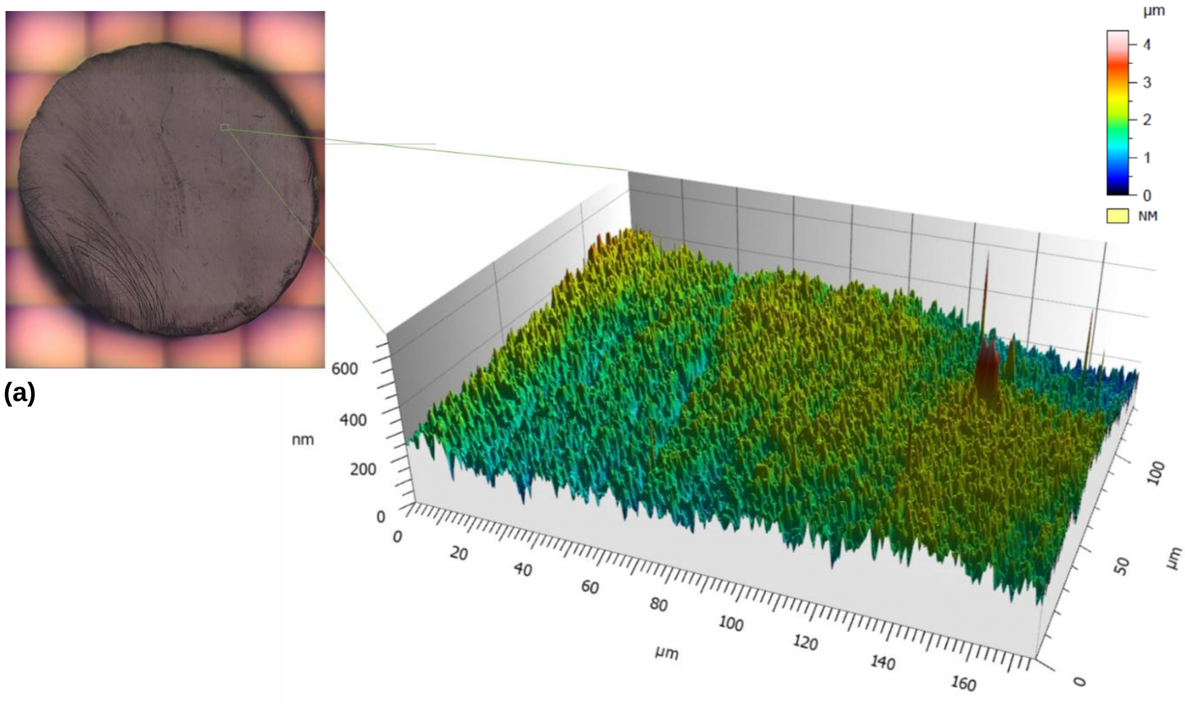


Figure 6: Three-dimensional image of surface roughness of Brilliant EverGlow™ (group 3). **(a)** General overview; **(b)** Surface of representative sample.

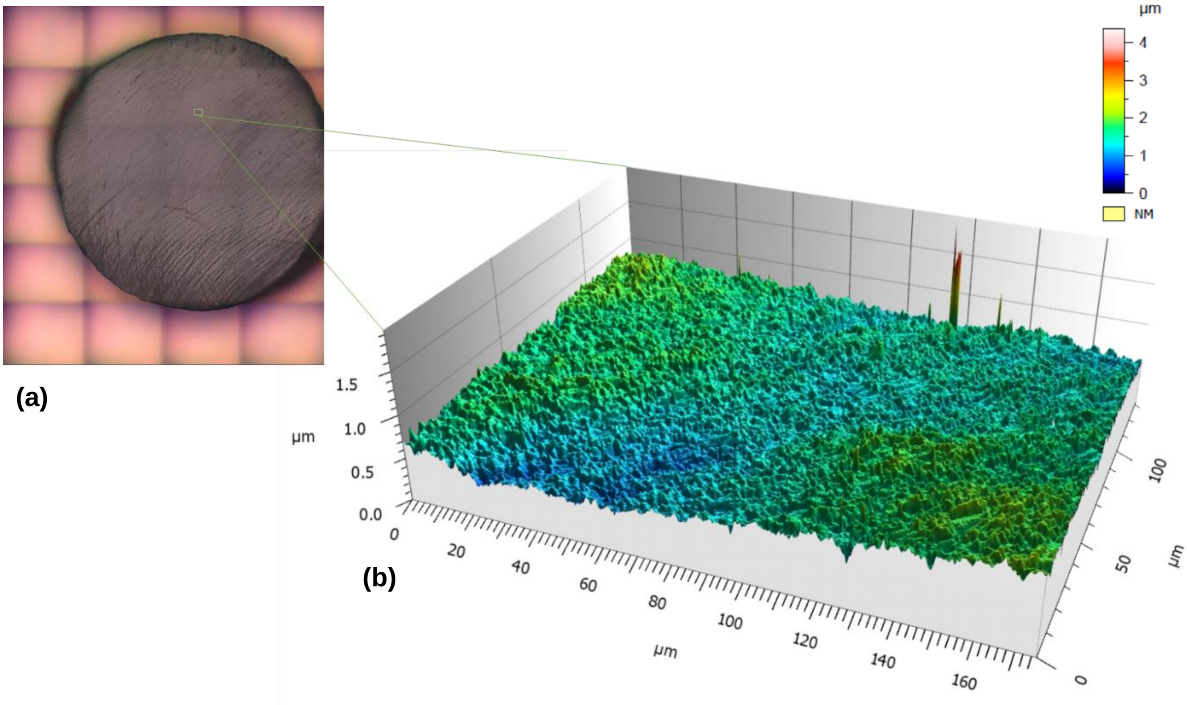


Figure 7: Three-dimensional image of surface roughness of Harmonize™ (group 4). **(a)** General overview; **(b)** Surface of representative sample.

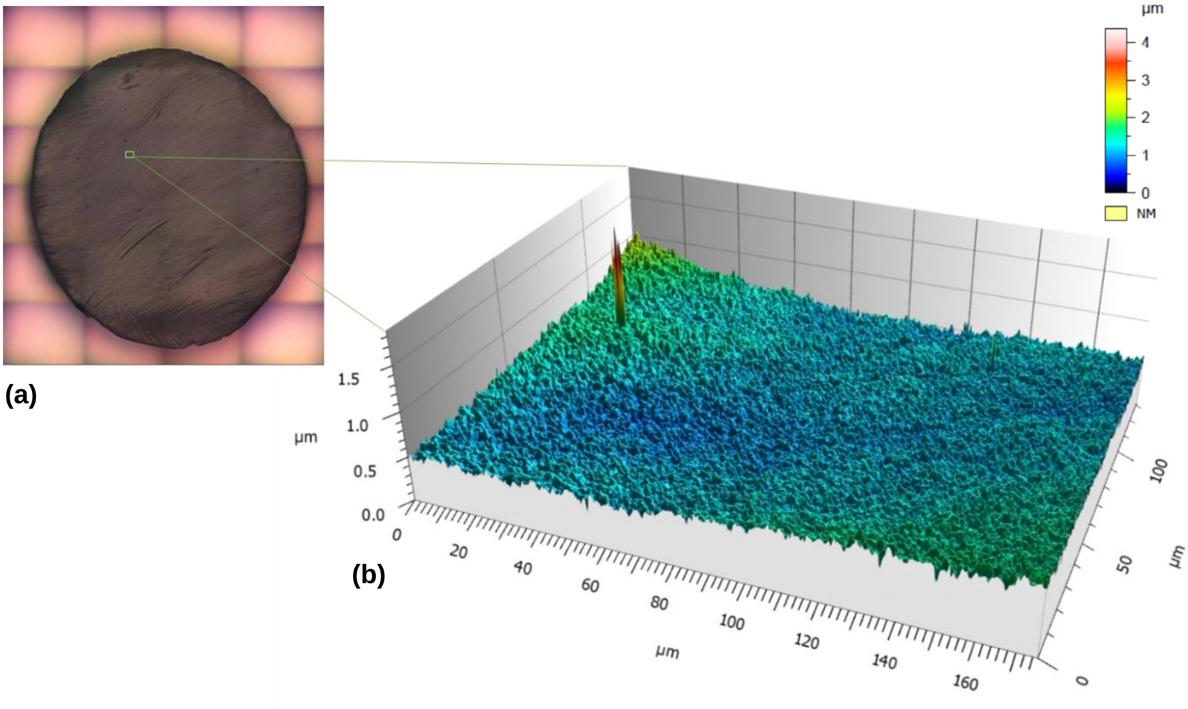


Figure 8: Three-dimensional image of surface roughness of Ceram.X® Duo (group 5). **(a)** General overview; **(b)** Surface of representative sample.

In the following images (figure 9 to 13) can be observed the Scanning Electron Microscopy (SEM) of the representative sample of each group of composite resins studied.

G1

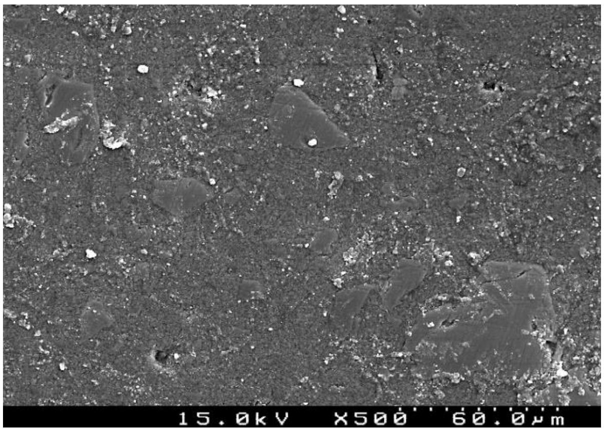


Fig. 9a: SEM picture with x500 amplification

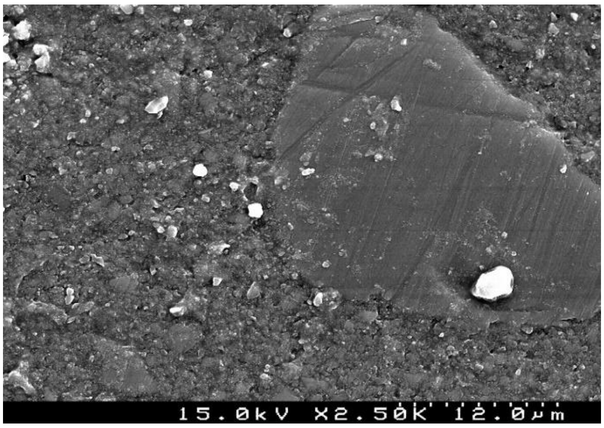


Fig. 9b: SEM picture with x2.500 amplification

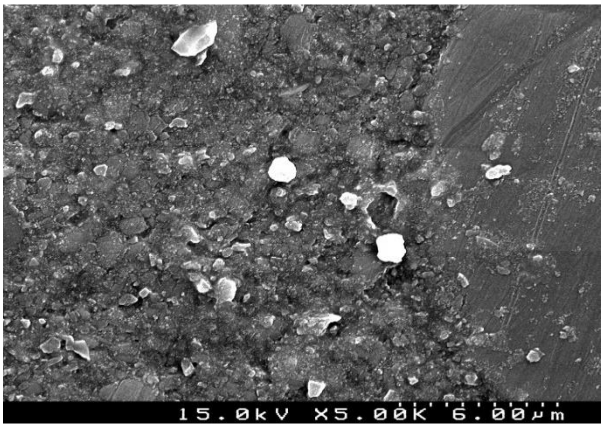


Fig. 9c: SEM picture with x5.000 amplification

Figure 9: Scanning Electron Microscopy pictures of the surface of Zirconfill® after polishing. With three amplifications of 500x; 2.500x and 5.000x (Fig. 8a; 8b and 8c respectively); it can be observed a heterogeneous surface with a prominence of the larger particles that were not polished.

G2

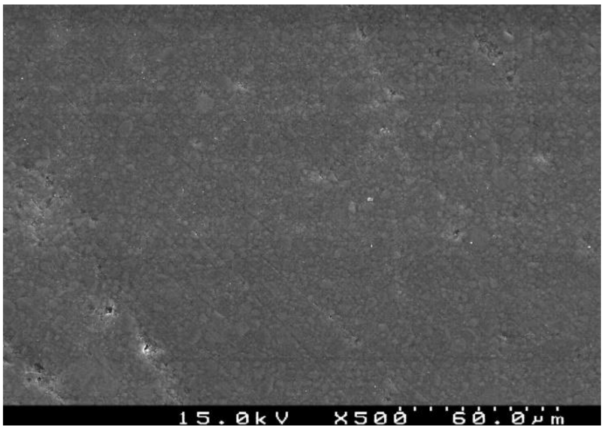


Fig. 10a: SEM picture with x500 amplification

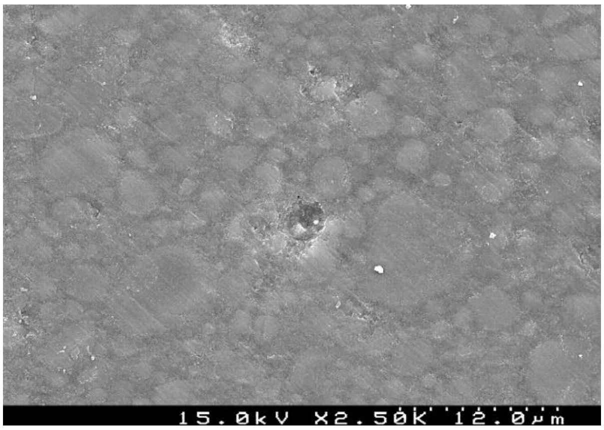


Fig. 10b: SEM picture with x2.500 amplification

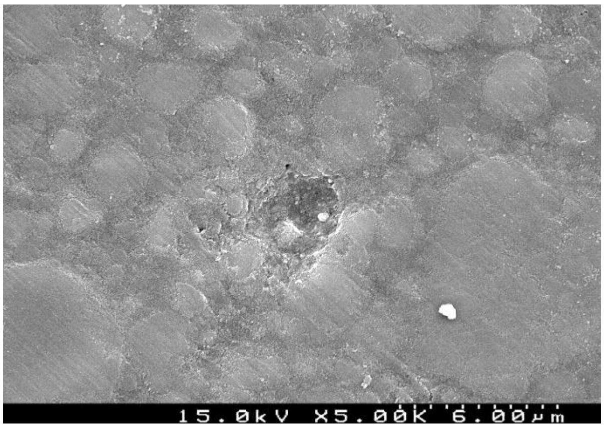


Fig. 10c: SEM picture with x5.000 amplification

Figure 10: Scanning Electron Microscopy pictures of the surface of Filtek™ Supreme XTE after polishing. With three amplifications of 500x; 2.500x and 5.000x (Fig. 9a; 9b and 9c respectively) a polished appearance can be observed although there are some areas with particle removal. The particles are large, and the surface have scratches in the same direction caused by the polishing system.

G3

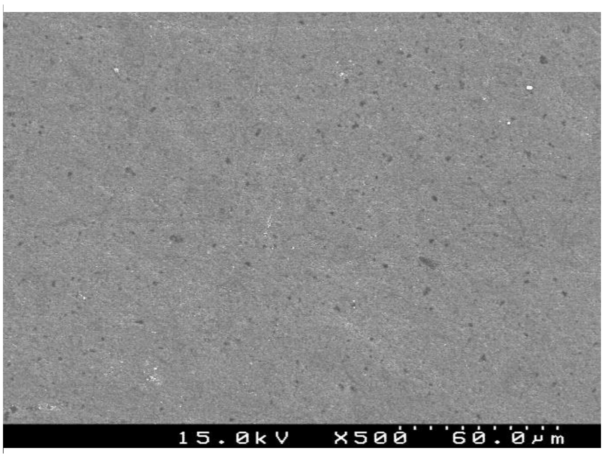


Fig. 11a: SEM picture with x500 amplification

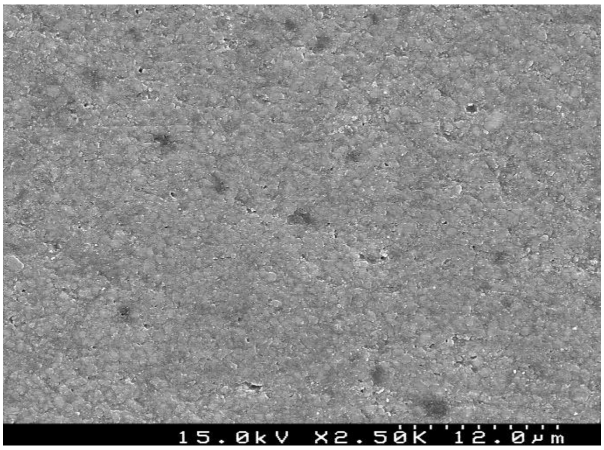


Fig. 11b: SEM picture with x2.500 amplification

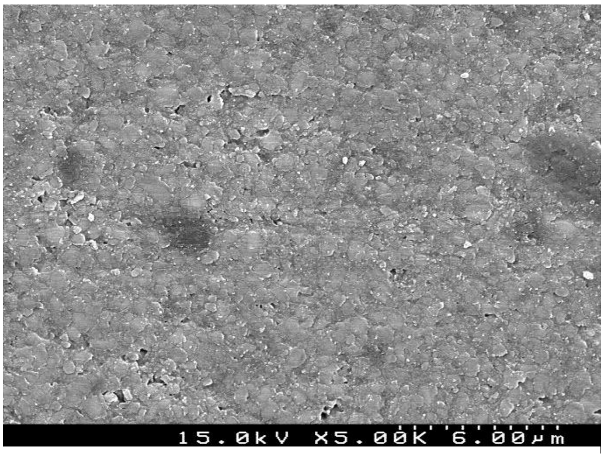


Fig. 11c: SEM picture with x5.000 amplification

Figure 11: Scanning Electron Microscopy images of the Brilliant EverGlow™ surface after polishing. With three amplifications of 500x; 2.500x and 5.000x (Fig. 10a, 10b and 10c respectively), the homogeneous surface can be observed; the darker areas are where there may be a slight depression on the surface because there is not much inorganic resin filling in those areas; some small scratches may also be observed.

G4

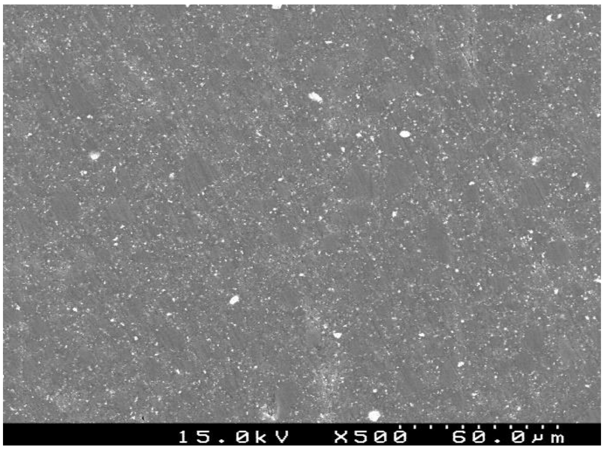


Fig. 12a: SEM picture with x500 amplification

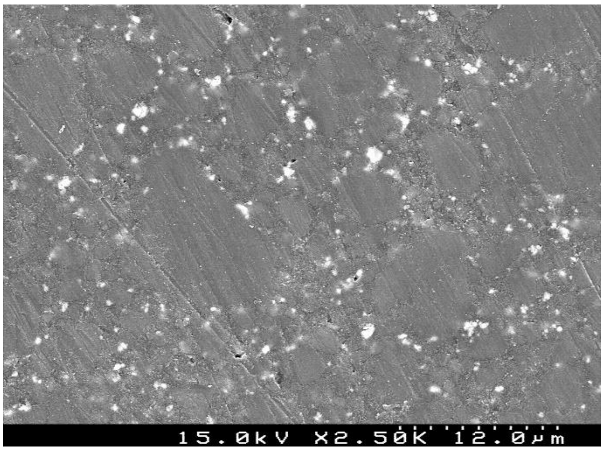


Fig. 12b: SEM picture with x2.500 amplification

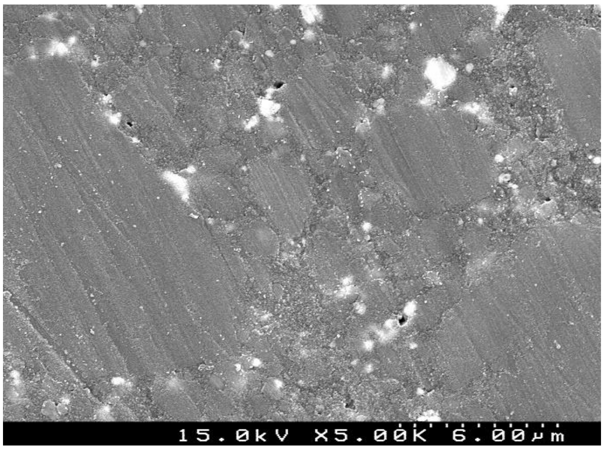


Fig. 12c: SEM picture with x5.000 amplification

Figure 12: Scanning Electron Microscopy images of the Harmonize™ surface after polishing. With three amplifications of 500x; 2.500x and 5.000x (Fig. 11a, 11b and 11c respectively) a uniform surface can be observed. It has large particles, but they are polished. Surface scratches and some resin detachments are observed.

G5

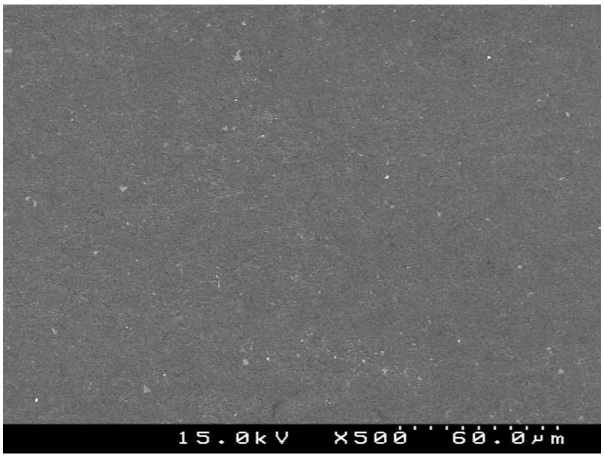


Fig. 13a: SEM picture with x500 amplification

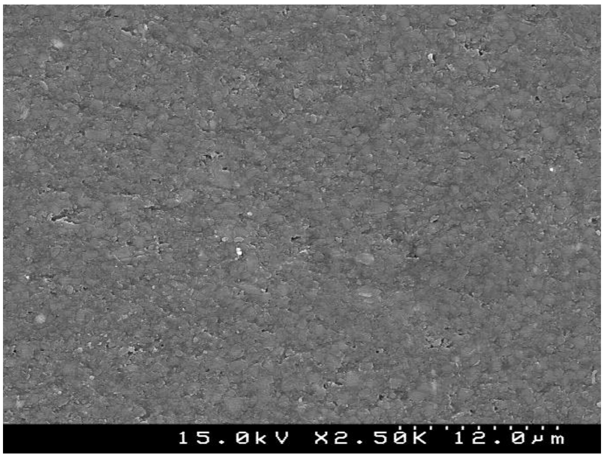


Fig. 13b: SEM picture with x2.500 amplification

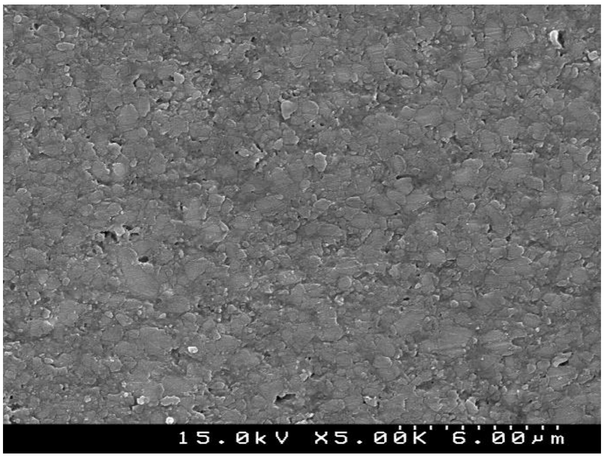


Fig. 13c: SEM picture with x5.000 amplification

Figure 13: Scanning Electron Microscopy images of the Ceram.X® Duo surface after polishing. With three amplifications of 500x; 2.500x and 5.000x (Fig. 12a, 12b and 12c respectively) a uniform surface, spherical particles and some detachments can be observed on the surface.

DISCUSSION

In the restorative process with composite resins is important achieve the effectiveness of finishing and polishing procedures. (4) According Dutra et al. (2018) (19), the use of a polishing system after finishing procedures improve the surface smoothness and decrease the biofilm retention. (19) It is a challenge to find the finishing and polishing systems with adequate hardness to polish the different content of composite resins. (17) Over the years these systems were submitted to constant modifications. (4) The polishing procedures can affect the surface roughness of restorations due to various factors such as time and pressure applied, handpiece speed, flexibility of the material, shape and chemical composition. (17) Poorly-polished restorations compromise the aesthetics and longevity of composite resin restorations, which leads to staining, plaque accumulation, gingival inflammation, and recurrent caries. (4, 7, 12, 14, 16, 19, 25-27, 30) The clinical performance of restorative materials in terms of surface roughness depends on several intrinsic and extrinsic factors. Intrinsic factors are related with resin monomer type and concentration of filler particles such as nature and size of material and their distribution of filler particles, shape, degree of polymerization, filler loading, matrix composition and durability of interfacial bonding between particles and matrix. Extrinsic factors are associated with finishing and polishing procedures and include the flexibility of polishing instrument, access to the surface to be polished, the hardness of abrasive particles, geometrical shape and its method of application. According to previous studies, a smoother surface is present in composite resins with smaller filler sizes. Therefore, filler particle size of resin composite affects their polishability; the smaller size will be easier to polish. Different sizes of fillers in resin composite decrease the effectiveness of finishing or polishing burs since these burs abrade better when particles have identical size. (4, 7, 12, 14, 26, 31)

The application of nanotechnology for the development of newer resin has great potential. (14) Nanohybrid resin is a new type of composite resin with characteristics that surpass other composites such as better polishing, ease of handling, and preservation of structure for long last time. (5) In this study, we used four nanohybrid and one nanofilled resins. The nanofilled presents smoother surfaces than microfilled composites. (16, 27) It is also known that the smoothest surface on a composite restoration could be achieved when formed by a well-applied matrix strip during curing but is not clinically relevant because normally the surface must be shaped and polished after removal of the matrix. (1, 7, 8, 14, 16, 17, 27, 31)

In this *in vitro* study, similar to Kemaloglu et al. (2017) (17), the finishing and polishing procedures were performed with a slow-speed handpiece applied to a standardized paralleling device which was developed to keep the applied pressure constant and perpendicular to the surface of the samples. (17) All samples were finished and polished in dried environment according to manufacturer’s instructions.

For the study of the samples, a quantitative analysis was performed through the profilometry and a qualitative analysis through microscopy (SEM).

The profilometers have been used in other studies *in vitro* (8, 12, 14-17, 26, 29, 31, 32) with dental composites to measure surface roughness. The 3D optical profilometer is an analytic system that provides the distance between an internal reference and point of the surface showing both qualitative and quantitative representation. (8, 26) After profilometric analysis we verified that different patterns of surface roughness were obtained between groups compatible with the average roughness values obtained. The differences in the mean values of Sa were statistically significant between the groups. These differences can probably be attributed to the intrinsic characteristics of the composite resin and due polishing system. (30) In the images obtained in 3D we found that it seems that there was deposition of particles of the polishing disc itself on the surface of the samples. The study of Nasoohi et al. (2017) (4) reported that surface roughness may increase when submitted to dry finishing and polishing because the abrasive particles separate from the polishing system and are also incorporated into the composite surface, which decrease the efficiency of the polishing system. Furthermore, heat generated during the dry process could degrade the filler/matrix bond.(4)

For the qualitative analysis a Scanning Electron Microscopy (SEM) was used, providing high-quality images of the surface morphology through a focused electron beam with high magnification and a large depth of focus. (14, 24) In terms of SEM images, Brilliant EverGlow™ (fig. 11) and Ceram.X® Duo (fig. 13) presented a uniform and smooth surface. This allows to conclude that the introduction of agglomerates of prepolymerized particles into the composite resins can lead to a better polishing of the surface.

In our study, all the Sa values (µm) of composites studied after finishing and polishing systems were < 0.2 µm, which is the critical size for bacterial adhesion. (23) However, in the systematic review of Dutra et al. (2018) (19), the studies evaluated have shown that topographic irregularities of restorative surfaces have a limited effect on bacterial retention *in vitro*, whereas in in vivo studies, bacterial retention is greater. Therefore, the value of 0.2 µm should be used carefully among the different materials evaluated due to the different results between the studies. (19)

In 2014, Kaizer et al. published a systematic review of *in vitro* studies and stated that dental materials manufacturers and the literature, in general, concluded that nanofills (and maybe submicrons) may perform better than microhybrids after finishing/polishing procedures due to the smaller size of the particles. However, methodologies used between studies are different and the impact of the evaluation method should be measured and there is no *in vitro* evidence that nanofill or submicron resin composites presented smoothness or gloss above microhybrids. (1)

According to Yadav et al. (2016) (14) and Nasoohi et al. (2017) (4), increase in filler content enhances the hardness of composites. (4, 14) Filler particles should be situated as close together as possible to protect the resin matrix from abrasives. Finer particles with greater distribution can achieve increased filler loading, which improves mechanical properties and decreases polymerization shrinkage. (14) In our study, Harmonize™ has 81wt% and Zirconfill® has 80wt% filler content, which is higher than other composites evaluated.

In present *in vitro* study, the roughness surfaces were obtained in the Zirconfill® group (Sa=0,126 µm). The filler content of this composite resin is mainly composed of zirconium/silica particles. However, the Filtek Supreme XTE (Sa=0,082 µm) and Harmonize (Sa=0,076 µm) also contain zirconia particles and presents lower roughness than the previous. A reason for this result could be the presence of the diatomite in the Zirconfill® resin composition. The diatomite is a silica with nanoscale pores, which causes a permeation of the monomers through the pores of the diatomite particles (information by manufacturer's). According manufacturer's, Zirconfill® presents low values of roughness (Ra=0,06 µm) after polishing with sandpapers (600, 1.200 e 1.500 µm) and polishing paste with granulation of 2 to 4 µm; but in present study, the values for same material were higher.

Studies such as those of Kemaloglu et al. (2017) (17) and Nair et al. (2016) (8) reported that low surface roughness on composites was achieved when used flexible aluminum oxide discs instruments. These results can be explained due to their ability to wear the filler particle and matrix equally. (8, 17) However, in present study, for composites with zirconia (particularly Zirconfill®), polishing procedures abraded the matrix around the zirconia particle and it remained more evident. One solution to avoid this situation may be to use the polishing system with less pressure for longer.

Tavangar et al. (2018) (7) compared the surface roughness between Filtek™ Supreme XTE (nanohybrid), Filtek™ Z250 (microhybrid) and Rok (hybrid). They used the Sof-Lex™ discs and Enhance® polishing systems and concluded that finer particle size results in less interparticle spacing, less filler plucking and a better polishing outcome. In this study Sof-Lex™ showed better results in surface roughness (Filtek™ Supreme XTE with Ra= 0.135 µm; Filtek™ Z250 with Ra= 0.160 µm and Rok with Ra= 0.189µm) compared to Enhance® (Filtek™ Supreme XTE with Ra= 0.222 µm; Filtek™ Z250 with Ra= 0.232 µm and Rok with Ra= 0.305 µm). However in this study they did not use PoGo® after Enhance®. (7) This results are similar to the study of Yadav et al. (2016), where they used 3 polishing systems (Super Snap® Rainbow Technique Kit, Sof-Lex™ Pop-On discs and Enhance®) and compared the surface roughness in 3 resin composites (Ceram.X®, Esthet-X® and Filtek™ Z250). The smoothest surface is produced by Sof-Lex™ (Ceram.X®=0.04303 µm; Esthet-X® =0.06847 µm and Filtek™ Z250=0.11254 µm), followed by Super Snap® polishing system (Ceram.X®=0.0799 µm; Esthet-X®= 0.1361 µm and Filtek™ Z250= 0.1970 µm) and Enhance® (Ceram.X®=0.1457 µm; Esthet-X®= 0.5419 µm and Filtek™ Z250=0.2446 µm) polishing system. The Enhance® polishing system led to lower polishability probably because it abrade smooth resin matrices and harder filler particles are left prominent from the surfaces. (14) Also Kocaağaoğlu et al. (2017) (26) compared the polishability of four resin composites (nanohybrid, hybrid and microhybrid) when polished with Enhance®+PoGo® or Bisco® Finishing Discs. In all composites, a smoother surface was obtained with the Bisco® Finishing Discs (BFD) than with Enhance®+PoGo® system (EP). One reason for these results could be polishing time. (26) The use of four BFD had a longer polishing period than the EP and according to Da Costa et al. (33) the time used for the polishing procedures can influence the surface smoothness and gloss of restorations. (26, 33) Nair et al. (2016) (8) also compared de performance of Enhance® PoGo® kit and Sof-Lex™ kit. Nanofill and microfill composites showed similar results when polished with these systems (0.089-0,098 µm). Nanohybrid composite showed greater surface roughness when polished with PoGo® (0.280 µm versus 0.098 µm) and microhybrid composite showed increased surface roughness when polished with Sof-Lex™ (0.280 µm versus 0.098 µm).(8)

Daud et al. (2018) (31), compares Filtek™ Supreme XTE and Filtek™ Z250 when polishing with Sof-Lex™ discs and Enhance® PoGo® system. They used a 3D contact optical profilometry and scanning electron microscopy and contrary to previous studies, concluded that a smoother surface was produced when polished with Enhance®+PoGo® system (Filtek™ Supreme XTE=0,09-0,25 µm and Filtek™ Z250= 0,10-0,25 µm) than the Sof-Lex™ (Filtek™ Supreme XTE=0,16-0,23 µm and Filtek™ Z250= 0,16-0,25 µm) system. (31)

In our study, all roughness values of composites are below of the previously mentioned studies (0,049 µm < Sa <0,126 µm) even though the same polishing system was used (Enhance®+PoGo®).

There were differences between samples of the same group and it can be explained by the way the samples were polished. Despite being a manual process, its efficacy depends on the polishing system used and on the operator´s expertise. (8)

It is known that the procedures of finishing and polishing the resin composite restorations guarantees the longevity of the treatment and the oral health of patients. However, there is no a single "gold standard" finishing and polishing technique in the literature, once there are various techniques, instruments and materials that have been described to obtain these goals. (5) The present *in vitro* study is important to the clinical practice, given that there is relatively little information published about the best way to finish and polish restorations, especially when using mainly of state-of-the-art composite restorative materials. (31) To best compare the findings about the efficacy of finishing and polishing systems, it would be useful a standardization of methodologies between the studies. (1, 31)

This study has some limitations. The authors evaluated only samples of flat surfaces, when in the oral cavity the restorations have various shapes. Furthermore, irregularities may be found on restoration margins and which would be important to be studied in the future through in vivo studies.

CONCLUSION

Within the limitations of this *in vitro* study we can conclude that:

- The polishing system used caused a certain level of surface roughness in all tested composite resins;
- The null hypothesis was rejected since the five composites tested showed statistically significant differences in the mean surface roughness (Sa) values after polishing procedures;
- The Zirconfill® composite showed the highest average surface roughness (Sa) and Brilliant™EverGlow composite showed the lowest average surface roughness (Sa).

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