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EVALUATION OF SURFACE ROUGHNESS OF NANOFILLED RESIN COMPOSITE AFTER THE USE OF DIFFERENT POLISHING SYSTEMS

AVALIAÇÃO DA RUGOSIDADE SUPERFICIAL DE COMPÓSITOS RESINOSOS NANOPARTICULADOS APÓS O USO DE DIFERENTES SISTEMAS DE POLIMENTO

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EVALUATION OF SURFACE ROUGHNESS OF NANOFILLED RESIN COMPOSITE AFTER THE USE OF DIFFERENT POLISHING SYSTEMS. Wlhadya Kaenny de Freitas COSTA; Angeline Castro ABREU; Lais Barbosa Pinheiro BASTOS; Francisco Anderson de Sousa SALES; Júlia Vitória de Souza GIRÃO; Vanara Florêncio PASSOS. JNT Facit Business and Technology Journal. QUALIS B1. ISSN: 2526-4281 - FLUXO CONTÍNUO. 2024 – MÊS DE DEZEMBRO - Ed. 57. VOL. 01. Págs. 455-469. http://revistas.faculdadefacit.edu.br. E-mail: jnt@faculdadefacit.edu.br.

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RESUMO

O processo de acabamento e polimento pode afetar muitos aspectos dos compósitos resinosos, sendo indispensável para a longevidade das restaurações. O estudo teve como objetivo avaliar a rugosidade superficial de um compósito resinoso nanoparticulado após o uso de diferentes sistemas de acabamento e polimento. Vinte e um espécimes foram divididos aleatoriamente em três grupos (n = 7): GI: Sistema abrasivo emborrachado, GII: Escovas abrasivas e GIII: Discos flexíveis. A rugosidade superficial (Ra) foi determinada para cada grupo em três momentos, sendo a primeira leitura, na linha de base, realizada 24 horas após o preparo dos espécimes. A segunda leitura, após o lixamento dos espécimes (após o lixamento) e a terceira, após os protocolos de cada sistema (pós-tratamento). Para comparação entre os grupos, foi utilizado o teste de Análise de Variância (ANOVA) e o teste de Tukey. Em todas as situações, o nível de significância adotado foi de 5%. A rugosidade superficial final observada de acordo com os sistemas de acabamento e polimento foi G1: 0,39 ± 0,23 µm, G2: 0,49 ± 0,16 µm e G3: 0,13 ± 0,05 µm, com redução considerável na rugosidade do compósito. O sistema de discos flexíveis apresentou resultados estatisticamente superiores em comparação ao sistema abrasivo emborrachado e escovas abrasivas.

Palavras-chave: Polimento dentário. Rugosidade. Compósitos à base de resina. Nanocompósitos. Restaurações.

ABSTRACT

The finishing and polishing process can affect many aspects of resin-based composites, being indispensable for the longevity of restorations. The study aimed to evaluate the surface roughness of a nanofilled resin composites after the use of different finishing and polishing systems. Twenty-one specimens were randomly divided into three groups (n = 7): GI: Rubberized abrasive system, GII: Abrasive brushes and GIII: Flexible disks. The surface roughness (Ra) was determined for each group in three moments, with the first reading, at baseline, performed 24 hours after preparing the specimens.

The second reading, after sanding the specimens (after grounding) and the third one, after the protocols of each system (post-treatment). For comparison between groups, Analysis of Variance (ANOVA) and Tukey's test was used. In all situations, the significance level was set at 5%. The final surface roughness observed according to the finishing and polishing systems was G1: 0.39 ± 0.23 μm, G2: 0.49 ± 0.16 μm and G3: 0.13 ± 0.05 μm, with a considerable reduction in the composite roughness. Flexible disks system presented statistically superior results compared to a rubberized abrasive system and abrasive brushes.

Keywords: Dental Polishing. Roughness. Resin-based composite. Nanocomposites. Restorations.

INTRODUCTION

Achieving good dental aesthetics using resin-based composites has become fundamental, especially for restorations of anterior teeth (Rai e Gupta, 2013). Within this conception, features such as brightness and smoothness are essential for restorative success, since rough surfaces may contribute to dental plaque accumulation, recurrent caries, gingival inflammation, and staining (Kamonkhantikul *et al*, 2014; Barakah e Taher, 2014). Therefore, finishing and polishing procedures are of the utmost importance to promote the esthetics and longevity of restorations (Barakah e Taher, 2014; Augusto *et al*, 2022).

The degree of surface polishing of a resin composite, in addition to the operator's technique and skillfulness, is directly related to some factors inherent in the material itself, such as organic matrix composition, size, shape, hardness, and distribution of the filler particles, as well as the degree of polymerization (Ereifej, Oweis e Eliades, 2012; Barcellos *et al*, 2013; Lopes *et al*, 2018; Severo e Reis 2022; Santos, 2023).

Some studies have reported that resins composed of micrometer-sized inorganic particles have lower wear resistance than those with larger particles, but have a higher degree of polishing (Germain e Samuleson, 2015). Thus, one of the most important innovations in cosmetic dentistry was the incorporation of nanotechnology to resin composites (Ansuj *et al*, 2016). Nanofilled resin-based composites have been recently introduced to the market, presenting higher wear resistance and enhanced polishing capacity. Due to the size and homogeneous distribution of the filler particles, in addition to a decreased interstitial space between these particles, which favors their use in all areas of the mouth, providing a smooth surface and appropriate mechanical properties for surfaces of high stress (Costa *et al*, 2007; Rai e Gupta, 2013; Alzraikat *et al*, 2018; Cho et al, 2022).

However, only a few studies have evaluated the effect of finishing and polishing systems available in the dental market on nanofilled resin composites (Antonson *et al*, 2011; Rodrigues-Junior, 2015). For a finishing and polishing system to be effective, the cutting particles of the instruments must be harder than the material to be polished (Endo *et al*, 2010; Barcellos *et al*, 2013; Schmitt *et al*, 2016; Santos, 2023). Moreover, the type and size of the grain, and the flexibility of the material in which the abrasive is embedded influence the final degree of polishing (Avsar, Yuzbasioglu e Sarac, 2015). Tungsten burs, diamond drill bits, several types of flexible disks, rubberized abrasive points and cups, sandpaper strips with metal or plastic backing, as well as polishing pastes, can be cited as the main products used in the finishing and polishing stages (Fernandes *et al*, 2016).

In recent years, efforts have been made to evaluate the finishing and polishing systems for composites. Nevertheless, there are no studies comparing the effect of flexible disk systems, rubber polishers and abrasive-impregnated brushes on the surface smoothness of nanofilled resin composites. Therefore, the present study aimed to evaluate the surface roughness of a nanofilled resin composite after treatment with different finishing and polishing systems. The initial hypothesis is that there will be no statistical difference between the different finishing and polishing systems as regards the surface roughness.

MATERIALS AND METHODS

Sample Preparation

Twenty-one disk-shaped specimens were prepared with the nanofilled resin-based composite - Filtek™ Z350XT (3M ESPE Dental Products, St. Paul, MN, USA - color

A3). The composite was inserted in a single increment in a metal matrix with a central hole (5 mm in diameter x 2 mm in height) and then covered with a polyester matrix strip and a glass plate. The plate was pressed until contacting with the metal matrix. After removal of the glass plate, the material was photoactivated (VIP Junior, BISCO, Schaumburg, IL, USA) for 40 seconds at an intensity of 600 mW/cm^2. Immediately after photoactivation, the specimens were removed from the matrix and stored in distilled water at 37 °C for 24 hours.

The specimens were randomly divided into three groups according to the finishing and polishing systems (Table 1). The surfaces of all specimens were washed with distilled water and air-jet dried. Then, the first surface roughness evaluation (baseline) was performed with a rugosimeter (Hommel Tech-T1000, Schwenningen, Germany).

Table 1: Protocols for use of different finishing and polishing systems.

Group (n)	Finishing and Polishing System (Manufacturer)	Composition	How to use
G I (n=7)	Rubberized abrasive system (Astropol™, Ivoclar, Amherst, NY, USA)	Astropol F and Astropol P consist of silicone rubbers, silicone with carbide particles and colored pigments. Astropol HP contains silicone rubber, diamond particles, aluminum oxide, titanium oxide and iron oxide. The shanks are made of stainless steel.	Use the rubber polishers for 20 seconds, in the sequence: gray, green and pink. Rinse and dry the specimen between disk exchanges.
G II (n=7)	Abrasive brushes (Jiffy Composite Polishing Brushes™, Ultradent Products Inc, South Jordan, UT, USA)	Nickel-plated steel, silicon carbide and dye.	Use the cup-shaped brush for 20 s in intermittent motion.

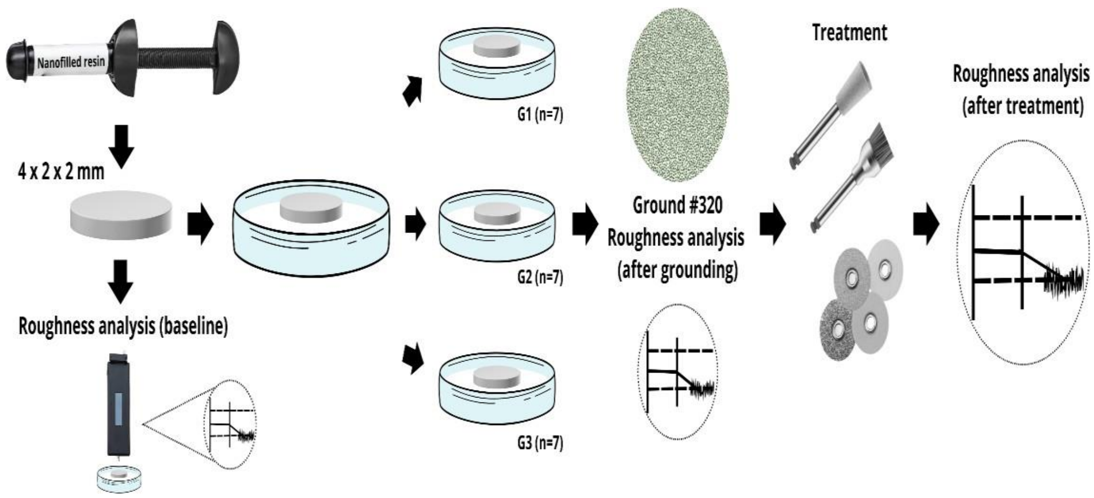
G III (n=7)	Flexible disks (Sof-Lex Pop-on®, -3M do Brasil Ltda, Sumaré, SP, Brazil)	Aluminum oxide	Use the disks for 20 seconds, in sequence: dark orange, medium orange, light orange and yellow. Rinse and dry the specimen between disk exchanges.

***In vitro* experiment**

The surfaces of the specimens were first treated with a #320-grit Al_2O_3 papers coupled to an electric polishing machine under abundant irrigation to provide a rough and homogeneous surface. The specimens were washed with distilled water and air-jet dried, which was followed by the second evaluation of surface roughness (after grounding).

After sanding, the specimens were submitted to different protocols of use according to each finishing and polishing system (Table 1). The procedures were performed manually and using low-speed handpiece for 20 seconds, and the materials were discarded after use. All specimens were treated by the same operator. At the end of the techniques employed, all specimens were washed with distilled water and dried with air jets and again evaluated (post-treatment), as seen in Figure 1.

Figure 1: Experimental design.



Measurement of Surface Roughness

The resin surface roughness was determined by the arithmetic mean of the Ra (average roughness as per ISO 4287) values. Three profile traces (1.5 mm in length) were recorded at intervals of 100 μm, in the center of each specimen, with use of a profilometer (Hommel Tester T1000; Hommelwerke GmbH, Villingen-Schwenningen, Germany). The roughness assessments were standardized with the following parameters: Lm=1.5 mm (extension); Lc=0.25 mm (cutoff). The radius of the diamond stylus was 5 μm, and the measurements were made at a constant speed of 0.5 mm/s under a force of 0.8 mN. For each sample, three means were calculated (baseline; after grounding; post-treatment) from the values obtained from three traces.

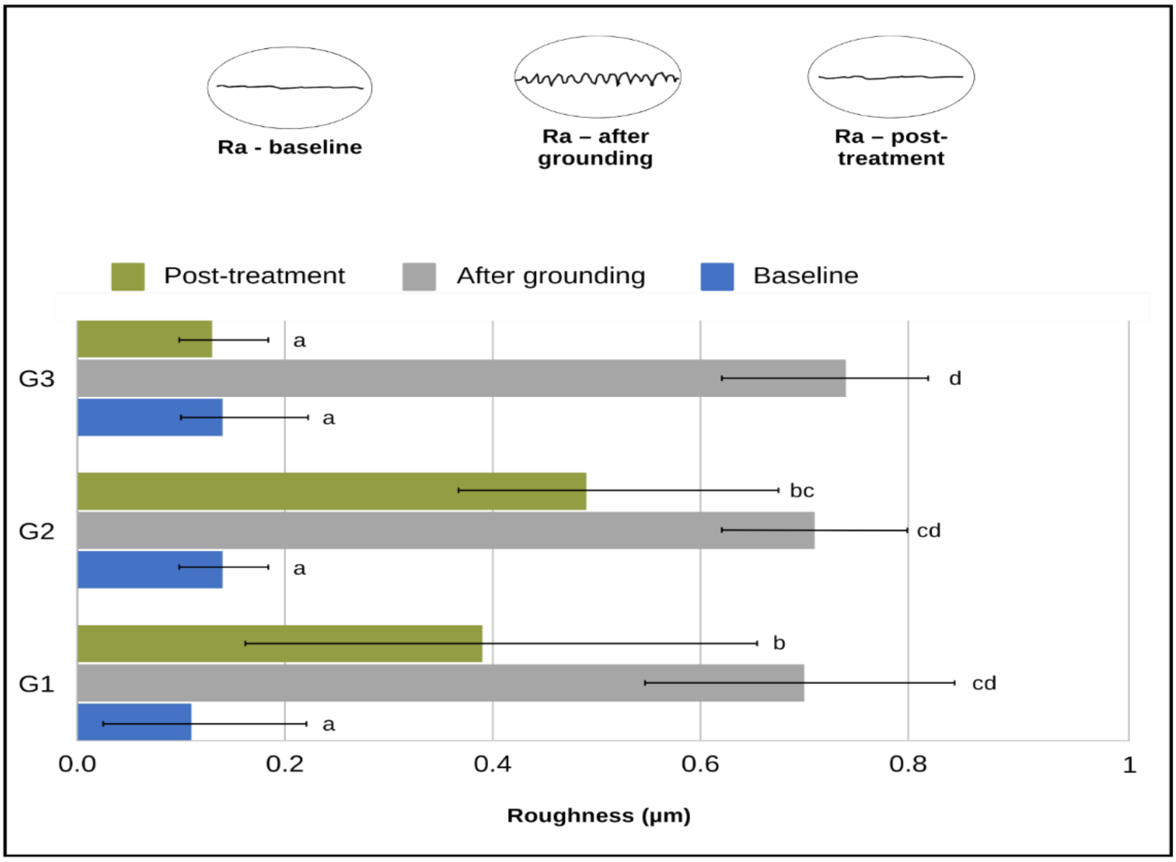
Statistical Design

Mean, and standard deviation of Ra was calculated from three roughness values per specimen, in each stage of the experimental design. From the data obtained in tests conducted after photoactivation (baseline), after grounding, and after the finishing and polishing protocols (post-treatment), a Kolmogorov-Smirnov test for normal distribution of errors was conducted. Because the values were widely distributed, ANOVA and Tukey's post hoc tests were used. The level of significance was set at 5%. Statistical procedures were performed using the Statistical Package for the Social Sciences (SPSS 17.0).

RESULTS

The means of values and standard deviation obtained by surface roughness analysis (Ra) at baseline, after grounding, and after the finishing and polishing protocols are presented in Figure 2. There were statistically significant differences between the baseline and the grounded surface in all groups ($p \leq 0.001$). After the polishing treatment, only the flexible disks (GIII) generated a polished surface with smoothness similar to the baseline. The rubber polishers (GI) and polishing brushes (GII), however, were not able to obtain the same smoothness of the baseline stage (p > 0.05). The abrasive brushes (GII) presented roughness data practically similar to the post- grounding stage (p = 0.05).

Figure 2. Surface roughness values (Ra; µm) for each finishing and polishing system applied to a nanofilled resin-based composite; each bar represents the mean values and standard deviation of n = 7 specimens. Different lowercase letters (displayed above the bars) indicate significant differences between groups and procedures.



DISCUSSION

The emergence of nanotechnology allowed great advances in dental materials, enabling the production of composites with improved mechanical and esthetic characteristics attributed to the reduced size and wide distribution of filler particles (Kumari, Bhat e Bansal, 2016; Yavad *et al*, 2016; Alzraikat *et al*, 2018; Lima, 2023, Babina, 2020).

Marghalani (2010) and Magdy *et al.* (2017), verified that the stress generated during the polishing procedure and concentrated on large and irregular particles tends to cause the displacement of these particles, rather than their cutting or wear, thereby increasing the roughness in the area. This event does not occur with nanofilled resin composites, since the nanomers range from 20 to 75 nm and are composed of silica and zirconia, a formulation that provides a more uniform matrix with reduced interstitial spaces between the particles, which are not displaced when in contact with the polishing abrasive, resulting in better physical properties and surface smoothness (Koh *et al*, 2008; Gonçalves *et al*, 2012; Soliman et al, 2020).

The methodology conventionally used for verification of surface smoothness is the roughness analysis, with Ra parameters in micrometers (μm), which evidences the presence of small protrusions and recesses in a surface. Thus, in the present study, the surface roughness analysis was performed to verify the action of different finishing and polishing systems.

The surface roughness of a material is a property that results from the interaction of multiple factors (Koh *et al*, 2008). Many of these are intrinsic to the material, and its type of inorganic filler (size, shape, and distribution) and others are extrinsic, associated with the type of polishing system, its flexibility, type of abrasive, hardness, instrument geometry, polymerization time of the composite and the way the system is applied (Marghalani, 2010; Lopes *et al*, 2018; Babina 2020).

For the study, Filtek Z350 XT™ nanofilled resin was used, subject to the same polymerization and initial finishing parameters. Thus, the initial surface roughness, obtained when the composite was polymerized against the polyester matrix, was similar for all groups, in addition to producing the smoothest surface, with Ra less than 0.2 μm. This finding has also been described in several studies found in the literature (Magdy *et al*, 2010; Germain e Samuelson, 2015; Avsar, Yuzbasioglu e Sarac, 2015; Yavad *et al*, 2016; Kocaağaoğlu *et al*, 2017). However, according to Fernandes *et al.* (2016), it would be impossible to reproduce the ideal anatomy of the restorations only by using that matrix.

In the surface area of resin composite fillings, contact with oxygen inhibits the formation of a well-structured polymer chain, preventing the monomers from being fully converted into polymers in the restoration surface layer, rendering it more susceptible to staining and less resistant to wear (Marghalani, 2010; Endo *et al*, 2010; Gonçalves *et al*, 2012; Carrillo-Marcos, 2022). Thus, finishing and polishing procedures are always necessary because they directly influence the clinical behavior of dental restorations, becoming fundamental for their quality and esthetic longevity (Eldemir *et al*, 2013; Kocaağaoğlu *et al*, 2017; Dietschi, Shahidi e Krejci, 2019).

The use of Al_2O_3 papers in the methodology of the present study simulates procedures of wear and contouring performed with diamond burs in resin composite fillings. It was thus observed that, after grounding, the roughness increased considerably and in a similar way for all groups. However, after applying the finishing and polishing systems, the mean roughness (Ra) values ranged from 0.13 μm for flexible disks, 0.39 μm for rubber polishers and 0.49 μm for abrasive brushes. The flexible disk system proved to produce the smoothest surface compared to the other two systems used and that its Ra value was similar to the initial value found after the composite polymerization with the polyester tape, similarly to what has been observed in other studies (Germain e Samuelson, 2015; Avsar, Yuzbasioglu e Sarac, 2015; Yavad *et a*, 2016; Fernandes *et al*, 2016; Magdy *et al*, 2017; Kocaağaoğlu *et al*, 2017).

This probably occurs because the disk system has a good malleability, allowing a homogeneous abrasion. Furthermore, because it has aluminum oxide particles, which are harder (2100 KHN) than the components of the resin composite, it enables the filler particles and the organic matrix to be cut equally (Rai e Gupta, 2013; Patel, Chhabra e Jain, 2016)[1,26]. Otherwise, the polishing agent would only remove the organic matrix from the resin, allowing the filler particles to protrude from the surface, impairing the surface smoothness (Barakah e Taher, 2014; Magdy *et al*, 2017). Gonçalves *et al*. (2012) report that such efficacy is linked to the anatomical shape and the accessibility of the restoration surface to be polished.

About the other systems, it was observed that the value of Ra after their use was considerably reduced, but their results were lower than the abrasive disk system. Extrafine rubberized abrasive points have a greater amount of impregnated diamond particles than aluminum oxide, while the abrasive disk system has the only alumina as its abrasive particle. Diamond presents higher hardness than alumina, and therefore it can cause deeper scratches on the surface of composites, resulting in greater roughness (Marghalani, 2010; Can-Say *et al*, 2014; St-Pierre *et al*, 2019).

Bittencourt *et al.* (2014) verified that the rubber polishing system Astropol caused greater surface roughness compared to other finishing/polishing systems due to its abrasive potential. In our study, however, it was seen that the abrasive brush system kept the surface rougher than the rubberized abrasive system.

According to Marghalani (2010), rubber polishers allow a greater smoothness in different resin-based systems, except for resins with high filler content, which corroborates our results, since resin Z350 XT presents 72.5% of inorganic filler.

Studies that prove the effectiveness of the polishing brushes system (composed of silicon carbide) in nanofilled composites are not known to the authors. After treatment with this material, however, the result was not satisfactory when compared to the other systems. Probably, this result is due to the characteristic of the system, which presents bristles of high hardness and little malleability, thus hindering the surface treatment.

Although a limit to an unacceptable surface roughness has not yet been proven, a Ra value above 0.2 µm has been reported to result in increased plaque accumulation, higher risk of cavities and periodontal inflammation, compromising the esthetics and longevity of restoration (Heintze *et al*, 2010; Hosoya *et al*, 2011; Yavad *et al*, 2016). Thus, it was seen that the Astropol™ and Jiffy™ systems, following the protocol of the present study, were not effective in the finishing and polishing procedure. Only the Sof-Lex™ pop-on system presented the best results statistically, obtaining values of Ra smaller than 0.2 µm and allowing a greater final smoothness.

It is important to note that the interpretation of *in vitro* results may vary from *in vivo* studies. It is known that resin composites are subject to surface changes due to the action of several events occurring in the oral environment over time, so that, ideally, this surface should be evaluated after being subjected to oral conditions.

CONCLUSION

It is concluded that only the flexible disks system obtained satisfactory results for finishing and polishing, with Ra less than 0.2 µm, compared to the rubberized abrasive system and polishing brushes.

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