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Oxygen-Inhibited Coating Roughness of Nanohybrid Composite Resins Compared by Two Polishing Systems

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ABSTRACT

A nanohybrid composite resin in dentistry is a dental restorative material that combines particles of different sizes to improve its mechanical and esthetic properties. It contains nano-sized filler particles (1-100 nanometers), which gives it excellent strength, polishability, and durability. The objective of this research was to evaluate the roughness of the oxygen-inhibited layer in nanohybrid resins using two polishing systems. Forty resin samples were made, applying two systems: (Forma, Ultradent) with (Diamond Pro, FGM) and (Super-Snap, SHOFU); and (Herculite Précis, Kerr) with the same systems. The results showed that, for (Forma, Ultradent) resin, there were no significant differences between the polishing systems, while for (Herculite Précis, Kerr) resin, it was observed that (Super-Snap, SHOFU) was more efficient than (Diamond Pro, FGM). However, no significant differences were found based on resin type.

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Introduction

Composite resins have revolutionized restorative dentistry since their introduction in 1954, providing an esthetic and functional alternative to silicate cements and methacrylate resins [1]. Over the years, the evolution of these materials has significantly improved their mechanical, esthetic, and biocompatibility properties. Advances include the introduction of hybrid resins in the 1980s and, more recently, the incorporation of nanotechnology, which has enabled the development of nanohybrid and nanofilled resins [2-4].

Nanohybrid resins have become a preferred choice due to their ability to combine silica and zirconia nanoparticles with larger glass particles, offering excellent durability, brightness, and stable mechanical properties. However, their fracture and wear resistance does not outperform microhybrid resins, which remain the reference in some clinical settings [4,5]. In addition, the correct selection of the polishing system plays a crucial role in the surface roughness of restorations, a key factor in preventing bacterial plaque accumulation and ensuring prolonged durability [6,7].

Forma resin (Ultradent) is a universal nanohybrid composite resin that stands out for its balance between esthetics, strength and color stability, ensuring prolonged durability even in thin layers. Its formulation includes zirconia and ytterbium trifluride, which gives it exceptional optical properties, such as transparency, opalescence and fluorescence, simulating the natural appearance of the tooth. This resin has in its composition Bisphenol A Glycidyl Methacrylate (Bis-GMA), Triethylene Glycol Dimethacrylate (TEGDMA), Bisphenol A Ethylhexyl Methacrylate (Bis-EMA) and Urethane Dimethacrylate (UDMA), with a zirconium/silica and barium glass filler, being ideal for both anterior and posterior restorations [8].

On the other hand, Herculite Précis resin (Kerr) is composed of nanoparticles and barium glass, which maximizes its filler loading and minimizes wear. Its nano-hybrid formula incorporates aluminum oxide, which gives it advanced nano-filler technology, ease of polishing, excellent handling and low polymerization shrinkage. This resin offers opalescence and fluorescence that mimics the natural vitality of the tooth, easily adapting to the tooth anatomy [9,10].

A crucial aspect in the clinical effectiveness of composite resins is their ability to maintain a low surface roughness, which reduces the accumulation of bacterial plaque and improves the longevity of the restoration. Different studies have shown that the polishing technique, together with the type of resin, significantly influences the final roughness. Research such as that of Aydin et al. and Liebermann et al. have compared various finishing techniques, concluding that polishing systems such as Sof-Lex and Shofu, in combination with nanohybrid resins, offer improved surface smoothness, reducing roughness to clinically acceptable levels [11,12].

The oxygen-inhibited layer forms when atmospheric oxygen interferes with the polymerization of the resins, generating a smooth, tacky surface that is susceptible to extrinsic pigments. This layer can negatively affect the quality of restorations, impacting hardness, wear resistance and color stability. Currently, the use of glycerin gel is recommended during photoactivation to enhance polymerization in hard-to-reach areas. Products such as DeOx (Ultradent) or Liquid Strip (Ivoclar Vivadent) act as barriers to inhibit this layer and ensure proper polymerization [13-15].

Surface roughness (Ra) is determined by the material properties and the surface formation process, being the result of factors such as working deflection, vibrations and heat treatments. A lower level of roughness implies a finer finish but may lack the same anchorage as surfaces with a larger grain. Roughness influences plaque accumulation, gingival inflammation, staining, and wear, making a good finish crucial to the integrity of restorations [11,16].

The roughness tester, which uses a diamond stylus to measure the surface profile, is the tool used to evaluate surface roughness, expressed in microns. The roughness of a composite resin is influenced by intrinsic factors, such as the type of filler, the matrix composition and the polishing system [16,17].

Polishing systems in dentistry are used to improve the surface of dental restorations, especially those made of composite resins, crowns, and other restorative materials. The goal is to achieve a smooth and shiny surface, which has several aesthetic as well as functional benefits [18].

The FGM Diamond Pro system consists of a set of flexible sandpapers with four grit variations (coarse, medium, fine and extra-fine) and diameters of 8 and 12 mm. These sandpapers have a quick mounting system on the mandrel, with no metal parts on the surface, which minimizes the risk of damaging the restoration. They are specifically designed for shaping, finishing and polishing composite resins. Instructions suggest selecting the appropriate disc according to the clinical procedure, attaching it to the mandrel, placing it in the contra-angle handpiece and polishing with controlled rotations, low pressure and short, intermittent movements [19].

SHOFU Super-Snap discs are designed to facilitate fast, easy and reliable contouring, finishing and polishing of composite resins. These tools are disposable and are intended for single use per patient. The kit includes 8 units with different types of discs: the black disc (coarse grit) for contouring, the violet disc (medium grit) for finishing, the green disc (fine grit) for polishing and the red disc (superfine grit) for final polishing [20].

The present study focuses on evaluating and comparing the surface roughness of two nanohybrid resins Forma (Ultradent) and Herculite Précis (Kerr) using different polishing systems.

Materials and Methods

Materials such as glycerin (DeOx, Ultradent), nanohybrid resins Forma (Ultradent) and Herculite (Kerr), as well as Super-Snap (SHOFU) and Diamond Pro (FGM) polishing discs were used. In addition, equipment such as a light curing light (Coxo, model: Nano) and a high-speed dental micromotor were used.

Forma Resin (Ultradent) with Super-Snap (SHOFU) Polishing Discs

The mold was cleaned with alcohol and petroleum jelly was applied to facilitate the demolding of the resin block. Subsequently, the resin was placed in increments inside the designed 4 mm x 1 mm matrix with a thickness of 2 mm. Once the cavity was covered, excess resin was removed using a glass slab. It was light cured on both sides with an LED lamp (≥1100 MW/cm²) for 10 seconds per side, keeping it perpendicular to 1 mm from the surface. A layer of glycerin (DeOx, Ultradent) was applied and light-cured again to facilitate polishing. Then, excess glycerin was removed with sterile gauze and polished using Super-Snap discs, starting with the black disc (coarse grit), followed by violet (medium grit), green (fine grit) and finally red (superfine grit).

Forma Resin (Ultradent) with Diamond Pro Polishing Discs (FGM)

The procedure was similar to that described above: cleaning with alcohol, application of petroleum jelly, incremental placement of the resin in the matrix and light-curing with the LED lamp (≥1100 MW/cm²) for 10 seconds per side. Subsequently, glycerin was applied and light cured again. Then, excess glycerin was removed with sterile gauze. For polishing, Diamond Pro (FGM) discs were used, which have four grit variations (coarse, medium, fine and extra-fine), with diameters of 8 and 12 mm.

Herculite (Kerr) Resin with Super-Snap (SHOFU) Polishing Discs

The mold was cleaned with alcohol and petroleum jelly was applied. The Herculite resin was placed in the 4 mm x 1 mm and 2 mm thick matrix in increments. After covering the cavity, the excess was removed with a glass slab. The material was light cured on both sides with the LED lamp (≥1100 MW/cm²) for 10 seconds. A layer of glycerin was applied and photopolymerized again. Excess glycerin was removed and polished using Super-Snap discs, following the same grain order as for the Forma resin.

Herculite Resin (Kerr) with Diamond Pro Polishing Discs (FGM)

The procedure for cleaning, petroleum jelly application, incremental resin placement, light curing and glycerin application was similar to that described for Forma resin. For polishing, Diamond Pro (FGM) discs were used, with four grit variations (coarse, medium, fine and extra-fine), in diameters of 8 and 12 mm.

Roughness

In the roughness tests, 20 samples of nanohybrid resin Forma (Ultradent) with Diamond Pro (FGM) (n=10) and Super-Snap (SHOFU) (n=10) polishing systems were used. Additionally, 20 samples of the nanohybrid resin Herculite Précis (Kerr) were used, subdivided into two groups: 10 samples for the Diamond Pro polishing system and 10 samples for the Super-Snap system.

For the preparation of the samples, the Materials Evaluation Laboratory (LEMAT) of the ESPOL University manufactured a metal mold divided into three parts, with a rectangular cavity of 4 mm x 1 mm and a thickness of 2 mm, following the specifications of the PHASE II digital roughness tester, model SRG4500.

Results and Discussion

The information provided by the LEMAT laboratory on roughness tests was organized in a Microsoft Excel 2018 spreadsheet. After debugging and coding, the data were exported as a database to the SPSS program, IBM® version 26, for further analysis.

The results of the samples are presented in Table 1 and were classified into two types of resins and two polishing systems. Resin 1 corresponds to the nanohybrid resin Forma, marketed by Ultradent, while Resin 2 is the nanohybrid resin Herculite Précis, from Kerr. As for the polishing systems, two were used: Polishing System 1, consisting of SHOFU Super-Snap polishing discs, and Polishing System 2, corresponding to the Diamond Pro polishing system, by FGM.

Homogeneity was observed in the data of the four groups, with low roughness values, all below 0.06 µm. With this information, a descriptive statistical analysis was performed first (Table 2) and then an inferential analysis (Table 3)

Table 2 evaluated the surface roughness values of two nanohybrid composite resins: Forma (Ultradent) and Herculite (Kerr). Both materials were subjected to removal of the oxygen inhibited layer by glycerin (DeOx, Ultradent) and subsequently polished with the Super-Snap (SHOFU) and Diamond Pro (FGM) disc systems.

Table 1: Descriptive Statistics for Surface Roughness (Ra) by Group.

Resin 1 - Polishing System 1 (µm)	Resin 1 - Polishing System 2 (µm)	Resin 2 - Polishing System 1 (µm)	Resin 2 - Polishing System 2 (µm)
0,040	0,040	0,045	0,053
0,040	0,038	0,041	0,053
0,040	0,037	0,040	0,056
0,037	0,034	0,035	0,055
0,037	0,035	0,035	0,049
0,038	0,032	0,035	0,045
0,038	0,039	0,032	0,040
0,029	0,031	0,034	0,043
0,029	0,038	0,034	0,053
0,029	0,036	0,032	0,049

Table 2: Normality Test.

Group	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistician	DF	Significance	Statistician	DF	Significance
G1	0,304	10	0,080	0,759	0	0,057
G2	0,149	10	0,200	0,953	0	0,705
G3	0,302	10	0,05	0,853	0	0,062
G4	0,236	10	0,123	0,915	0	0,316

The results revealed that the nanohybrid resin Forma (Ultradent), polished with the Super-Snap (SHOFU) system, presented the lowest surface roughness values, with a Ra of 0.0357 µm. This value is comparable to that obtained in the study of Altamirano et al. where an Ra of 0.0571 µm was recorded, although without the use of glycerin for the removal of the oxygen layer [21]. These results suggest that the use of glycerin improves surface roughness.

It was also observed that there were no significant differences between the three groups of samples with nanohybrid resin Forma (Ultradent) with both polishing systems and the third group with nanohybrid resin Herculite (Kerr) polished with the Super-Snap (SHOFU) system (Figure 1). This suggests that being composite resins with filler nanoparticles, they present a lower susceptibility to generate loose particles.

However, when subjected to polishing systems, their roughness is reduced, which is in agreement with the results of Ramirez et al. [22]. This shows that nanohybrid resins, thanks to their filler, improve the surface quality and, together with the polishing systems, significantly reduce grooves and irregularities, resulting in lower surface roughness.

Figure 1 shows that the median values of the first three groups are quite similar and the fourth group has a higher median value; it is also observed that there is low dispersion within each group, with no values outside the predictable ranges. The data distributions are asymmetric, so it was necessary to develop the test of adjustment to the normal distribution (Table 3).

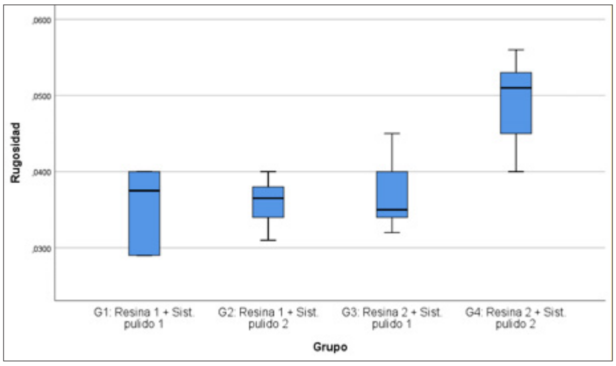

Figure 1: Box-and-Whisker Plot for Surface Roughness (Ra) by Group.

Given that 10 data per group were collected, the Kolmogorov-Smirnov test with Lilliefors correction was applied, determining that in all groups the significance value was greater than the critical level ($p > 0.05$). This observation was confirmed by the Shapiro-Wilk test ($n < 30$). In conclusion, the data passed the normality test, which justified the use of the parametric ANOVA test for comparison.

In group 1, a mean roughness of 0,0357 ± 0,0048 µm was estimated, being the lowest among the groups. Group 2 presented a mean roughness of 0,0360 ± 0,0030 µm; group 3; 0,0363 ± 0,0043 µm; and finally, group 4 showed the highest surface roughness, with a mean value of 0,0496 ± 0,0054 µm. The ANOVA test yielded a significance ($p < 0,001$), indicating the existence of significant differences between the mean roughnesses of the four groups. Tukey's test was used for pairwise comparison.

Table 3: Tukey's Test Results.

(I) Group	(J) Group	Mean difference (I-J)	Sig.
G1	G2	0,000	0,999
	G3	-0,001	0,990
	G4	-0,014	0,000
G2	G3	0,000	0,999
	G4	-0,014	0,000
G3	G4	-0,013	0,000

No significant differences were observed between the first three groups ($p > 0.05$); however, significant differences were found between them and the fourth group ($p < 0.05$). This suggests that, in the case of resin 1, the polishing system does not notably influence roughness, since the values are very similar. On the other hand, for resin 2, the polishing system does generate a difference, demonstrating that polishing system 1 is more efficient than polishing system 2. Furthermore, considering only polishing system 1, no significant differences in roughness as a function of resin type were identified.

There were no significant differences in roughness between the two resins with the different polishing systems. However, when considering particle size, the Forma resin (Ultradent) contains smaller particles compared to the nanohybrid resin Herculite (Kerr). The larger particle size results in a rougher surface, as the filler particles tend to detach during the polishing process, generating a higher roughness [23].

Forma (Ultradent) and Herculite (Kerr) resins, when polished with the Super-Snap (SHOFU) disc system, presented minimum surface roughness values of 0.0357 µm and 0.0360 µm, respectively. In contrast, with the Diamond Pro polishing system (FGM), the same resins achieved minimum roughness values of 0.0360 µm and 0.0496 µm. These results are within the surface quality parameters established by ISO 1302:2002, which considers acceptable roughness values between 0.0025 µm and 0.80 µm [24].

The surface roughness of nanohybrid composite resins (Forma, Ultradent and Herculite Précis, Kerr) was evaluated using two polishing systems: Diamond Pro, FGM and Super-Snap, SHOFU. The Forma, Ultradent resin presented a surface roughness of 0.0360 µm with Diamond Pro, FGM and 0.0357 µm with Super-Snap, SHOFU.

In Herculite Précis, Kerr resin, the roughness was 0.0360 µm with Super-Snap, SHOFU and 0.0496 µm with Diamond Pro, FGM. No significant difference was observed between Forma, Ultradent and Herculite Précis, Kerr resins using Super-Snap, SHOFU ($p > 0.05$), but a significant difference was found when using Diamond Pro, FGM on Herculite Précis, Kerr ($p < 0.05$). This suggests that both polishing systems are equally efficient for Forma, Ultradent resin, while the Super-Snap, SHOFU system presented the lowest roughness values in both resins.

Conclusions

The surface roughness of nanohybrid composite resins (Forma, Ultradent and Herculite Précis, Kerr) was evaluated using two polishing systems: Diamond Pro, FGM and Super-Snap, SHOFU. The Forma, Ultradent resin presented a surface roughness of 0.0360 µm with Diamond Pro, FGM and 0.0357 µm with Super-Snap, SHOFU.

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It is recommended to extend the research to evaluate surface roughness by different measurement techniques, applying more demanding polishing systems and nanohybrid resins. In addition, it is suggested to study the removal of the inhibited oxygen layer without glycerin, to test other polishing methods different from discs and to complement with microhardness tests to determine the resistance of the resins.

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