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Effects of different polishing systems on the surface roughness and microhardness of a silorane-based composite

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Abstract

The current study investigated the effects of different polishing systems on the surface roughness and microhardness of a silorane-based resin composite. Forty disks were fabricated (ø = 12 mm, *h* = 2.5 mm) of Filtek P90 (3 M ESPE, USA). The specimens were divided into four groups (n = 10), according to the polishing system: G1 - Mylar strip (control); G2 - Felt-disc + diamond paste, G3 - Sandpaper discs; G4 - Silicone tips. The specimens were stored in distilled water at 37°C for 24 h. The external surface roughness was determined through measuring the R_a of the specimens. The Vickers microhardness was measured using a microhardness tester. The values of surface roughness and microhardness of each specimen were statistically analyzed using one-way ANOVA, Games-Howell and Ryan-Einot-Gabriel-Welsch (REGW-Q), and setting the statistical significance at $p \leq 0.05$. It was observed that G2 (0.42 μm) and G4 (0.43 μm) showed statistically significant differences when compared to groups G1 (0.25 μm) and G3 (0.19 μm) ($p < 0.05$). There was no statistical difference between groups regarding microhardness ($p > 0.05$). The polishing systems altered the surface roughness of a silorane-based resin composite, but did not influence the microhardness values.

Keywords: Composite resins; Dental materials; Dental polishing; Surface properties; Permanent dental restoration

Background

The microhardness and surface roughness are properties of a composite that are related to the material's resistance to masticatory forces, its appearance such brightness and surface texture and the longevity of the restoration. The finishing and polishing procedure may influence these properties of a composite. With the results of this article, the authors related that the polishing systems altered the surface roughness of a silorane-based resin composite, but did not influence its microhardness.

Introduction

A silorane-based resin matrix presents less curing shrinkage when compared to a methacrylate resin matrix. The silorane is chemically composed of oxirane and siloxane molecules. The siloxane gives the material the property of hydrophobicity, while oxiranes are rings which act chemically during formation of polimers through a cationic ring-opening mechanism. This process results in polymerization shrinkage of less than 1% [1]. A low volume contraction of the material lessens the stress generated at the adhesive bond and, consequently, reduces the incidence of microleakage, secondary caries, postoperative sensitivity, enamel fractures, and improves the marginal adaptation of restorations [2-4]. The silorane-based resin has physical, biologhical and mechanical properties that are clinically acceptable and perform either similarly [5-8] or superiorly [9-12] to methacrylate-based resins.

The surface roughness of a restorative material influences the aesthetic appearance of a restoration in terms of brightness and texture [13]. An increased surface roughness allows for the accumulation of plaque, increasing the occurrence of recurrent caries [14]. The step of finishing and polishing composite restorations aims to provide adequate occlusal anatomy, remove small excesses and get a smooth, flawless surface that allows for adequate light reflection [15]. The surface roughness depends on various factors, such as: the amount and size of the filler particles, the type of resin matrix, and the type and particle size of the abrasives. Larger filler particles in a material protrude from the surface; as the resin matrix is removed during the finishing and polishing, the arithmetic average roughness values (R_a) tend to increase [16,17]. According to Marghalani (2010) [18], the surface smoothness obtained in silorane-based composite was greater than or equal to the smoothness obtained with methacrylate-based resins.

The mechanical properties of a composite, such as hardness and flexural strength, are fundamental to the material in resisting masticatory forces and providing greater longevity. The microhardness of a composite is directly related to the depth of cure of the restorative material. A lower microhardness of a resin composite indicates that the material is more susceptible to scratches and surface defects that can reduce the materials flexural strength and cause premature failure of the restoration [19,20]. Thus, the purpose of this current study is to evaluate the effect of different polishing systems on the surface roughness and hardness of a silorane-based resin composite.

Methods

Forty disks were fabricated using a silorane-based resin composite (Filtek P90, 3 M ESPE, St Paul, MN, USA) (Table 1). The internal mold of a metal matrix (ø = 12 mm, h = 2.5 mm) was filled with the composite in one increment. A mylar strip was placed on top of the uncured composite. A glass slide (1.1 mm thick) was applied on top of the mylar strip and pressure applied to remove excess resin. The composite was light-cured on both sides of the disks according to the manufacturer's instructions, using an LED light-curing unit (Translux Blue - Heraeus Kulzer, South Bend, USA) with a light intensity of 876 mW/cm^2. The specimens were stored in distilled water at 37°C for 24 h, and divided into four groups (n = 10) according to the polishing system used. In group G1, no polishing was performed (control). In groups G2, G3 and G4, the specimens were individually coupled to a metallic circular matrix and polished with SiC sandpaper (#1200) for 5 s to remove the outer resin layer, obtain a standardized and stable surface. Then, the

Table 1 Composition of the resin composite

Material	Shade	Filler	Filler-size	Matrix	Filler (wt %)	Manufacturer
Filtek P90	A3	Quartz and yttrium fluoride	47 μm	Silorane (oxirane and siloxane)	76	3 M ESPE, St Paul/MN, USA

specimens were submitted to differing polishing procedures: G2 - felt disc and diamond paste (Diamond Flex and DiamondExcel, FGM, Joinville, SC, Brazil), G3 - Sandpaper discs with sequential granulation: coarse, medium, fine and extra-fine (Diamond Pro, FGM, Joinville, SC, Brazil) and G4 - Silicone tips with two different granulations (DFL polishers, DFL, Rio de Janeiro, RJ, Brazil) (Table 2). The polishing systems are described in Table 3.

The time of polishing with each instrument was standardized at 30 s. The pressure exerted on the surface of the composite was intermittent and controlled by the operator. The silicone tips were used in a low-speed contra-angle handpiece and under water cooling, according to the manufacturer's recommendations. The felt discs and sandpaper discs were also used at low speed, but without water cooling. After the use of each instrument, the specimens were rinsed with water spray for 15 s to remove debris.

Prior to measuring the surface profile, the specimens were stored in distilled water at 37°C for 24 h. The evaluation of surface roughness was performed on all 10 specimens of each group instrument using a Surface Roughness Digital Portable Tester (RP-100, Instrutherm, São Paulo, Brazil). The Surface Roughness Tester was operated with a cut-off of 0.8 mm, a reading speed of 0.1 mm/s and a measurement distance of 4 mm, according to the JIS (Japan Industrial Standard B 0601, 1994). The specimens were placed in a metal device so that the polished surface was facing upwards and parallel to the base of the Surface Roughness Tester. There were three measurements in different areas of each specimen and the individual average value was used for statistical analysis.

Vickers microhardness number (VHN) was evaluated using a microhardness tester (HMV 2 1.23 version - Shimadzu Corp., Kyoto, Japan) with a 500 g load applied for 15 seconds. The specimens were individually positioned perpendicularly to the tester tip, and the VHN values were recorded by a software program (CAMSTM_WIN program - Newage Testing Instruments, Southampton, PA, USA). In each sample, three indentations at different points were recorded, and the average microhardness value was calculated.

Representative specimens from each group were observed by scanning electron microscopy (SEM). Following sputter gold coating, the surface morphology of the specimens was observed under 500 × magnification.

Data were submitted to the Levene normality test. Surface roughness (R_a) and Microhardness (VHN) variations were evaluated by one-way ANOVA at a significance level of 5% ($p \leq 0.05$). The Welch adjustment for the ANOVA and the *post hoc* Games-Howell test was used to evaluate the surface roughness. The *post hoc* Ryan-Einot-Gabriel-Welsch (REGW-Q) was used to evaluate the microhardness test.

Results

The R_a values were statistically similar between groups G2 and G4, and both were significantly when compared to G1 and G3 ($p < 0.05$). Also, these two other groups

Table 2 Groups according to the polishing system utilized

Group	Polishing procedure	Specimen distribution	
		Roughness and microhardness	SEM
G1	Mylar strip (control)	10	1
G2	Felt disc + diamond paste (Diamond Flex and Diamond excel)	10	1
G3	Sandpaper discs (Diamond Pro)	10	1
G4	Silicone tips (DFL polishers)	10	1

Table 3 Composition of the polishing systems

Material	Type of presentation	Composition	Manufacturer
DFL polishers	Tips	Stainless steel rods with hard siliconized rubber tips	DFL, Rio de Janeiro/RJ, Brazil
Diamond Flex	Discs	Flexible felt disks	FGM, Joinville/SC, Brazil
Diamond Excel	Paste	Micronized diamond, base lubricant, thickener and emulsifier	FGM, Joinville/SC, Brazil
Diamond Pro	Discs	Disc polyester, adhesive, abrasive, and silicone rubber	FGM, Joinville/SC, Brazil

did not have statistically significant differences from each other (Table 4 and Figure 1). There was no statistically significant difference among the groups regarding microhardness (Table 5 and Figure 2).

The observation of surface morphology under SEM showed good agreement with the numerical data of surface roughness. The selected images indicate that groups G1 and G3 (Figures 3 and 4) showed a more smooth and polished surface when compared with groups G2 and G4 (Figures 5 and 6).

Discussion

Resin composite with larger filler particles are expected to have higher R_a values after polishing [17,18,21]. Silorane-based resin composites presents filler particles of quartz and yttrium fluoride, which make up 76% of its weight and which have an average size of 0.47 μm and is classified as a microhybrid composite. This lower amount of filler particles with a relatively small size may have contributed to its ability to obtain smaller roughness values [18,22]. The values of roughness (R_a) ranged numerically from 0.19 (0.05) to 0.43 (0.16) μm, and in ascending order: Sandpaper discs (G3) < Mylar strip (G1) < Felt disc with diamond paste (G2) < Silicone tips (G4).

The filler particles present in a polishing instrument must have higher hardness than the filler particles of the composite resin so that the resin matrix and the particles are both reduced to a higher surface smoothness [21,23]. In this present study, the average roughness (R_a) of G1 (0.25 μm) was statistically equal to G3 (0.19 μm), in which sandpaper discs were used with decrescent abrasiveness of coarse, medium, fine and extra-fine. One explanation for the smaller numerical value of G3 is that the Mylar strip could produce some blisters and defects in the composite surface [24]. These irregularities were probably reduced after sanding with #1200 SiC sandpaper, and the subsequent use of sandpaper disks decreased the surface roughness. Some other studies have shown that sandpaper discs with aluminum oxide particles provide smoother surfaces

Table 4 Description and comparison of surface roughness (R_a) values according to the polishing systems used

Groups	R_a (μm)			
	Min	Max	(*s*)	p
G1 (control)	0.11	0.51	0.25 (0.14)^{b}	0.01
G2 (felt disc + paste)	0.11	0.66	0.42 (0.20)^{a}	
G3 (sandpaper discs)	0.11	0.29	0.19 (0.05)^{b}	
G4 (silicone tips)	0.21	0.71	0.43 (0.16)^{a}	

Note: Different letters indicate statistically different means (p <0.05).

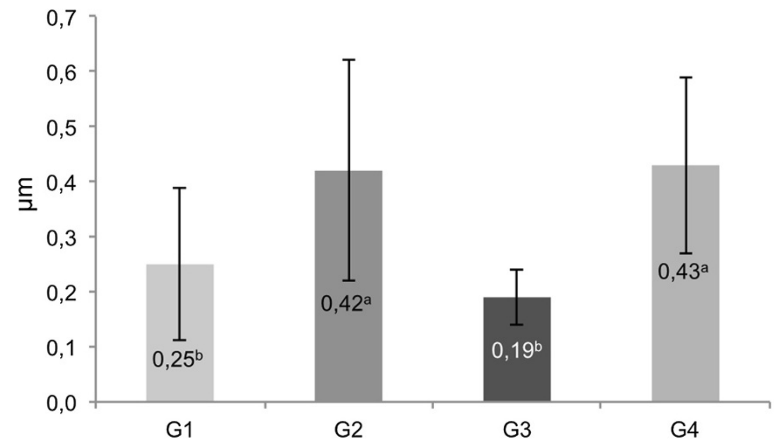

Figure 1 Surface roughness (R_a) of each group. Different letters indicate statistically different means (p <0.05).

because they have the ability to erode both the particles and the matrix resin. Çelik et al. (2009) [25], evaluated the effect of sandpaper disks (Sof-Lex Pop-On - 3 M ESPE) compared to silicone polishers (Astropol and Astrobrush - Ivoclar Vivadent) on surface roughness of three flowable resins, and the results reported that sandpaper disks produced a smoother surface the silicone polishers. In the study of Marghalani (2010) [18] the surfarce roughness of silorane-based composites using different polishing systems was evaluated and compared to other composite with different organic matrix. It was observed that the sandpaper disks sequence (Sof-Lex Pop-On - 3 M ESPE) provided the smoothest surface for silorane resin.

The average roughness (R_a) of G2 (0.42 μm) was statistically similar to G4 (0.43 μm) and significantly higher to G1 (0.25 μm) and G3 (0.19 μm). The polishing paste used in this study is composed of microionized diamonds particles with 2 to 4 microns of grit size. Probably, the G2 group presented higher R_a values because the use of felt disc associated to the polishing paste was not capable to reduce both the resin and filler matrixes and resulted in increased surface roughness [15]. This method could be more efficient when applied as the last step of the multiple-step polishing systems [26]. However, a two-step polishing system was used in group G4. Jung, Sehr and Klimek (2007) [27] related that a three-step system was more effective for polishing nanoparticle composites when compared to two- and one step systems, this result was similar to that found by Watanabe, et al. (2005) [21]. Moreover, the silicone polishers may wear the resin matrix and left the filler particles protruding while it also scratches the resin surface [23], and produced a rougher surface in the silorane resin composite. According to Baseren

Table 5 Description and comparison of microhardness (VHN) values according to the polishing systems used

Groups	Microhardness (VHN-49gF)			p
	Min	Max	(*s*)	
G1 (control)	154.09	199.03	170.60 (15.54)	0.99
G2 (felt disc + paste)	141.58	183.27	168.92 (13.41)	
G3 (sandpaper discs)	133.90	186.89	169.52 (15.20)	
G4 (silicone tips)	157.32	182.72	170.24 (9.27)	

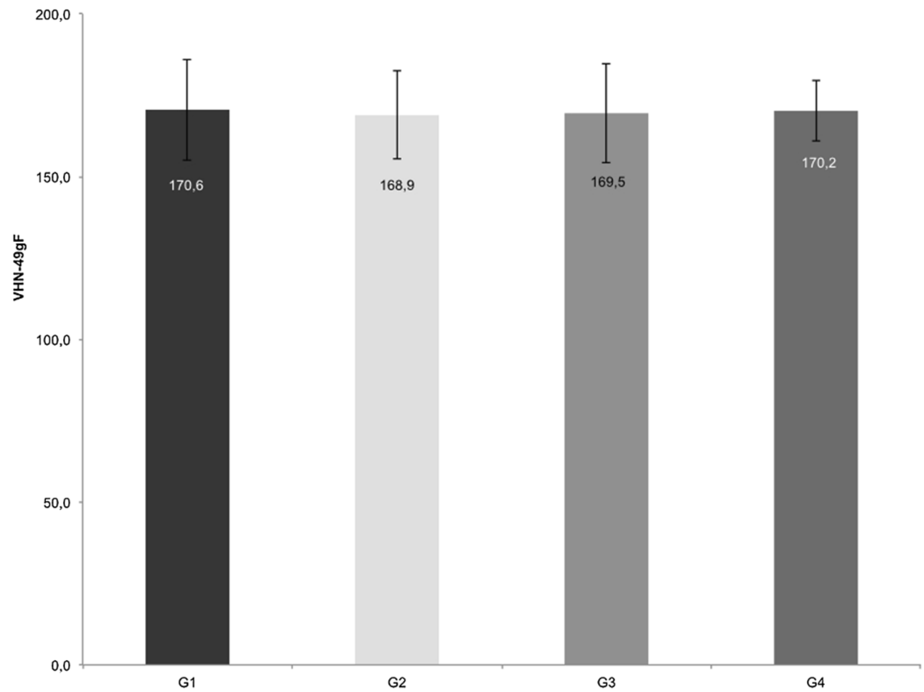

Figure 2 Vickers microhardness (VHN) of each group.

[28] the silicone polishers might be insufficient to polish the surfaces finished with diamond or carbide burs.

Additionally, the use of sandpaper discs in G3 provided an average value that is below the threshold for bacterial adhesion (0.20 μm) [29]. This fact implies that certain polishing systems, such as felt disk and diamond paste (G2) and silicone tips (G4), will cause the silorane-based resin composite to be more prone to plaque accumulation, due to the production of greater surface roughness. However, the values obtained with these groups are within the limits of variation of roughness (0.25 to

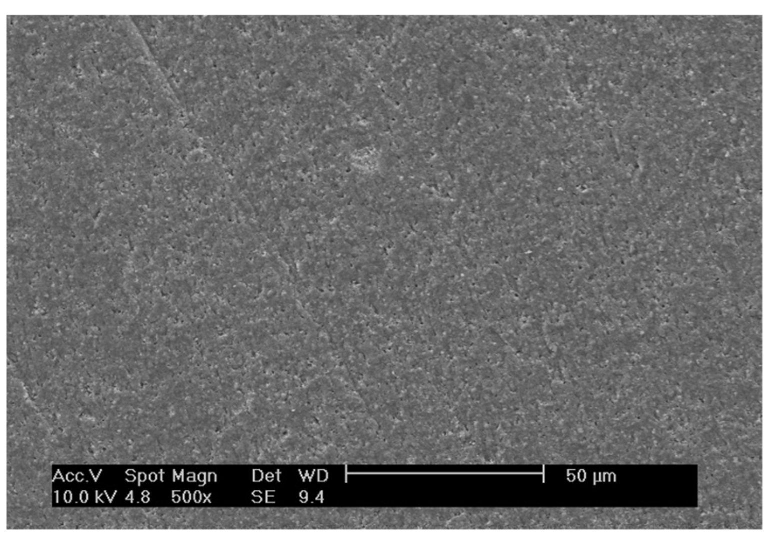

Figure 3 SEM photomicrograph of G1: Filtek P90 composite resin without polishing (control).

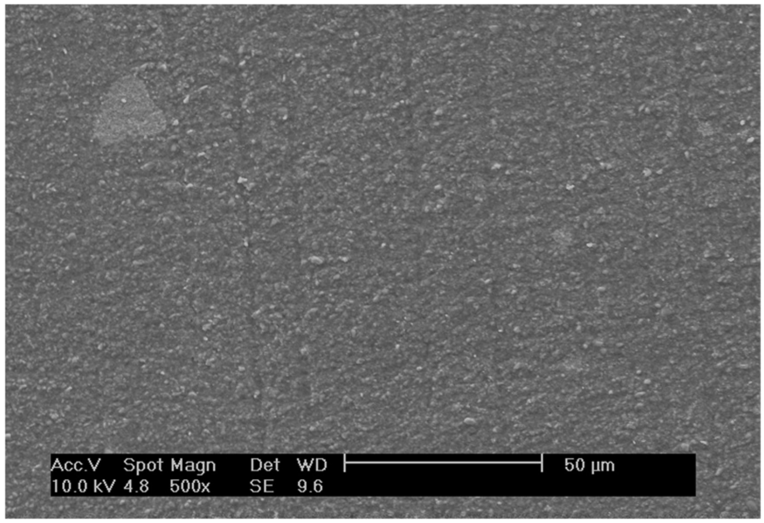

Figure 4 **SEM photomicrograph of group G2: Filtek P90 composite resin polished with felt discs and diamond paste.**

0.50 µm), so indicating that the roughness of the restoration is imperceptible to the human touch [30].

According to Tjan & Chan (1989) [31], a direct correlation between microhardness and surface roughness was observed, indicating that a material with a higher roughness generally has higher microhardness. This correlation was not observed with the results obtained in this current study, since the microhardness values were statistically similar between groups and only the roughness showed statistically significant differences. Boaro et al. (2013) [32] investigated some physical and mechanical properties of low-shrinkage composites and reported that the silorane-based composite Filtek LS (3 M ESPE) was the only low-shrinkage composite that presented lower shrinkage values compared to conventional composites, but lower degree of conversion as well. The authors stated that this might be due its low shrinkage property.

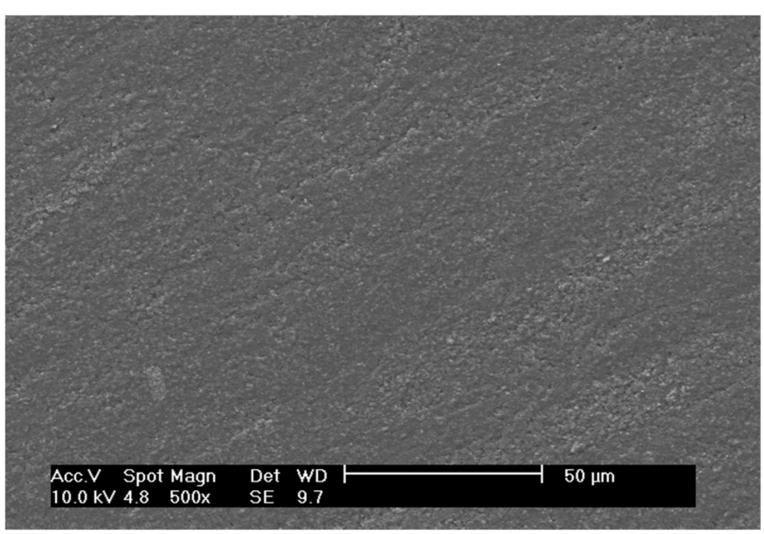

Figure 5 **SEM photomicrograph of group G3: Filtek P90 composite resin polished with sandpaper discs of sequential granulation: coarse, medium, fine and extra-fine.**

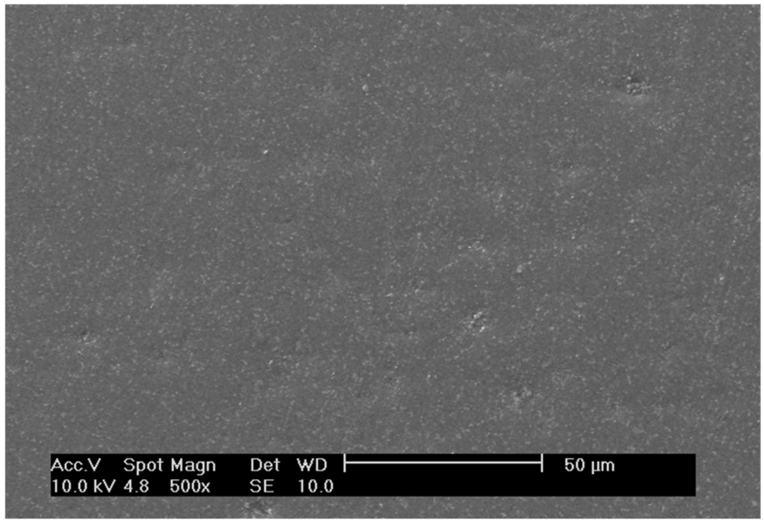

Figure 6 SEM photomicrograph of group G4: Filtek P90 composite resin polished with silicone points.

Different factors influence the polymerization of composite resins, such as light intensity, exposure time and distance between the material and the curing light tip [5,6,33]. D'Alpino et al. (2011) [34] evaluated the influence of energy dose on hardness, polymerization depth and internal adaptation of silorane- and methacrylate-based resins in Class II restorations with different bonding procedures. They related that an energy density of 20 J/cm^2 was found to reduce the formation of internal cracks and increased the hardness of silorane-based composite resin. In this present study, the distance between the curing light tip and the resin composite surface was standardized at 1.1 mm. Caution was taken so that the matrix filling was performed in two increments, with exposure times of 20 s and a light intensity of 876 mW/cm^2 was produced for each increment. Thus, it can be considered that the polymerization of the composite resin was effective in all specimens.

The Silorane Adhesive System (SAS) is different from the conventional adhesives. The high content of HEMA and water present in the composition of the self-etch primer of SAS makes it more hydrophilic and increases the susceptibility of the hybrid layer to water absorption, which potentially causes degradation and reduces the adhesion durability [35,36]. However, the application of a second hydrophobic layer decreases this permeability and improves the bonding stability [37]. This step could contribute to a thicker hybrid layer [38] which could increase the roughness on the adhesive interface and, probably, the restoration could be more prone to plaque accumulation and, consequently, microleakage.

Further studies are necessary to evaluate the influence of polishing on the physico-mechanical properties of the silorane-based composite involving other polishing methods and experimental conditions, such as thermal cycling and different storage media, as well as the comparison of composites with different compositions.

Conclusions

Within the limitations of this current study:

- Polishing with felt disc and diamond paste or silicone points significantly increased the surface roughness of a silorane-based resin composite. However, the use of sandpaper discs had no significant influence on surface roughness;
- The different polishing systems did not significantly influence the microhardness of the silorane-based resin composite.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
VCR carried out the laboratory research, drafted the manuscript and performed the manuscript formatting and revision. GRB participated in the laboratory research, carried out the SEM images and contributed to the manuscript formatting and revision. MACA contributed to the laboratory research and the manuscript revision. HPM contributed to the project developing, the laboratory research sequence, the manuscript formatting and revision. All authors read and approved the final manuscript.

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