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Comparison of Surface Roughness of Two Single Shaded Resin Composites After pH cycling and Simulated Teeth Brushing - an in-Vitro Study

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ABSTRACT: **Background**: New single-shade composites enhance color blending with the surrounding environment. However, data on their performance after pH cycling and simulated teeth brushing is limited.

Aim: To examine and compare the surface roughness of two single-shaded resin composites after pH cycling and simulated toothbrushing.

Methodology: Forty disc-shaped composite specimens were fabricated using Teflon mold and divided into two main groups (C1: Omnichroma, C2: Charisma Topaz One) according to the resin composite utilized (n=20). After finishing and polishing, the baseline surface roughness was measured using a non-contact profilometer. The specimens were then immersed in demineralization-remineralization solutions at room temperature followed by another surface roughness measurement. Subsequently, all specimens underwent simulated teeth brushing and received a final surface roughness measurement.

Results: Charisma Topaz One exhibited significantly higher initial surface roughness values compared to Omnichroma. However, after pH cycling and simulated tooth brushing, no significant differences in surface roughness were observed between the two materials.

Conclusions: Although Omnichroma demonstrated superior initial smoothness compared to Charisma Topaz One, both restorative materials exhibited comparable performance after pH cycling and simulated tooth brushing. The surface roughness is influenced significantly by the aging method.

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INTRODUCTION

Shade selection remains one of the biggest challenges faced by dentists. Therefore, using a single-shade composite based on nanotechnology, rather than more complex color systems, is easier and fulfills the esthetic demands of both patients and dentists.[1] A new single-shaded resin composite has been introduced to the dental market, simplifying shade selection and reducing required time. It provides more shade harmony with the surrounding teeth because of its "chameleon effect", which overcomes the problem of color mismatch in restoration during shade selection.[2]

Wear of composite restorations denotes debonding of inorganic fillers from the resin matrix, resulting in voids that elevate surface roughness. Microorganisms adhere firmly to rough surfaces, facilitating caries and plaque accumulation.[3] Thus, the finishing step creates a smooth surface by removing any scratches, while the polishing step, giving the restoration a glossy, enamel-like finish by reducing surface roughness.[4]

The long-term success of composite restorations hinges on their chemical stability in the oral cavity. The pH-cycling model simulates these oral conditions by subjecting composite materials to alternating cycles of demineralization and remineralization, thereby replicating the chemical challenges encountered in the oral cavity.[5] In addition to chemical acid exposure, restorations are also subjected to the abrasive effects of daily toothbrushing. This routine mechanical process can contribute to surface roughening and wear of restorations.[6] Limited studies have been conducted to date on the performance of single shaded composites. Therefore, this study aimed to examine and compare the surface roughness of two single-shaded resin composites after pH cycling and simulated teeth brushing. The null hypothesis was that there is no difference in surface roughness between the two single-shaded resin composites at baseline, after pH cycling, and following simulated teeth brushing.

MATERIALS AND METHODS

The materials used in the current study, along with their compositions and manufacturers, are listed in [Table 1].

Table 1: Data on the resin composites utilized in this research, including their chemical compositions and manufacturers

Ethical approval

The study was approved by the Ethical Committee of the Faculty of Dentistry, Suez Canal University, Egypt (No. 693/2023).

Sample size calculation:

Based on a prior study,[7] the total sample size was determined to be 40 discs, split into two groups according to the type of resin composite material (n=20).

Specimen preparation and grouping:

A split Teflon mold measuring 5 mm in diameter and 2 mm in thickness was used to fabricate composite discs.[7] The specimens were distributed into two main groups based on the single-shaded resin composites utilized (n = 20 per group): C1 (Omnichroma) and C2 (Charisma Topaz One). A clear celluloid strip (Mylar, SS white, USA) was first placed on a clean glass slab, followed by positioning the Teflon mold on the top. One composite increment of 2 mm thickness was packed by a Goldstein composite instrument with Tin-coated fine tips applicator (Medesy, Italian) into the mold until completely filled. After that, a second celluloid strip was placed over the mold's upper surface and pressed with a glass slab to remove excess composite and ensure smooth, non-porous, and flat surfaces.[8] The glass slab was then removed, and the specimens were light-cured for 20 sec using LED light curing device (RTA MINI S, Woodpecker, China) positioned in direct, perpendicular contact with the mold surface and operated in standard mode at an intensity of 800 mW/cm². Each specimen received an additional 20 sec of curing from the opposite side. Residual flashes were carefully removed using 1200-grit SIC grinding paper after the Teflon mold was removed. The light intensity of the LED light curing device was regularly checked after every five specimens using a digital dental radiometer (Blue Phasemeter, Ivoclar Vivadent, Austria).[7,8]

Finishing and polishing procedures

Immediately after removal from the mold, the bottom surfaces of all specimens were distinguished by a permanent marker.[9] According to manufacturer's instructions, contouring was performed using a medium-grit Sof-Lex extra thin disc fixed to low-speed handpiece (Sirona T4, Germany) at speed of 10,000 rpm for 15 sec without water spray. The specimens were then

rinsed for 10 sec to remove any residual material powder and dried with water/air tip for 5 sec.[10] During contouring, light pressure was applied, and the disc was moved in one direction from left to right.[1] Next, a fine-grit (beige) pre-polishing spiral wheel was utilized to remove scratches developed during contouring. Finally, a superfine-grit (white) spiral wheel was used for the final polishing to achieve a lustrous surface.[10-12] It is worth noting that specimens were rinsed for 10 sec and air-dried for 5 sec between each step [11]. After polishing, the cured polished specimens were kept in distilled water at room temperature for 24 hrs.[13]

pH cycling protocol

The specimens were exposed to demineralization-remineralization cycles at room temperature to mimic pH cycling model. The demineralizing solution (pH 4.3) was prepared using a 74 mM acetate buffer containing 2.0 mM phosphate and 2.0 mM calcium. The remineralizing solution (pH 7.4) was prepared with 20 mM TRIS buffer supplemented with 0.9 mM phosphate, 150 mM KCl, and 1.5 mM calcium. Each pH cycle consisted of a 6 hrs immersion in 5 mL of demineralizing solution, followed by an 18 hrs immersion in 5 mL of remineralizing solution.[5] This remineralization-demineralization cycle was performed over 10 days.[14] After each immersion, the discs were washed with 20 mL of distilled water.[15] Following the completion of the pH cycling, the specimens were kept in distilled water at room temperature for 24 hrs before surface roughness assessment.

Simulated tooth brushing

The specimens were exposed to a tooth brushing simulation machine (Robota, AD-TECH, Germany). Each specimen was embedded in wax within the orifice of an acrylic plate (55 × 25 × 4 mm), with its test surface positioned 1 mm above the edge of orifice to ensure consistent exposure during simulated brushing. Each acrylic plate was positioned inside an acrylic tank containing a standardized abrasive slurry, prepared at a ratio of 1 g of dentifrice paste (Colgate Cavity Protection; Colgate-Palmolive, USA) per 1 mL of distilled water. Brushing was performed using soft-bristled toothbrushes (Colgate Extra Clean Full Head Toothbrush, Colgate-Palmolive, USA) under a constant vertical load of 200 g. Brushing was conducted at a speed of 250 cycles per minute, totaling 10,000 cycles of simulated teeth brushing, which corresponds to approximately 12 months of daily teeth brushing. After every brushing cycle, the toothpastes and toothbrushes were changed, and specimens were subjected to ultrasonic cleaning in distilled water for 10 min.[16]

Surface Roughness assessment

At baseline, the initial surface roughness (R0) was evaluated using a 3D non-contact profilometer (Profilm3D, KLA, USA). 3D images of the surface profile of each specimen were created using a digital image analysis system. Three measurements were taken from different regions of each specimen (one central, one right, and one left), with a cutoff of 0.25. The mean surface roughness value of surface roughness (µm) at baseline was detected (R0) for each specimen.[5] Then surface roughness was measured again for all specimens after pH cycling (R1) and simulated tooth brushing (R2), following the same procedure as at baseline.

Statistical analysis

For intra-group comparisons, repeated measures ANOVA was utilized, followed by Tukey's post hoc test for multiple pairwise comparisons. For inter-group comparisons, independent samples t-tests were conducted. Statistical significance was defined as $p \leq 0.05$.

RESULTS

At baseline, Charisma Topaz One demonstrated higher initial surface roughness values (0.3737) compared to Omnichroma (0.2549). Following pH cycling, Omnichroma and Charisma Topaz One exhibited similar increased surface roughness values with no difference between them (0.7669 vs. 0.7599, respectively). After simulated teeth brushing, both materials continued to exhibit increased surface roughness values, with no significant difference between them (0.8785 vs. 0.8094, respectively). There was a statistically significant increase in surface roughness values for both materials across all aging conditions: at baseline, following pH cycling, and after simulated tooth brushing [Table 2 and Figure 1].

Table 2: Descriptive statistics and Independent T test analysis of surface roughness for both materials at baseline, after pH cycling and following simulated teeth brushing

Figure 1: Surface topography of resin composites utilized in the study

DISCUSSION

To simulate the natural oral environment, this study utilized a pH-cycling model using a demineralizing solution at pH 4.3 and a remineralizing solution at pH 7.4 over a total period of ten days.[17] Additionally, 10,000 simulated teeth brushing cycles were performed, representing one year of routine daily oral hygiene practice.[5] A non-contact profilometer was utilized to evaluate surface roughness of the resin composites tested. Compared to other available evaluation methods, non-contact profilometry offers the benefit of determining the full depth of surface flaws. It is a reliable, precise, and nondestructive method for surface roughness measurements, giving repeatable, quick, and quantitative data of surface roughness profiles.[18,19]

In the present study, Charisma Topaz One demonstrated higher initial surface roughness values compared to Omnichroma at baseline. This difference can be attributed to filler size and shape, which determine the surface properties of dental restorations.[20] Omnichroma is a nanofilled composite containing smaller, uniformly arranged spherical filler particles with reduced inter-filler spacing, offering greater protection to the organic resin against abrasive forces. In contrast, Charisma Topaz One is a nanohybrid composite with larger filler size and increased inter-filler spacing.[20]

Regarding pH cycling, both materials exhibited a significant increase in surface roughness, with no significant difference between them. The hydrolytic degradation of the resin matrix, which is the primary cause of structural disintegration and subsequent dissolution, was accelerated by low pH.[18] Both materials showed rougher surface, which could be related to their high-water sorption. This behavior is linked to their resin matrix, which primarily composed of UDMA/TEGDMA. These monomers are more sensitive to pH changes due to their hydrophilic nature.[7,21]

Regarding simulated teeth brushing, both materials exhibited a significant increase in surface roughness, with no significant difference between them. The abrasion process during simulated teeth brushing with toothpaste induces wear on the surface of resin composites.[22] Various mechanisms contribute to this wear: abrasion of the organic matrix; filler loss resulting from interfacial debonding or shearing of exposed particles; filler dislodgement due to matrix cracking; and the exposure of intrinsic voids created during the restorative process.[23]

The null hypothesis of the present study was partially accepted. Although this study highlights the promising potential of single shaded composite restorations, the in vitro design, absence of real oral conditions, and limited long-term evaluation remain the key limitations. Further in vivo studies are needed to assess the efficacy and properties of the single shaded resin composites.

CONCLUSIONS:

Given the limitations of the current study, the following conclusions can be drawn:

Single-shaded nanofilled composites initially exhibited superior smoothness compared to nanohybrid single-shaded resin composites. Repeated pH cycling similarly affected the surface roughness of both types of single-shaded resin composites. Additionally, combining pH cycling with tooth brushing yields comparable results on the surface roughness of both composite types.

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Material (Type)	Chemical composition		Fillers loading	Manufacturer (Batch No)
	Filler type, size and average	Monomer		
Omnichroma (Single shaded composite)	Round shaped and supranano spherical zirconia-silica fillers (0.2 – 0.6 μm).	UDMA, TEGDMA	68% by vol 79% by wt.	Tokuyama, Japan (030E81)
Charisma Topaz One (Single shaded composite)	Highly discrete nano particles and glass-pre-polymerized fillers (5 nm – 5 μm).	UDMA, TCD-DI-HEA, and TEGDMA.	59% by vol, 69% by wt.	Kulzer, Germany (M010206)

UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, and TCD-DI-HEA: Tricyclodecane urethane monomer.

	Omnichroma		Charisma Topaz One		P value
	M	SD	M	SD	
Baseline	0.2549 AE	0.01311	0.3737 BE	0.01678	<0.0001*
pH cycling	0.7669 CF	0.03120	0.7599 CF	0.09255	0.7503 (NS)
Simulated teeth brushing	0.8785 DG	0.01399	0.8094 DG	0.2414	0.2090 (NS)
	<0.0001*		<0.0001*		

M; Mean, SD; Standard Deviation, P; Probability level, NS; Insignificant difference at P>0.05, and *; Significant difference at P≤0.05. A, B, C, D superscripts in the same row indicate statistically significantly difference between composite types while E, F, G superscripts in the same column indicate statistically significantly change by aging methods

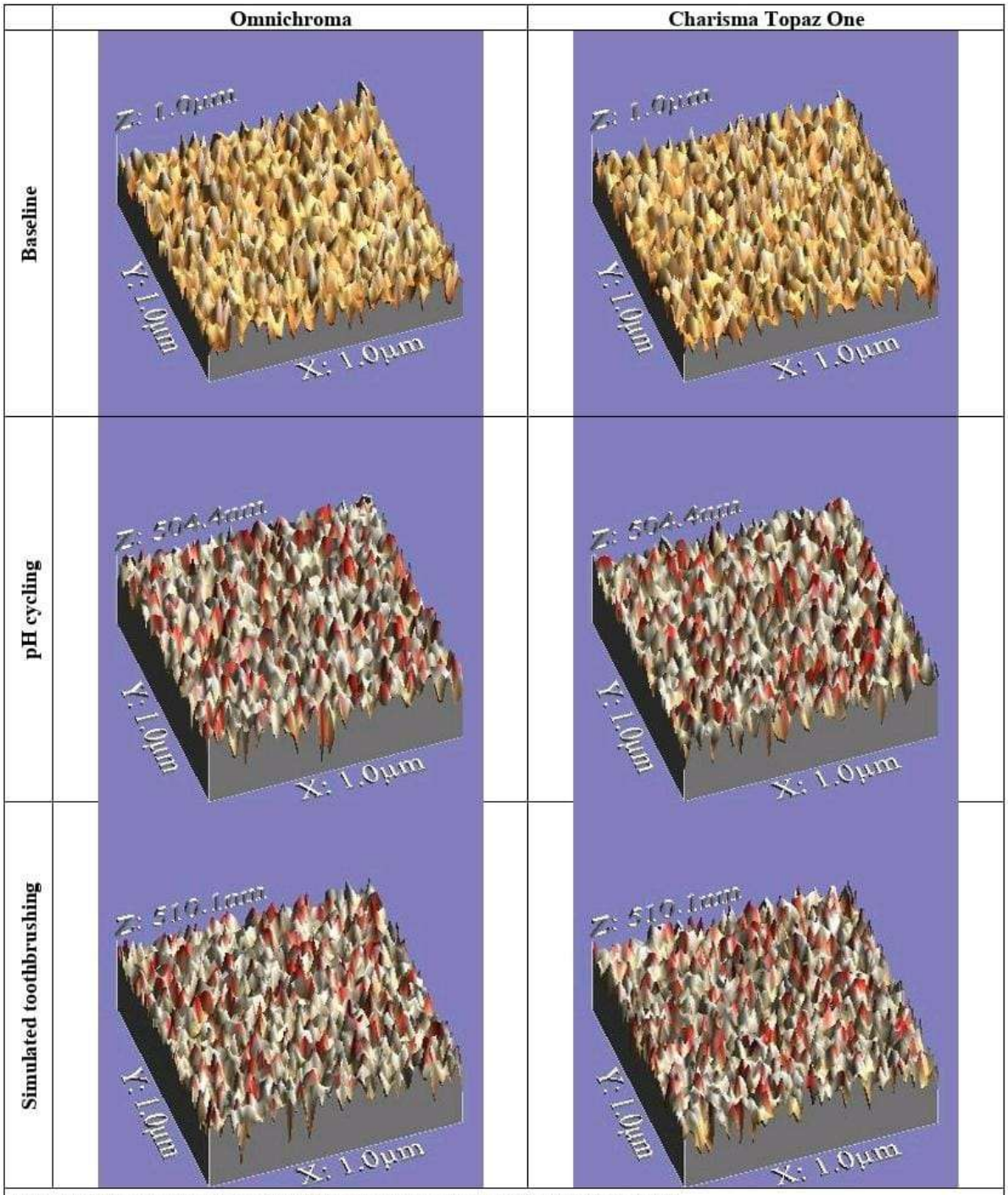


Figure 1: Surface topography of resin composites utilized in the study