RESEARCH NOTE

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In vitro comparative effects of alcohol-containing and alcohol-free mouthwashes on surface roughness of bulk-fill composite resins

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Abstract

Objectives This study aimed to compare the effects of alcohol-containing and alcohol-free mouthwashes on the surface roughness of bulk-fill composite resins. In this in-vitro, experimental study, 60 composite specimens measuring 6 mm in diameter and 2 mm in height were fabricated from Tetric N-Ceram and X-tra fil composite resins using a stainless-steel mold. After curing for 20 s, the specimens were immersed in distilled water and incubated at 37 °C for 24 h. Baseline roughness was measured before dividing them into three groups for immersion in water, alcohol-containing, or alcohol-free Listerine for 24 h, simulating two years of use. The specimens were then dried at room temperature, and their surface roughness was measured again. Data was analyzed by two-way ANOVA and t-test ($\alpha = 0.05$).

Results No significant change occurred in surface roughness of specimens after immersion in the respective solutions ($P > 0.05$). The type of composite and the type of solution had no significant effect on the surface roughness of specimens ($P > 0.05$). The results showed that Listerine alcohol-containing and alcohol-free mouthwashes had no significant effect on the surface roughness of the tested bulk-fill composite resins and no significant difference with each other in this respect.

Keywords Mouthwashes, Dental composite restorative material, Surface roughness

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Introduction

Increased surface roughness of restorative materials enhances the accumulation of dental plaque, dental bacteria, and the subsequent development of secondary caries, gingival irritation, and wear of the opposing teeth.

Composite resins are increasingly used for dental restorations due to the growing demand for tooth-colored restorative materials [1]. However, the surface properties of composite resins may be influenced by the consumption of acidic foods and drinks, saliva composition, finishing and polishing methods, and the effects of bleaching agents, mouthwashes, and fluoride [1, 2]. Some advantages of composite restorations include optimal esthetics, not requiring extensive cavity preparation and reinforcement of the residual tooth structure. The majority of the currently available composite resins are polymerized by light and are clinically applied by the layering technique to allow optimal curing and ensure complete polymerization of each increment. However, this process is time-consuming and may cause voids. It is important to note that surface characteristics play a crucial role in the clinical durability of restorative materials, as surface degradation caused by chemical solutions can affect their properties. Surface roughness refers to the microscopic irregularities on the final restoration surface, which can influence composite discoloration, plaque and bacterial accumulation, leading to secondary caries, gingival irritation, and wear of opposing teeth. Since surface smoothness is an important property of restorative materials, it has been shown that restorations with smoother surfaces have greater durability [3]Moreover, non-uniform curing can result in residual uncured resin monomers in the lower or middle increments, and lead to poor strength, marginal leakage, decreased durability, and postoperative tooth hypersensitivity. To overcome these problems, accelerate the restorative process, and decrease technical sensitivity, bulk-fill composite resins were introduced to the market, allowing bulk application of resin-based composites with up to 4 mm thickness without excessive polymerization shrinkage [2]. The main advantage of bulk-fill composite resins is their increased curing depth [4].

Mouthwashes are increasingly used for bacterial plaque reduction, antimicrobial activity, and elimination of mouth malodor as an adjunct to toothbrushing and flossing [5, 6]. Mouthwashes mainly contain water, antibacterial agents, salt, fluoride, emulsifiers, and organic acids. Some types of mouthwashes also contain alcohol [7]. Mouthwashes alter the acidity of the oral environment due to their composition. Thus, they often affect the polymer matrix of composite resins, change their organic phase, and adversely affect their physical properties such as surface roughness [8, 9]. Also, the alcohol present in the composition of alcohol-containing mouthwashes may accelerate the hydrolytic degradation of composite resins and soften them by affecting their surface roughness [10]. In addition to alcohol which serves as a plasticizer in the oral cavity, saliva may also play a role in this regard and attenuate or aggravate this effect by dilution or thickening of mouthwashes [11]. The degree of softening has a direct correlation with the percentage of alcohol in the mouthwash [12]. However, saliva can decrease or neutralize this effect [13].

Although the effects of different mouthwashes on composite resins have been previously investigated, the effects of alcohol-containing versus alcohol-free mouthwashes on different types of bulk-fill composite resins have not been well addressed in the literature [14]. Therefore, this study aimed to compare the effects of alcohol-containing and alcohol-free mouthwashes on the surface roughness of bulk-fill composite resins. The null hypothesis of the study was that the effects of alcohol-containing and alcohol-free mouthwashes on the surface roughness of bulk-fill composite resins would not be significantly different.

Methods & Materials

This in vitro, experimental study was conducted on 60 Tetric N-Ceram (Ivoclar Vivadent, Liechtenstein) and X-tra fil (Voco, Germany) bulk-fill composite resin specimens.

Sample size: The sample size was calculated to be 10 in each group according to a study by Festuccia et al. [6], using two-way ANOVA and Bonferroni test assuming $\alpha = 0.05$, $\beta = 0.2$, and effect size of 0.34 to find a difference equal to one unit of standard deviation between the groups.

Specimen preparation: Composite discs measuring 6 mm in diameter and 2 mm in thickness were fabricated from Tetric N-Ceram and X-tra fil bulk-fill composite resins ($n = 30$ from each) by using a rectangular two-piece inter-locking stainless-steel mold with holes measuring 6 mm in diameter and 2 mm in depth [15].

A thin Mylar strip was placed on a glass slab measuring $26 \times 76 \times 1$ mm, and the mold was placed over it. Composite resin was packed into the mold in one increment by a plastic instrument [16]. Another Mylar strip was placed over the mold and another glass slab was placed over it and gently compressed by finger pressure for the excess material to leak out [15]. A smooth surface was obtained as such, which did not require polishing and had no void [16]. The specimens were not polished to eliminate the confounding effect of the polishing technique on the results [10]. The glass slab was then removed, and light-curing was performed using an LED curing unit (Woodpecker, China) in contact with the Mylar strip with 1200 mW/cm2 energy density for 20 s as instructed by the manufacturer [17, 18]. The tip of the curing unit was in contact with the Mylar strip throughout the curing process for the purpose of standardization of the distance between the device tip and the specimen surface [2]. Also, the curing unit light intensity was monitored and calibrated by a radiometer (Model 10; Kerr Demetron, Danbury, CT, USA) before each time of use [19]. All the specimens were immersed in distilled water and incubated at 37 °C for 24 h to allow completion of delayed polymerization [20]. All the specimens were then inspected under adequate lighting to exclude specimens with voids or defects [2]. After completion of 24-hour incubation, the specimens were randomly assigned to 6 groups ($n = 10$) [21] including two control and 4 experimental groups, color-coded (for blinding of the examiner), and their initial surface roughness (Ra value) was measured. For this purpose, the surface roughness of each specimen was measured at 3 randomly selected points.

In group 1, X-tra fil composite specimens were immersed in 300 mL of distilled water at room temperature for 24 h. In group 2, X-tra fil composite specimens were immersed in 300 mL of Listerine alcohol-free mouthwash at room temperature for 24 h. In group 3, X-tra fil composite specimens were immersed in 300 mL of Listerine alcohol-containing mouthwash at room temperature for 24 h. In group 4, Tetric N-Ceram bulk-fill composite specimens were immersed in 300 mL of distilled water at room temperature for 24 h. In group 5, Tetric N-Ceram bulk-fill composite specimens were immersed in 300 mL of Listerine alcohol-free mouthwash at room temperature for 24 h. In group 6, Tetric N-Ceram bulk-fill composite specimens were immersed in 300 mL of Listerine alcohol-containing mouthwash(26.9% alcohol -ethanol) at room temperature for 24 h [7, 22].

Twenty-four hours of immersion corresponded to 2 years of using the mouthwashes for 2 min daily [23]. The specimens were then dried at room temperature away from sunlight [24].

Assessment of surface roughness: The surface roughness of specimens was quantitatively measured by a digital hand-held roughness tester (TR200-TIME Group Inc., CA, USA) before and after immersion in the aforementioned solutions [23]. For this purpose, the specimens were safely mounted in wax [2]and their surface roughness (Ra value) was measured by movement of the needle for 0.25 mm along the surface with 0.001 µm accuracy at three randomly selected points on the surface. The mean of the three values was calculated and reported as the mean surface roughness [2, 25]. The speed of movement of the needle was 0.25 mm/s with a cut-off (control) of 0.3 mm [26].

Statistical analysis: Independent t-test was applied to compare the mean initial and final surface roughness values between the two composite groups. Two-way and one-way ANOVA were applied to analyze the effect of storage medium and composite type on the surface roughness of specimens, and paired t-test or Wilcoxon test (depending on the normality of data distribution) was used to compare the surface roughness of each composite type before and after immersion. All statistical analyses were carried out using SPSS version 26 (SPSS Inc., IL, USA) at a 0.05 level of significance.

Table 1 Mean initial and final surface roughness (Ra values) of specimens in the six study groups

Composite type	Storage medium (24 h)	Initial surface roughness		Final surface roughness	
		Mean	Std. deviation	Mean	Std. deviation
X-tra fil	Water	0.477	0.459	0.559	0.425
	Alcohol-free mouthwash	0.651	0.482	0.744	0.467
	Alcohol-containing mouthwash	0.365	0.260	0.500	0.335
Tetric N-Ceram	Water	0.435	0.243	0.505	0.241
	Alcohol-free mouthwash	0.541	0.246	0.533	0.374
	Alcohol-containing mouthwash	0.488	0.207	0.607	0.239

Table 2 Comparison of initial and final surface roughness of XTF and N-Ceram composites

	Composite type	Quantity	Std. Deviation	t	*P* Value
Initial Surface Roughness	X-tra fil	30	0.497	-0.517	0.605
	Tetric N-Ceram	30	0.487		
Final Surface Roughness	X-tra fil	30	0.601	0.574	0.569
	Tetric N-Ceram	30	0.548		

Results

Table 1 presents the mean initial and final surface roughness (Ra values) of specimens in the six study groups. One-way ANOVA showed the highest change in surface roughness for both X-tra fil and Tetric N-Ceram specimens following immersion in alcohol-containing Listerine; while the lowest change was observed following immersion in alcohol-free Listerine.

Initial surface roughness: As shown in Table 2, the X-tra fil specimens prior to immersion in alcohol-free Listerine had the highest initial surface roughness while the X-tra fil specimens prior to immersion in alcohol-containing Listerine had the lowest initial surface roughness. Nonetheless, the difference among the study groups was not significant in initial surface roughness as shown by one-way ANOVA ($P = 0.230$). Comparison of the initial surface roughness of X-tra fil and Tetric N-Ceram composite resins revealed no significant difference either ($P = 0.605$).

Final surface roughness: As shown in Table 3, The X-tra fil specimens after immersion in alcohol-free Listerine showed the highest final surface roughness while the X-tra fil specimens after immersion in alcohol-containing Listerine showed the lowest final surface roughness. However, the difference in final surface roughness was not significant among the study groups as shown by one-way ANOVA ($P = 0.610$). Comparison of the final surface

Table 3 Comparison of initial and final surface roughness in different holding solutions

Composite type	Storage medium (24 h)	Mean	Std. Deviation	F	*P* Value
Initial Surface Roughness	Water	0.456	0.358	1.508	0.230
	Alcohol-free mouthwash	0.569	0.376		
	Alcohol-containing mouthwash	0.426	0.237		
Final Surface Roughness	Water	0.532	0.337	0.499	0.610
	Alcohol-free mouthwash	0.638	0.425		
	Alcohol-containing mouthwash	0.553	0.288		

Table 4 Within group comparison of initial and final surface roughness values ($n=10$)

Group	Mean	Std. deviation	t	*P* value
X-tra fil in water	0.082	0.306	-0.850	0.285[1]
X-tra fil in alcohol-free Listerine	0.092	0.491	-0.594	0.567[2]
X-tra fil in alcohol-containing Listerine	0.135	0.329	-1.299	0.226[2]
Tetric N-Ceram in water	0.0705	0.191	-1.165	0.274[2]
Tetric N-Ceram in alcohol-free Listerine	-0.007	0.486	0.048	0.963[2]
Tetric N-Ceram in alcohol-containing Listerine	0.118	0.349	-1.075	0.310[2]

1: Wilcoxon Test

2: Paired t-Test

roughness of X-tra fil and N-Ceram composite resins revealed no significant difference either ($P=0.569$).

Within-group comparison of surface roughness by paired t-test: As shown in Table 4, the final surface roughness was higher than the initial surface roughness in all groups except for Tetric N-Ceram specimens immersed in alcohol-free Listerine. The highest change in surface roughness was noted in X-tra fil specimens immersed in alcohol-containing Listerine while the lowest change was observed in Tetric N-Ceram specimens immersed in alcohol-free Listerine. However, the initial and final surface roughness values were not significantly different in any group as shown by paired t-test and Wilcoxon test ($P>0.05$).

Discussion

This study compared the effects of alcohol-containing and alcohol-free mouthwashes on the surface roughness of bulk-fill composite resins. The null hypothesis of the study was that the effects of alcohol-containing and alcohol-free mouthwashes on surface roughness of bulk-fill composite resins would not be significantly different. The results showed an increase in final surface roughness in all groups after immersion in the respective solutions for 24 h (corresponding to 2 years of daily use for 2 min) compared with initial surface roughness except in Tetric N-Ceram specimens immersed in alcohol-free mouthwash. However, none of the differences were statistically significant. The highest surface roughness was noted in X-tra fil specimens immersed in alcohol-containing Listerine while the lowest surface roughness was found in Tetric N-Ceram specimens immersed in alcohol-free mouthwash; nonetheless, the difference among the groups was not significant neither in the initial nor in the final surface roughness. Thus, the null hypothesis of the study was accepted.

Consistent with the present results, Mostafavi et al. [23] reported no significant change in the surface roughness of Filtek Z350 XT composite specimens after immersion in alcohol-free and alcohol-containing mouthwashes. They concluded that use of such mouthwashes had no significant effect on the surface roughness of composite resins, which was in agreement with the present results. Similarly, Aragão et al. [1] compared the surface roughness of Filtek Z350 composite specimens immersed in distilled water, Listerine, Oral B, and Colgate mouthwashes. However, they found no significant difference among the study groups in surface roughness. Urbano et al. [24] evaluated the effect of different mouthwashes on surface roughness of Filtek Z350 nano-fill composite resin and showed that different mouthwashes caused no significant change in surface roughness of composite specimens following 30 days of immersion. Their results were in line with the present findings. Some studies have reported that a reduction in filler content (weight and volume percentage) increases the surface roughness [27–29]. The agreement between the results of the aforementioned studies and the present findings can be due to the fact that the weight-to-volume percentage ratio of the composite resins evaluated in the present study is close to that of Filtek Z350.

Yofarindra et al. [10] reported a significant increase in surface roughness of nano-hybrid composite resins following exposure to Listerine mouthwash containing 26.9% alcohol and Frezza mouthwash containing 17% alcohol after different immersion times. The surface roughness was further increased by increasing the percentage of alcohol or prolonging the immersion time. This significant increase in surface roughness following immersion in alcohol-containing mouthwashes can be due to the alcohol percentage of the mouthwashes and the measurement of their pH. Alcohol present in the composition of mouthwashes lowers the pH and accelerates hydrolytic degradation of composite resins. Accordingly, it affects the surface roughness of composite resins and causes their softening. Also, the nano-hybrid composite resin evaluated in this study has three main monomers of urethane dimethacrylate, bisphenol A-glycidyl methacrylate (bis-GMA), and trimethylene glycol dimethacrylate, which affect its physical properties such as water sorption and solubility. Resultantly, changes in the surface roughness of composite may occur due to the effect of a liquid medium [21]. Prado et al. [30] evaluated the effect of alcohol-free and alcohol-containing mouthwashes on water sorption and solubility of conventional and low-viscosity bulk-fill resins and showed that resins immersed in alcohol-containing mouthwashes had higher water sorption and solubility; X-tra Base immersed in Listerine Cool Mint showed the highest water sorption, and this difference was significant. Thus, it may be concluded that the size and density of mineral fillers may be responsible for greater change in surface roughness of some types of composite resins following immersion in alcohol-containing mouthwashes.

In contrast to the present findings, Furtado and Amorim [31] reported a significant difference in the severity of surface morphological changes depending on the concentration of chlorhexidine and alcohol content of mouthwashes, as a bipolar molecule that affects the hydrophilic and hydrophobic resin components. Differences between their results and the present findings may be attributed to differences in the sample size and use of scanning electron microscopy for assessment of surface roughness in their study. However, Bohner et al. [15] demonstrated that the surface roughness of composite resins after 30 days of immersion was significantly lower than that at baseline and after 7 days of immersion. Thus, it appears that different assessment time points and methodologies can also explain the variations in the reported results regarding surface roughness changes.

Composite resins are two-phase systems composed of a dispersed phase of filler particles and a continuous phase of polymer matrix. The chemical composition of monomers, weight and volume percentage and shape, size, and dispersion of fillers, degree of polymerization, matrix composition, and durability of the filler-matrix bonding interface play important roles in mechanical properties of composite resins and particularly their surface roughness [12, 27, 29]. Ethanol, present in the composition of alcohol-containing mouthwashes, causes fragility of quartz, strontium, and barium fillers, softens them, and leads to composite matrix degradation. Organic solutions such as ethanol have the potential to damage the polymer, and monomers have a higher solubility in them than in water. These solutions can well penetrate into the resin matrix, and increase and release inactive monomers. Partial dissolution of the resin matrix may change the matrix-filler interface and cause an increase in surface roughness of composite resins [27]. In the present study, the highest surface roughness was noted in specimens immersed in alcohol-containing mouthwash. Since the resin base of both composite resins is bis-GMA, and the softening effect of ethanol on bis-GMA-based polymers has been previously documented, this increase is probably due to the fragility of the fillers and hydrolytic degradation of composite resins by the effect of alcohol [10]. Also, the initial surface roughness of X-tra fil composite specimens was slightly higher than that of Tetric N-Ceram specimens. This finding may be due to the fact that the filler content of X-tra fil (86wt% and 70v%) is higher than that of N-Ceram (81wt% and 61v%), which can directly increase the surface roughness [19].

The increase in surface roughness of X-tra fil specimens was greater than Tetric N-Ceram specimens following immersion in the respective solutions. A new technology has been employed for the production of fillers in Tetric N-Ceram in which, barium aluminum silicate glass particles are combined with ytterbium trifluoride iso-fillers to achieve ideal composite properties. This mixture of spherical oxide particles increases the durability of composite restorations, and decreases their wear. The iso-filler of this composite is the result of a combination of glass fillers, ytterbium fluoride, and polymerized dimethyl methacrylate. The glass fillers decrease wear and surface roughness. This technology is believed to prevent severe increases in the surface roughness of Tetric N-Ceram composite specimens. It is believed that following immersion in aqueous solutions, tensile stresses form at the resin-filler interface of composite resins, enhancing the release of fillers [27]. Also, it appears that the polymer matrix is mainly responsible for water sorption, and results in softening of composite surface. Both composite resins evaluated in the present study have a bis-GMA base, and this polymer is more susceptible to water sorption and softening than other polymers. The Higher hydrophilic properties of bis-GMA resin monomers are probably due to the presence of hydroxyl groups that increase water sorption [27]. The hydroxyl groups present in the composition of bis-GMA resin form stronger hydrogen bonds with water molecules compared with other resin groups, which probably increases the surface roughness after water storage.

Evaluation of two commonly applied bulk-fill composites and two frequently used mouthwashes and also application of a locking mold (which does not interfere with the polymerization process unlike the polyethylene molds) were among the strengths of the present study.

This study had an in vitro design. Thus, the generalization of results to the clinical setting should be done with caution. Future studies are recommended to immerse the specimens in artificial saliva instead of distilled water to better simulate the clinical setting. Also, similar studies on other composite types and mouthwashes with different alcohol concentrations are required to measure the pH during the course of the study.

Limitations

Due to the widespread impact of COVID-19 and resulting city-wide restrictions and altered working hours, laboratory procedures were delayed. Furthermore, the use of advanced measurement devices in laboratory settings proved to be costly. Future research could focus on better simulating the oral cavity environment by storing samples in artificial saliva for 24 h instead of distilled water. Additionally, further studies could investigate other types of composites and mouthwash solutions with varying alcohol concentrations, while also measuring pH levels throughout the experiment.

Conclusions

Within the limitations of this in vitro study, the results showed that surface roughness increased in all groups except the N-Ceram composite when placed in alcohol-free mouthwash. The increase in surface roughness was higher in alcohol-containing mouthwash. Additionally, it is worth noting that changes in surface roughness in N-ceram composite after exposure to two types of Listerine mouthwash showed better performance than X-trafil composite. The initial surface roughness in the X-trafil composite showed a higher value than the N-ceram composite.

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Author contributions
SA: Writing - original draft, Investigation, Data curation, Formal Analysis AD: Writing - original draft, Investigation HM: Conceptualization, Writing - original draft, Project administration, Supervision.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical statement
Written informed consent was obtained from all participants. The study protcol was approved by the ethics committee of the IAU University of Medical Sciences (IR.IAU.DENTAL.REC.1399,156) and is in accordance with the Declarations of Helinski.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

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