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Surface Roughness Modulation in S-PRG-Containing Resin Composites: Impact of Prebiotics and Probiotics

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Aim: This study's objective was to investigate the impact of gut-friendly supplements on the surface roughness of bulk-fill resin composites.

Materials and methods: A hundred composite discs (10 mm × 2 mm) were prepared from a bioactive surface pre-reacted glass (S-PRG) filled composite Beautifil Bulk Restorative (BBR) and nanohybrid Tetric N-Ceram bulk (TNB) restorative resin-composite. Ten discs were examined per group after 24 hours without treatment (baseline). Then, each group was split up into four subgroups (n=10) based on the immersion media: distilled water (control), probiotics, prebiotics, and pro/prebiotic media. Specimens were submerged for 10 minutes/day for 1 month. A 3D non-contact optical Profilometer was utilized to measure surface roughness (Ra). Three subsequent measurements in each specimen were taken to calculate the mean surface roughness values. Data were calculated and statistically analyzed using Two-way ANOVA followed by Tuckey's post hoc test ($P \leq 0.05$).

Results: The results showed that the supplements-immersed surfaces of all tested materials were roughest. There was a statistically significant difference between TNB and BBR immersed in prebiotic and baseline at p=0.003 and p=0.022, respectively. The BBR specimens immersed in prebiotic solution had the highest surface roughness value (10.57 ± 0.90 µm).

Conclusion: The S-PRG and nanohybrid composite resins' surface roughness may be adversely affected by dietary supplements that are gut-friendly. BBR composite resin was the one that suffered the most damage in surface roughness analysis after storage in the prebiotics solution.

Keywords: Bulk-fill resins, Nanohybrid resin, Prebiotics, Probiotics, S-PRG filler, Surface roughness.

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Introduction

Dental materials are presently changing their behavior from being biomaterials that are passive and lack active or adverse effects on the body to being constantly active biomaterials that have positive and anticipated effects, favoring the remineralization process, stimulating cells, or acting as an antibacterial.[1] In general, bioactive materials cause local physiological reactions by chemical or physical action.

Shofu Dental introduced Giomer technology in the early 2000s to address the shortcomings of Glass Ionomer Cement (GIC), a revolutionary class of composite materials that used resin composites and glass ionomer cement chemistry to create a controlled release of fluoride. [2]

The Beautifil composite lines use a bioactive surface pre-reacted glass (S-PRG) filler that actively releases six beneficial ions, including fluoride. The products are created by reacting fluoro-boro-aluminosilicate glass with the solution of polyacrylic acid. The mentioned method involves forming a steady-phase glass ionomer, "wet siliceous hydrogel," by pre-reacting fluoro-aluminosilicate glass fillers with polyacrylic acid believed to be in control of fluoride recharging and release. The glass ionomer phase of the bioactive filler is shielded from water sorption and material solubility by the surface-modified layer. [3] The finished product is then created by fusing these fillers into the resin matrix. [4]

Just the surface of the glass filler includes polyacrylic acid; the glass core is left in place and releases six different ions, namely sodium, borate, aluminum, silicate, strontium, and fluoride ions.[4,5] Within the low pH solution, the release of ions encourages acid buffering action and inhibits demineralization surrounding the material.[6,7,8] Pre-reacted glass (S-PRG) technology was created to improve material characteristics, offering wear resistance linked to the release of fluoride.[9]

Bulk-fill composites have been around for many years to make direct restoration methods simpler.[10,11,12] They offer the benefit of reducing the number of clinical procedures and time required for dental direct restorations because they are easily packed in a single layer and light-cured in layers of 4-5mm.[10, 13] The integration of air bubbles, the coupling in between increments, the modeling of every composite layer, and the extended treatment duration were among the limitations of the multi-layer techniques that were consequently limited. [1415,16] They also have the benefit of showing less polymerization shrinkage, which results in less cusp deflection.[17] After improvement and evolution, manufacturers have used a variety of techniques to increase the depth of polymerization, including decreasing the filler content, raising filler size, and adding photo-initiators. Besides, polymerization accelerators were added to speed up light curing.[18,19]

One of the S-PRG-based bulk composites, Beautifil Bulk Restorative is a true hybrid of resin and glass ionomer composites. Its exceptional aesthetics, exceptional shade stability, optimal translucency with continuous fluoride release, and rechargeability are all present [4]. Besides, Tetric® N-Ceram Bulk Fill promised to replace both bulk-fill flowable and conventional composite by achieving full-depth bulk fill up to 4 mm, lacking the use of a superficial layer for capping. The manufacturer claims that it has a shrinkage stress relieving agent to reduce polymerization shrinkage. [11,20, 21]

Polishing of restorations is one influencing factor affecting the clinical effectiveness of composites. Rough surfaces were known to retain pigment and accumulate plaque, which promotes the growth of secondary caries, the degradation of restorations, and gingival inflammation.[18,22]

Live microbes, or probiotics, have several health advantages. They are used as dietary supplements, which are made up of good bacteria and yeast that are essential for boosting the immune system. Like probiotics, prebiotics are substances that induce the growth of microorganisms like bacteria and fungi. They increase the activity of the probiotics and thus contribute to the health of their host.[23] Supplements are vital for oral health impacts in addition to overall well-being. Dairy probiotics are efficient in lowering Streptococcus mutans and elevating salivary pH balance.[24] Additionally, pre-and probiotics include a variety of micronutrients like Ca^{+2} and Mg^{+2} that may contribute to oral biofilm's ionic balance. [25]

Certain fibers, known as prebiotics, nourish the good bacteria in the digestive tract. Several prebiotics will encourage the growth of dissimilar types of natural gut flora. Prebiotics possess immense potential to alter the gut microbiota, yet these changes are difficult to anticipate in advance and happen at the level of specific strains and species. Probiotics can be supplemented with prebiotics as a backup or used in place of them.

A probiotic and a prebiotic together may work in concert. The literature suggests that prebiotics may improve the probiotic microorganisms' resistance to environmental elements, including temperature, pH, and oxygenation in a particular person's gut.[26] By combining prebiotics and probiotics to stimulate the gastrointestinal tract, one can maintain intestinal biostructure, promote the growth of beneficial microbiota, and prevent potential infections while also controlling metabolic activity in the colon. [27]

In the context of dentistry, specific research on the outcome of probiotics together with prebiotics on the surface roughness of bioactive materials is limited,[28] especially after regular immersion in both solutions. Therefore, the present study aimed to investigate the surface roughness of bioactive restorative material compared to a nano-hybrid bulk-fill one after exposure to probiotics, prebiotics, and pro/prebiotics media. The developed null hypothesis stated that immersion media would not affect any of the evaluated restorative materials.

Materials and methods

Materials used in the study

Two light-polymerized composites were examined in this investigation: Beautifil-Bulk Restorative (BBR; BF; Shofu, Kyoto, Japan) and Tetric-N Ceram Bulk Fill (TNB; Ivoclar Vivadent, NewYork, NY, USA). The code, type, composition, and manufacturer of the tested materials used in the study are listed in Table (1).

Table 1: The code, type, composition, and manufacturer of the tested materials used in the study

Material (CODE)	Type	Composition*	Manufacturer
Beautifil Bulk Restorative (BBR)	S-PRG-filled RBC	Matrix: Bis-GMA, UDMA, Bis-MPEPP, TEGDMA Fillers: S-PRG filler based on fluoroboroaluminosilicate glass. Polymerization initiator, pigments and others. (87%w-74.5%v)	Shofu Inc., Koyoto, Japan.
Tetric® N-Ceram Bulk Fill (TNB)	Nanohybrid bulk fill	Matrix: Bis-GMA, Bis-EMA and UDMA, involving advanced composite-filler technology, patented light initiator Ivocerin® Fillers: Barium aluminum silicate glass with two different mean particle sizes. (61% v and 17% polymer fillers or “Isofiller”)	Ivoclar Vivadent, NewYork, NY, USA.

***Abbreviations: Bis-GMA: bisphenol glycidyl methacrylate; UDMA: urethane dimethacrylate, Bis-MPEPP: 2,2, bis (4-methacryloxypolyethoxyphenyl) propane, TEGDMA: triethylene-glycol dimethacrylate, and Bis-EMA: Ethoxylated bisphenol-A-dimethacrylate.**

Preparation of the specimens

The King Abdulaziz University Research Ethics Committee (165-12-22) approved this work based on the World Medical Association's Declaration of Helsinki, which provides guidelines for research procedures. Following a test project, the sample size was determined with 80% power to detect a 25% difference and a 0.05 alpha value (PiFace, http://homepage.stat.uiowa.edu/\rlenth/Power/ (accessed on 22 January 2023).

The common standard deviation within every group was assumed to be 18%. The approximate sample size for each group should be at least 10.[29] A ready-made plastic Teflon cylindrical mold (10 mm in diameter * 2 mm thick) (Curing Depth Tester, Dentsply, UK) was used to create 50 discs from each composite resin material. The material was sandwiched between two opposing strips of celluloid matrix after being put into the mold. After that, a one mm-thick glass slide is positioned over the mold, and continuous pressure is used to extrude all excess material and ensure the material's structural integrity during the curing process. After removal of the glass slide, the composite resin was then polymerized for 20 seconds using an LED light-curing unit (Valo LED Curing Light; Ultradent Products Inc., UT, USA) with a light intensity of 1000 MW/cm^2, in keeping with the manufacturer's guidelines. Throughout the trial, the intensity was continuously monitored using a radiometer (Litex 682, Dentamerica®, CA, USA). The light curing tip was placed at zero distance after the removal of the glass slide. Finishing and polishing of specimens was done using three grades of Sof-lex discs (3M ESPE, St. Paul, MN, USA) from coarse to fine grit with a low-speed handpiece under wet conditions. By the manufacturer’s recommendations, in the present study, 20 seconds of polishing were applied per disc. After polishing, the top surface was labeled to make identification easier while measuring surface roughness. One operator finished all the discs' preparations to address uniformity concerns.

Grouping of specimens

Fifty discs were prepared from each resin composite material: BBR and TNB. Each group was divided into five experimental subgroups according to the immersion solution (n=10); with the baseline group with no immersion (None), Probiotic (Pro), Prebiotic (Pre), Probiotic/ Prebiotic combination (Pro/Pre), and distilled water (Control).

Immersion media preparation

Specimens from each subgroup were immersed for 10 min/day for one month (30 days) in the assigned immersion medium: the (Pro) subgroup in probiotics, the (Pre) subgroup in Prebiotics, the (Pro/Pre) subgroup in Probiotic/ Prebiotic combination, and the (Control) subgroup in distilled water. The name, brand, pH, and composition of immersion media are listed in table (2).

After polymerization, in the baseline (no immersion group), specimens were stored in labeled empty airtight containers for 24 hours at 37 C to complete the setting, then specimens were subjected to surface roughness measurement. In (Pre, Pro, and Pro/Pre) groups, one scoop of each supplement (3 grams) was added to 100 ml of water at room temperature and mixed until completely dissolved. The pH value of each immersion media was determined using a pH meter (Orion 420, Beverly, MA, USA). In the control group, specimens were kept in distilled water, and in the (Pre, Pro, and Pro/Pre) groups specimens were stored in labeled airtight containers containing 20 ml of the assigned immersion medium of the prepared supplement. Specimens in all groups were stored for 10 minutes daily for one month.[30] Immersion media were used at room temperature and were changed every day. The specimens were maintained in distilled water at 37±1°C within an incubator between experimental cycles. All surfaces of specimens in all groups were totally in contact with the immersion solution.[11]

Table 2: Name, brand, pH, and composition of the immersion media used in the study

Groups	Name	Brand	PH	Composition
Probiotic (PRO)	Probiotic-10 Powder (Healthy Intestinal Flora)	Now Foods, USA	4.4	10 Probiotic strains (50 billion CFUs), Inulin powder and FOS (Fructo-oligosaccharides).
Prebiotic supplements (PRE)	Certified organic Inulin prebiotic pure powder		3.3	Organic Inulin powder
Pro/Prebiotic (PRO/PRE)	Friendlier Flora probiotic and prebiotic powder	Sunbiotics, USA.	4.6	Probiotic blend: 4 Probiotic strains (20 billion CFUs). Prebiotic blend: Organic Jerusalem Artichoke powder, Organic Yacon Root Powder.
Distilled water (CONTROL)	Distilled water	Pharmapack, Egypt	7	Pure water H2O (H+, OH-)

Surface roughness measurements

The surface roughness was measured by a 3D non-contact optical profilometer (Bruker contour GT-K, Tucson, AZ, USA). Using the white light interferometry approach, the gadget measures height differences on the specimen surfaces by utilizing the refractive indices of the white light component. The surface of specimens was scanned with a 5× Michelson magnification lens using a 1 × 1 mm field of view at 1× scan speed. The simple Vision 64 software was used to modify the settings on the device and provide high-resolution graphical output of all scanned specimen surfaces. Before measuring each group, the system was recalibrated. Three readings from three different areas on the surface of each specimen were made, and the arithmetic mean/ Average roughness (Ra-arithmetic mean of the absolute departures of the roughness profile from the mean line) of surface roughness was calculated.[31] Ra is a usual parameter used to quantify surface roughness. It represents the arithmetic average of the absolute deviations of the surface profile from the mean line over a specified length. It provides a measure of the overall texture of a surface, indicating how smooth or rough it is. A lesser Ra value signifies a smoother surface, while a higher Ra value indicates a rougher surface. Scans were subsequently auto-leveled and categorized to derive the Ra values expressed in micrometers (µm). A diagram representation of the distribution of specimens is presented in Figure 1.

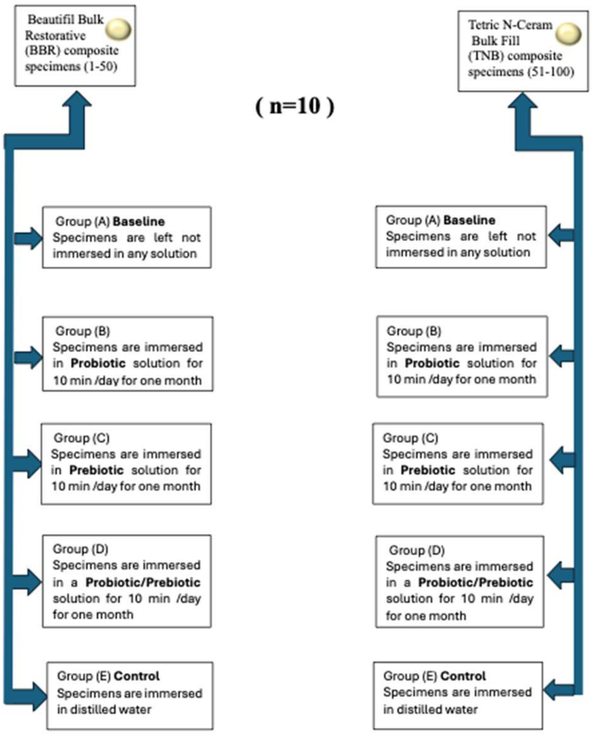

Figure 1: Schematic representation of the distribution of specimens

Statistical analysis

The normality of the collected data was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests. A normal parametric distribution was given for all numerical data. The mean and standard deviation values of the data were displayed. Tukey's post hoc test at $P < 0.05$ and two-way Analysis of Variance (ANOVA) was used to compare the roughness values of various resin composites. With IBMR SPSSR

Statistics Version 20 for Windows, statistical analysis was carried out.

Results

The profilometric findings of BBR and TNB composites are presented in Table (3). (Figure 2).

The BBR immersed in the prebiotic medium showed the highest mean surface roughness (10.57± 0.90), and the control group reported the lowest (9.98 ± 1.00) with a non-statistically significant difference between both groups.

The BBR group showed a statistically significant increase in mean surface roughness values with a non-significant difference between probiotic, prebiotic, pro/prebiotic, and control groups. However, a statistically significant difference was recorded between the Baseline and the rest of the tested groups at p-value <0.001.

Table 3: Mean and standard deviation values of Ra (µm) of Beautifil Bulk Restorative and Tetric N-Ceram Bulk Fill resin composite materials immersed in different immersion media

Composite resins / Immersion medium	Beautifil Bulk Restorative	Tetric® N-Ceram Bulk Fill	p-value
	Mean ± SD	Mean ± SD	
Probiotic	10.07 ± 0.70 a	10.03 ± 1.13 b	0.927
Prebiotic	10.57 ± 0.90 a	9.58 ± 0.003 c	0.003*
Pre\Probiotic	10.08 ± 1.08 a	10.16 ± 0.65 b	0.841
Distilled Water (control)	9.98 ± 1.00 a	10.61 ± 0.42 a	0.087
Baseline	7.46 ± 0.33 b	7.18 ± 0.12 d	0.022*

***Statistically significant (p<0.05), Similar letters in the same column indicate no significant difference (p>0.05)**

Regarding TNB, the control group showed the highest statistically significant mean surface roughness value (10.61 ± 0.42), and the prebiotic group showed the lowest with a non-significant difference between both groups. A statistically significant increase of mean surface roughness values of TNB immersed in probiotics, prebiotics, pro/prebiotics, and distilled water (control) was recorded when compared to baseline (7.46 ± 0.33) at p-value <0.001. However, there was no significant difference between the TNB resin composite immersed in probiotics (10.03 ± 1.13) and pro/prebiotics (10.16 ± 0.65) after one month of immersion. 3D images of surface topography by profilometer of two representative samples are presented in (Figure 3).

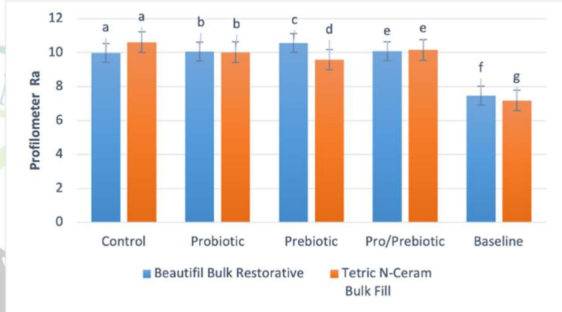

Figure 2: Results of surface roughness analysis by storage solutions by using a profilometer. Different letters indicate a statistically significant difference between groups.

Comparison between mean and standard deviation values of surface roughness of BBR and TNB resin composites at baseline and after immersion in different media is presented in Table (3). There was a statistically significant difference found between BBR (10.57± 0.90) and TNB (9.58 ± 0.003) bulk-fill resin composites immersed in prebiotic at p= 0.003 and between BBR (7.46± 0.33) and TNB (7.18 ± 0.12) before immersion (baseline) at p= 0.022. No statistically significant difference was found among the other subgroups, including probiotics, pro/prebiotics, and distilled water, after one month of immersion at the p-values of 0.927, 0.841, and 0.087, respectively.

Discussion

Researchers have developed pre-reacted glass (PRG) technology, which may demonstrate ion release, to create the perfect restorative material with bioactive qualities. The pre-formed glass-ionomer phase,

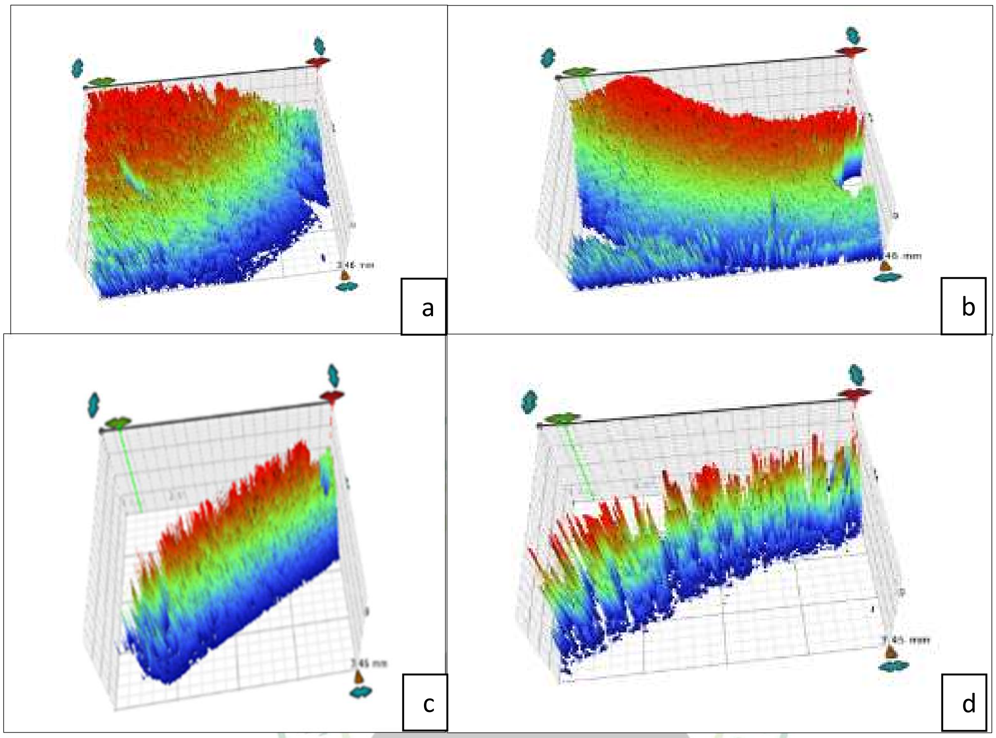

Figure 3: Representative 3D images of surface topography of Beautifil Bulk Restorative (a,b) and Tetric N-Ceram Bulk Fill resin composites (c,d). (a)Profilometric images of Beautifil Bulk Restorative resin composite material before immersion. (b) Profilometric images of Beautifil Bulk Restorative resin composite material after immersion in the prebiotic medium. (c) Profilometric images of N-Ceram Bulk Fill resin composite material before immersion. (d) Profilometric images of Tetric N-Ceram Bulk Fill resin composite after immersion in the prebiotic medium.

or S-PRG filler, is created when an acid-base reaction occurs when there is water present between the acid-containing polymer and the glass particles containing fluoride. This reaction enables the phase to function as a reservoir. S-PRG-filled resin composites are considered restorative materials with comparable results to conventional resin composites because of their high fracture toughness and flexural strength. [28, 32]

According to the study by Gordan et al., which had the longest observation duration of all the studies in the literature, with a 13-year evaluation period, these restorations have an acceptable clinical prognosis over the long term.[33] The material composition, specifically the kind, amount, and distribution of the inorganic fillers and the organic matrix in the resin composite, greatly influences surface roughness.[34] This study intended to investigate the surface roughness of S-PRG-based composites compared to nano-hybrid resin composites after immersion in probiotics, prebiotics, and pro/prebiotics. A 3D non-contact optical profilometer is an advanced metrology tool used to measure the surface topography of materials without physically touching them.

It is accurate, efficient, and offers a comprehensive, detailed surface characterization, including surface roughness.

Numerous investigations have made use of continuous immersion in liquids. The time of exposure to liquids in the oral cavity was restricted in the current investigation to 10 minutes, in line with recent *Gupta et al.* [30] This period is, therefore, thought to reflect the effects of tested liquids simulating oral cavity circumstances for restorative materials.

The use of gut-friendly drinks in this study is due to the trend of living healthily and understanding the significance of helpful gut bacteria. Additionally, these bacteria function in the oral cavity to slow the impacts of cariogenic bacteria on teeth and dental restorations over time.[35] The null hypothesis was rejected since the surface roughness values of tested resin composite materials rose significantly after being submerged in gut-friendly supplements.

This study reported that the surface roughness of BBR at baseline was significantly higher than TNB, which could be attributed to the higher content of S-PRG particles (87.0 wt% 74.5vol %), with relatively greater size (0.8 µm), resulting in a rougher surface compared to TNB (76 wt%, 54 vol %) with a mean particle size of 0.6 µm and nanoparticles <100nm. The size of the filler particles directly impacts the surface roughness and external colorations of resin composites. By having smaller filler particles, however, nanohybrid resin composites minimize an increase in surface roughness during polishing by reducing the interparticle gap and minimizing the removal of both particles and the organic matrix.[36,37]

In addition, the immersion of both types of resin composite discs in distilled water increased surface roughness significantly compared to baseline, which may be due to water sorption by resin matrix that could result in plasticization, softening, and hydrolysis of material, which results in the displacement of the filler particles promoting greater surface roughness.[15] Furthermore, the increased water absorption could raise the osmotic pressure at the filler-organic matrix contact, which could roughen the surface and cause cracks to appear.[10]

However, because the pro, pre, and pro/pre-media are acidic, this investigation demonstrated that immersing the two composite resin materials in them increased their surface roughness. Because acidic meals and drinks have low pH levels, they negatively impact tooth surfaces. It has been demonstrated that restoration materials deteriorate with time and display surface roughness, reduce wear resistance, and decrease microhardness when exposed to acidic environments. Remaining monomers may be released, fillers may be removed, surface gaps may form, and surface roughness may rise as a result of biodegradation.[13] A higher incidence of secondary caries and postoperative sensitivity can result from changes in the surface topography, which can also enhance biofilm deposition.[38]

Also, this statistically significant increase in surface roughness after immersion in probiotics, prebiotics, and pro-prebiotics may be due to the exposure to a wet environment that can result in hydrolytic degradation of ester radicals found in methacrylate monomers like Bis-GMA, Bis-EMA, TEGDMA, and UDMA or matrix dilatation, lowering the forces of friction between the polymer chains and breaking of the bonds between filler particles and organic matrix leading to elution of fillers and increasing surface roughness.[39, 40]

The surface roughness of BBR was significantly higher than TNB after immersion in prebiotic media. This might be attributed to the inherent nature of TNB, which is a nanohybrid composite designed to have high polish ability and surface smoothness due to its filler technology. [41] It tends to maintain its surface integrity better than other composites under similar conditions. [42] However, BBR is a giomer-based composite, which incorporates pre-reacted glass ionomer fillers. This unique filler composition can influence its surface properties, including roughness, especially when exposed to various solutions. [43] It also increases the potential for higher water absorption. Besides, the breakdown of the matrices [44] and degradation of the polyacrylate salts [38] occurred as a result of the glass fillers in GIC materials being more sensitive and prone to breaking off at lower pH values.

Additionally, BBR contains TEGDMA, which is a hydrophilic monomer, and this composition may have encouraged composite degradation and filler elution, resulting in higher surface roughness. [39]

Both tested materials contain Bis-GMA, which is a high molecular weight monomer. Large molecules are less effective in creating cross-links and create a less dense polymer network, which makes it easier for liquids to penetrate and act within the polymer, potentiating the effects of liquid acid substances. Both materials behaved differently when immersed in probiotics and prebiotics, with a non-significant increase in surface roughness in the former and a significant difference in the latter. This might be explained by the difference in the chemical composition between both immersion solutions that caused their different interaction with dental materials. Probiotics are live organisms, such as specific strains of bacteria and yeast, that provide health benefits when consumed in adequate amounts. [45] Prebiotics, on the other hand, are typically complex carbohydrates that serve as food for these beneficial microorganisms. They are not live organisms but rather substances that promote the growth and activity of beneficial bacteria in the gut.[46,47]

Yoshihara et al.'s report of irregularities on the surface of resin composites containing S-PRG filler and immersed in lactic acid at pH 4.0 for three days was in line with the current study's findings that BBR's surface roughness increased statistically significantly more than TNB's when immersed in prebiotics. [48] For other traditional resin composites, however, there was no discernible rise in surface roughness. They asserted that the surface modification resulted from the breakdown of the S-PRG filler. Conversely, several clinical trials demonstrated their improved performance.[49] [50] So, the long-term surface durability of S-PRG filler-containing resin composites keeps on being examined.

Conclusion

Under the limitation of this study, the results revealed that gut-friendly supplements could negatively interfere with the surface roughness values in S-PRG-based composites and nanohybrid composite resins. BBR composite resin was the one that suffered the most damage in surface roughness analysis, with storage in prebiotics solution.

Acknowledgment

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Declarations

Funding

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Data Availability

Upon a reasonable request, the corresponding author will make the datasets created and/or examined during the current work available.

Ethical approval

The study protocol received approval from the King Abdulaziz University Research Ethics Committee on November 15, 2022 (165-12-22) based on the World Medical Association's Declaration of Helsinki, which provides guidelines for research procedures.

Conflicts of Interest

No conflicts of interest are disclosed by the authors.

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