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Effect of whey protein beverages on surface roughness of a packable resin composite

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Abstract

Objective: This study aimed to analyze the effect of whey protein beverages on the surface roughness of a packable resin composite restorative material.

Methods: Twenty disc-shaped specimens were prepared from a resin composite (Ivoclar Te-Econom Plus). The specimens were divided into two equal groups (n=10) and subjected to different immersion media, as follows: Group 1: Whey-1 solution (BigMuscles Essential Whey) and Group 2: Whey-2 solution (Muscletech Nitro Tech 100% Whey Gold). Each whey solution was prepared by mixing 25 g of the corresponding whey powder into 250 ml of water. The samples were immersed in the respective solutions for 10 minutes daily for 14 days. The surface roughness of each composite specimen was analyzed pre- and post-immersion using a stylus profilometer. The average surface roughness value (Ra) of each specimen was recorded in µm at each interval. The data were subjected to statistical analysis using SPSS software 26.0. Wilcoxon signed-rank test and Mann-Whitney U test were used for statistical analysis. P-values less than 0.05 were considered significant.

Results: Both groups exhibited a significant increase in surface roughness values after immersion in whey protein drinks (P= 0.045 for group 1 and P=0.038 for group 2). The mean post-immersion Ra value was significantly greater in group 2 (0.402 ± 0.328) compared to group 1 (0.302 ± 0.167) (P=0.048).

Conclusions: Both types of whey protein beverages significantly increased the surface roughness of a packable resin composite. These results imply that exposure to whey protein beverages may adversely affect the surface roughness of composite restorations.

Keywords: Beverages, Resin composite, Restorative material, Surface properties, Surface roughness, Whey protein

Introduction

The increasing patient-driven demands for esthetics have made composite restorations an extensively employed dental material to restore anterior and posterior teeth (1, 2). Achieving a restoration that mimics the color and appearance of a natural tooth is one of the most challenging aspects of every restorative treatment in the esthetic zone (3). The surface properties of restorations influence the interaction between the restorative material and the oral environment (4). Roughness is a surface characteristic that influences the quality and clinical behavior of restorative materials. Rough surfaces increase the risk of secondary caries development and predispose the restoration to stain, compromising the esthetic outcomes and jeopardizing the longevity of the treatment (5).

Health supplements and sports drinks have gained tremendous popularity in the past years due to the increased health consciousness among the general public (6). Whey protein is a mixture of proteins derived from the liquid byproduct of cheese production. It is recognized for its diverse health benefits and functional properties and is commonly marketed as a protein supplement. The proteins consist of α-lactalbumin, β-lactoglobulin, serum albumin, and immunoglobulins. Glycomacropeptide also makes up the third largest component of whey protein but is not a protein (7, 8). Whey proteins are a popular option for athletes and the general public trying to increase their protein consumption (9).

Despite their nutritional value, whey protein beverages can have a detrimental effect on oral health.

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These drinks frequently include lactose and other carbohydrate components that lower the pH of the oral environment and can compromise the integrity of teeth and restorative materials (10). The low pH may limit the lifespan of resin composites by increasing their susceptibility to wear and discoloration (11). Whey protein drinks have a thicker viscosity than other commonly consumed beverages, which increases the length of time they come into contact with teeth and restorations and exacerbates their erosive effects. Because decreased salivary flow during physical activity impairs the mouth's capacity to neutralize acids and wash out hazardous compounds, there is a higher risk when these drinks are consumed after exercise (12). Additionally, the acidic environment created by acidic whey protein drinks can cause surface pitting and roughness in restorative materials, diminishing their esthetic and functional qualities. As the surface roughness of resin composites increases, plaque and bacteria adhere more quickly, raising the risk of gingivitis and periodontal disease and further compromising overall oral health (13).

Given the widespread consumption of whey protein beverages, it is necessary to investigate their potential impact on the surface properties of composite materials. Although some studies have evaluated the effect of whey protein beverages on the microhardness and other physical properties of composite restorations, the impact of these beverages on the surface roughness of packable resin composites has not been sufficiently studied. This study aimed to analyze the effects of whey protein beverages on the surface roughness of a packable resin composite restorative material.

Materials and methods

Sample preparation

A total of 20 resin composite discs (Figure 1) were fabricated from a packable resin composite material (Ivoclar Te-Econom Plus; Ivoclar Vivadent, Schaan, Liechtenstein). The composite material was packed into a stainless steel mold 10 mm in diameter and 2 mm in height, using a Teflon instrument to ensure complete filling without air entrapment. The filled molds were then subjected to a light curing process using an LED curing unit (Guilin Woodpecker Medical Instrument Co. Ltd, Guangxi, China). Each disk was cured for 30 seconds. The samples were then polished in planar motion using coarse, medium, fine, and superfine abrasive discs (Shofu Inc., Kyoto, Japan) for 10 seconds to obtain a uniform and smooth surface. They were then measured by a digital caliper (INSIZE, Gujarat, India) to ensure that all the samples had a uniform size.

The prepared specimens were randomly divided into two equal groups (n=10). The specimens in groups 1 and 2 were immersed in whey-1 and whey-2 solutions, respectively.

Solution preparation

Two different whey protein powders were selected for the study. Twenty-five grams of each whey protein powder was dissolved in 250 ml of lukewarm water to prepare the immersion solutions. The mixing process involved constant stirring with a rod to ensure complete dissolution of the protein powder, resulting in homogenous solutions. The solutions were as follows:

- Whey-1: This solution was made by mixing BigMuscles Essential Whey (BigMuscles Nutrition Pvt. Ltd., Haryana, India) powder with lukewarm water. The composition of the powder was whey protein concentrate, maltodextrin, cocoa powder, and lactase sweetener (INS 955).
- Whey-2: The whey-2 solution was prepared by mixing Muscletech Nitro Tech 100% Whey Gold (TGTMC Supply Chain Private Limited, Mumbai, India) powder with lukewarm water. According to the manufacturer, this powder's components are a protein blend

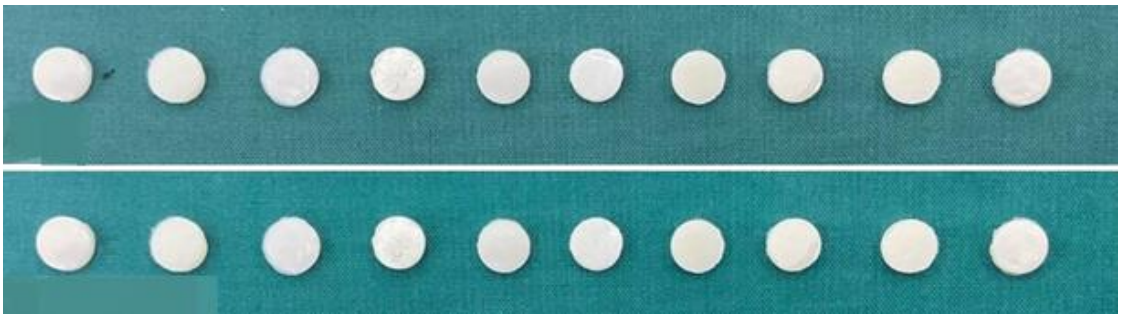

Figure 1. Twenty composite disc samples were prepared for immersion in their respective whey solutions

(whey peptides, whey protein isolate, whey protein concentrate), natural and artificial flavors, lecithin, a gum blend (xanthan gum, carrageenan), salt, silicon dioxide, and sweeteners.

Surface roughness was measured using a stylus profilometer (Mitutoyo South Asia Pvt. Ltd. New Delhi, India) (Figure 3). The profilometer traced the surface topography of each composite sample, and the Ra (average roughness) value was recorded. One measurement was made per sample before (baseline)

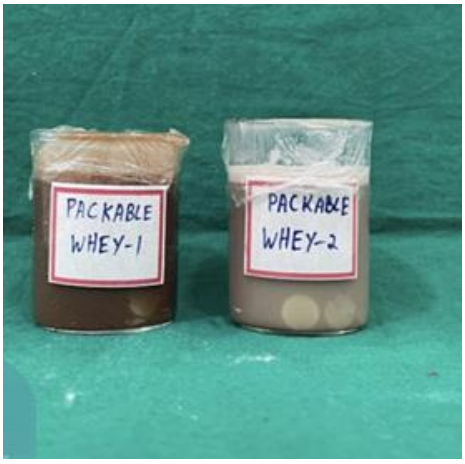

Figure 2. Ten resin composite disk samples were immersed in whey protein solutions, labeled as whey-1 and whey-2

Figure 3. Evaluating the surface roughness value of the composite disk specimen using the SJ-310 Mitutoyo stylus profilometer

Immersion protocol

The immersion protocol involved submerging the samples in the respective whey protein solutions for 10 minutes daily over 14 days (Figure 2), simulating a typical daily exposure over a short period (14). Post-immersion, each sample was gently wiped clean using a blotting paper to remove any residual solution. Afterwards, the samples were stored in distilled water until the next immersion cycle, which had to be conducted the next day.

Surface roughness testing

and after the completion of the immersion protocol. The parameters of the stylus profilometer were as follows: cut-off length of 0.8 mm, evaluation length of 2.4 mm, and measurement speed of 0.5 mm/s.

Statistical analysis

Data were subjected to statistical analysis using SPSS 26.0 (IBM Corp., Armonk, NY, USA) software. The distribution of the data was assessed using the Shapiro-Wilk test. Since the data had a non-normal distribution ($P<0.05$), non-parametric tests were employed. The Wilcoxon signed-rank test was used to assess the pre-

and post-immersion microhardness values in each study group. The Mann-Whitney U test was used to compare the microhardness values between the two groups. P-values less than 0.05 were considered statistically significant.

Table 1. Comparison of pre-and post-immersion surface roughness values within each group and between the two study groups

	Pre-immersion Ra values (µm)		Post-immersion Ra values (µm)		P-value
	Mean±SD	Minimum-Maximum	Mean±SD	Minimum-Maximum	
Group 1	0.146 ± 0.056	0.077 - 0.249	0.302 ± 0.167	0.126 - 0.600	0.045*
Group 2	0.191 ± 0.058	0.092 - 0.275	0.402 ± 0.328	0.111 - 0.983	0.038*
P-value	0.123		0.048**		

SD: Standard deviation; Group 1: BigMuscles Essential Whey; Group 2: Muscletech Nitro Tech 100% Whey Gold
*Values less than 0.05 represent a significant difference between pre-and post-immersion Ra values within each group according to the Mann-Whitney U test.
**Values less than 0.05 represent a significant difference between groups according to the Wilcoxon signed-rank test.

Results

Table 1 displays the pre- and post-immersion surface roughness values in each study group. Before immersion in any whey solutions, samples in groups 1 and 2 displayed an average surface roughness of 0.146 ± 0.056 and 0.191 ± 0.058, respectively. The Wilcoxon signed rank test revealed that after immersion in the corresponding whey solutions, there was a statistically significant increase in Ra values of composite specimens in both group 1 and group 2 (P=0.045 and P=0.038, respectively; Table 1).

According to the Mann-Whitney U test, the two groups were not significantly different regarding the baseline Ra values (P=0.123; Table 1). However, the mean post-immersion Ra value was significantly greater in group 2 (0.402 ± 0.328) compared to group 1 (0.302 ± 0.167) (P=0.048; Table 1).

Discussion

This in-vitro study investigated the impact of whey protein beverages on the surface roughness of a packable composite material. The Ra value was used to assess the surface roughness of composite resin before and after exposure to whey protein beverages. Ra (average roughness) is a commonly used parameter for assessing the surface texture of dental materials. It represents a measure of the average deviation of the surface profile from its mean line over a specified sampling length. Lower Ra values indicate smoother surfaces.

Packable composites are among the most commonly used esthetic restorative materials. The study assessed the changes in the surface roughness of packable composites after exposure to whey beverages for 14 days. Twice daily usage of whey beverages was estimated to take 10 minutes. The 14-day period of the experiment represented the short-term use of whey protein beverages in real scenarios.

According to the results of this study, both tested whey protein powders caused a statistically significant increase in surface roughness values of composite specimens. Although the roughness values of composite specimens were comparable at baseline, the mean post-immersion Ra value was significantly greater in group 2 (Muscletech Nitro Tech 100% Whey Gold solution) (0.402 ± 0.328) compared to group 1 (BigMuscles Essential Whey powder) (0.302 ± 0.167). The various composition of tested whey protein powders, i.e., acidic ingredients, flavoring agents, preservatives, and sweeteners, may lead to different pH values of prepared beverages, thus affecting the surface roughness of dental composite specimens differently.

This study's outcomes agree with several studies that indicated whey protein beverages deteriorate the physical properties, such as the surface roughness and microhardness of composite restorative materials over time (12, 14). Kaur and Nikhil (14) found a decline in the microhardness of the bulk fill, microhybrid, and nanofilled composites after immersion in whey protein beverages. An in-vitro study by Satnin et al. (12) evaluated the color and surface roughness changes of different composite materials after prolonged exposure to whey protein. Nanohybrid composites showed a statistically significant increase in surface roughness values after immersion in the whey solution. However, nanoparticle samples demonstrated a decline in surface roughness post-immersion. A study by Das et al. (15) showed that nanohybrid composites are more resistant to acidic beverages than bulk-fill resin composites. The difference in the behavior of dental composites to whey protein may be related to their different

microstructures, water sorption characteristics, and acidic resistance (15, 16).

Whey protein beverages can negatively impact composite restorations through various mechanisms. Their acidic nature lowers the pH of the oral environment, potentially falling below the critical threshold and leading to erosion of teeth and restorative materials. This erosion creates surface roughness and micro-irregularities, facilitating plaque accumulation and biofilm formation and increasing the risk of secondary caries. Over time, these effects may compromise the integrity and longevity of composite restorations. Several studies reported that a decrease in the pH of the oral cavity increases the risk of erosive tooth wear and adversely affects dental restorative materials (17, 18). Hamouda (13) reported that continuous exposure to low-pH beverages, such as orange (pH=2.85) and mango (pH=3.49) juices caused an increase in the surface roughness of the tested microhybrid composite resin.

One of the main reasons for the acidic nature of whey protein formulations is to improve the beverage's heat stability and enhance its clarity ((19- 21). Although the pH of the tested whey drinks was not evaluated in the current study, the increase in composite surface roughness is probably attributable to the low pH content of these beverages. Maganur et al. (22) showed that consuming acidic juices and soft drinks could affect the integrity and surface properties, such as the surface roughness of commonly used restorative materials. Meenakshi et al. (23) also stated that acidic drink usage significantly affected the surface roughness of posterior composite resin materials. The present study also noted increased Ra values after exposure to acidic whey protein drinks.

Another important factor that may cause detrimental effects on the restoration surface is that whey protein beverages have a higher viscosity than other regularly consumed beverages, resulting in a longer contact time with the tooth structure and restorative materials. This extended contact period thereby increases the erosive effect of the whey protein drinks, which can lead to changes in the material's physical properties, such as increased surface roughness.

The clinical implication of the present findings is that repeated exposure to acidic whey protein beverages can cause increased surface roughness of packable dental composites, creating a favorable environment for plaque accumulation, bacterial adhesion, and biofilm development, thus increasing the risk of secondary caries (24). Furthermore, rougher surfaces are more perceptible to staining caused by external sources, compromising the esthetic outcomes of restorations (18, 25).

One of the limitations of the present study was that due to its in-vitro nature, we could not simulate the oral environment's complex conditions. The effect of factors such as temperature, oral bacteria, and saliva could not be included in the analysis of the study outcomes. In addition, only one type of packable composite was tested. We did not assess the pH of the beverages in which the composite resin samples were immersed. Future studies should analyse a broader range of whey protein beverages and dental restorative composite materials to provide more conclusive and generalized results. Analyzing the surface roughness properties of different composite materials using atomic force microscopy would also be beneficial and provide more detailed surface data.

Conclusions

According to the results obtained, the tested whey protein drinks significantly increased the surface roughness of packable dental composites. These findings suggest that whey protein beverages can act as a potential risk factor for the surface properties and longevity of composite restorations.

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Conflicts of interest

Authors have no conflicts of interest to disclose.

Author contribution

J.S. conceived the ideas for framing the methodology, inspected the research work, and analyzed the data. B.G.S. carried out the study and prepared the initial manuscript. M.Z.M. conducted the data collection and data analysis procedures. All authors have read and approved the final manuscript.

Ethical approval

Not applicable

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