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Assessment of Surface Roughness and Color Stability of Different Composite Resins Following Exposure to Common Beverages.

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Abstract

Background: Surface roughness and discoloration are the key concerns to consider in the longevity and esthetics of composite resin restorations. Frequent intake of staining and/or acidic drinks can increase the breakdown of restorative materials. ***Objective:*** To compare the surface roughness and color stability of different composite resin materials following exposure to commonly consumed beverages. ***Methods:*** This in vitro experimental comparative study comprised 80 standardized composite resin specimens of four different composite materials. Surface roughness (Ra) was evaluated by using a contact profilometer, and colour parameters (L*, a*, and b*) were recorded by using a digital spectrophotometer. The paired t-test and one-way ANOVA were used for data analysis, with a significance level of $p \leq 0.05$. Tukey's post hoc test and two-way ANOVA were also used for data analysis. ***Results:*** Coffee produced the greatest color change, whereas carbonated soft drink resulted in the highest increase in surface roughness. Minimal alterations resulted from the use of distilled water. There were significantly different results between composite resin materials, with the supra-nano spherical composite having the least discoloration and surface degradation and the bulk-fill composite having the most degradation ($p<0.001$). ***Conclusions:*** The most common drinks cause significant alteration of surface integrity and colour stability of composite resin restorations. The role of composite resin composition in resistance to staining and surface deterioration is an important role, which means it is important to select the appropriate material in order to achieve long-term esthetic success.

Keywords: Composite resin; Surface roughness; Color stability; Dental restorative materials; Coffee.

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INTRODUCTION

Composite resin materials have become the restorative material of choice in contemporary restorative dentistry owing to their superior esthetics, adhesive properties, and minimally invasive application.[1] The chemistry of resins and the filler technology, together with the variety of polymerization systems, have made a significant contribution to improving mechanical strength, wear resistance and optical properties of composite resins, which have successfully been used in anterior and posterior restoration applications.[2] These developments have not made composite restorations more successful in the long term, however, as they are now not only mechanically durable but must also maintain their surface integrity and color stability during service.[3] One of the most frequent reasons for restoration replacement is surface roughening and discoloration, which are associated with unfavorable esthetic, plaque retention, adhesion of bacteria, and the risk for secondary caries and periodontal complications.[4] Thus, maintaining the quality of the surface and the color of composite restorations is crucial for patient satisfaction and for prolonging the life of the restorations.[5]

Dental composite resins are subjected to a number of chemical and physical stresses in the mouth on a regular basis.[6] Coffee, tea, carbonated soft drinks, fruit juices, and energy drinks are just a few of the drinks that contain acids, pigments, and temperature changes that occur in restorative materials routinely.[7] Drinks like coffee, tea, carbonated soft drinks, fruit juices and energy drinks provide repeated exposures of acidic, pigmented and thermal changes to restorative

materials.[8] The composition, chromogenic potential and pH values of these beverages vary significantly, affecting the degradation of the resin matrix and the interface between the resin and the filler.[9]

Acidic drinks can demineralize the resin matrix, cause water sorption, and lead to loss of filler particles, which leads to an abraded restoration surface.[10] At the same time, coffee can become discolored by chromogenic fluids that contain tannins, polyphenols and artificial dyes that penetrate the resin matrix or adhere to roughened surfaces, causing visible discoloration in the clinic.[11] Thus, diet is a significant extrinsic determinant of the longevity of esthetic performance of composite restorations.

The surface roughening parameter is one of the most important parameters that affects the biological and clinical behaviour of restorative materials. A roughened restoration surface reduces both gloss and the esthetic appearance, and it is easy for microorganisms to colonize and mature in the biofilm.[12] Research indicates that surface roughness greater than about 0.2 µm may lead to an increase in bacterial plaque adherence and increased risk of gingivitis and/or recurrent caries.[13] Similarly, color stability is one of the basic parameters for esthetic longevity, which is typically measured by the CIE Lab* color system and reported as the color difference (ΔE).[14] Color changes can be caused by intrinsic or extrinsic factors, such as resin composition, level of conversion, and the nature of the fillers, as well as diet, smoking, and oral hygiene habits.[15] The interaction between the restorative material and commonly consumed beverages is therefore critical in choosing materials that can hold up their esthetic look over time.[16]

The use of direct composite restorations has risen significantly in the last 20 years worldwide.[1] With the popularization of adhesive restorative techniques in today's dentistry, it is estimated that more than 800 million direct resin composite restorations are placed in the world every year.[17] Moreover, failed restorations contribute to almost 50-70% of all restorative dental procedures; discoloration and surface degradation are the major indications for failed restoration replacement.[18] The replacements place a high cost on the healthcare system and the patient, and lead to a progressive loss of dentition.[19] Thus, it is of paramount importance to identify restorative materials that exhibit greater resistance to surface deterioration and staining if material selection and clinical success are to be based on evidence.[20]

The effects of these drinks on restorative materials are more relevant in countries where tea, coffee, and carbonated drinks consumption is high, such as Pakistan. Dietary patterns are different from one population to another and can be related to the longevity of esthetic restorations in routine clinical practice. In-vitro comparison of the various composite systems under conditions simulating the oral cavity may be helpful in choosing the appropriate material for patients who drink beverages that stain or are acid formulations. Furthermore, this evidence could aid in educating patients on diet habits that could affect the aesthetic longevity of composite restorations. This study aimed to evaluate and compare the surface roughness and color change of various composite resin materials after stimulation with beverages commonly consumed in the mouth to evaluate the resistance of these materials to surface degradation and color change under simulated oral conditions.

METHODOLOGY

This is an in vitro experimental comparative study to assess and compare the surface roughness and color stability of various composite resin materials after exposure to the commonly consumed beverages under standardized laboratory conditions. The study took place at the Dental Materials Department. The study was conducted for six months from July to December, 2025

The sample size was determined using OpenEpi Version 3.01 (Two means). The calculation was based on the coffee staining study performed by Alharbi et al., which found a mean color change (ΔE) of 4.10 ± 1.30 for one composite and 2.90 ± 1.20 for another after being immersed in coffee.[21] The minimum sample size required was determined at 19 specimens/group based on a study power of 80%, a 95% confidence level and an allocation ratio of 1:1. In order to account for the potential loss of specimens during sample preparation, polishing or testing, the sample size was raised to 20 specimens per group. A total of 80 composite specimens were produced in the final sample, which included four composite resin groups.

A non-probability consecutive sampling technique was employed. The predefined dimensions and quality standards were applied to composite specimens, which were prepared one by one until the number of specimens for each study group was reached. A total of 12 composite resin materials commercially available and belonging to different categories of composite were studied and used for direct posterior and anterior restoration. Composite syringes were used only if they were newly purchased and had a valid expiration date.

The specimens were prepared in the same stainless-steel moulds, which are in the shape of a disc, 10 mm in diameter and 2 mm in thickness. Following the curing and finishing procedures, specimens with smooth surfaces and no defects, voids,

fractures or polymerization errors were included for testing. Any specimen with obvious air bubbles, marginal defects, surface contamination or cracks, incomplete polymerization or dimensional inaccuracies from the production process or from polishing was rejected. The specimens that were damaged during finishing, polishing, storage, and laboratory testing were not included in the study.

Standardized disc-shaped specimens (10 mm × 2 mm) were prepared from four different composite resin materials following the manufacturers' instructions. To achieve a uniform surface and reduce oxygen inhibition, a transparent Mylar strip and glass slide were positioned on either side of each mold prior to light curing. Polymerization was done by a calibrated LED curing unit having an output intensity of about 1200 mW/cm² and for the recommended time by the manufacturer. After polymerisation, all specimens were completed and polished with the same operator using a standard multi-step polishing system with constant water irrigation to reduce the effect of operator variability. The baseline surface roughness (Ra) of each specimen was measured with a contact surface profilometer, and baseline color values (L*, a*, and b*) in accordance with the CIE LAB color system were recorded with a calibrated digital spectrophotometer. Three readings were taken of each specimen, and the mean was recorded to reduce error in measurement.

The specimens of each composite group were randomly assigned to the immersion solutions: distilled water (control), tea, coffee, and carbonated soft drink. New drinks were made every day on a standard formula to ensure consistency. Each specimen was placed in a separate container and filled with 20 mL of each of the different beverages and then placed in an incubator at 37°C for the period of immersion. The media in which the sample was immersed was changed every 24 hours to simulate the drinking of beverages over a day. After the end of the immersion period, the specimens were washed extensively with distilled water, then dried gently with absorbent paper and finally measured for their surface roughness and colour. Colour change (ΔE) was determined using the CIE Lab* formula between baseline and post-immersion colour coordinates.

The collected data was entered and analyzed by IBM SPSS Statistics 27.0 (IBM Corp., Armonk, NY, USA). The quantitative variables, such as the surface roughness (Ra) and color change (ΔE), were reported as mean ± standard deviation, while the categorical variables were reported as frequencies and percentages when appropriate. The normality of the data was evaluated by the Shapiro–Wilk test. One-way analysis of variance (ANOVA) was used to compare the mean surface roughness and color stability between various composite resin materials and immersion beverages, with Tukey's post hoc test for individual means comparisons, where appropriate, for normally distributed data. Within-group comparisons of baseline and post-immersion data were made using a paired t-test. The Kruskal–Wallis test, followed by Dunn's post hoc analysis, was used for data that did not conform to a normal distribution. To assess the interaction effect of the composite resin type and beverage type on both outcome measures, a two-way ANOVA was also conducted. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

A total of 80 composite resin specimens, equally distributed among four composite resin materials (nanohybrid, nanofilled, bulk-fill, and supra-nano spherical composites), and 20 specimens in each of the beverage groups were included in the study. The baseline assessment showed that there were no statistically significant differences in terms of surface roughness (Ra) or baseline color coordinates (L*, a*, and b*) between the composite resin materials, suggesting that they shared similar initial characteristics before immersion (Tables 1 and 2). Immersion in all drinks resulted in increased surface roughness, but this was not significantly different from the pre-immersion value for the distilled water group ($p=0.152$), but was for tea ($p<0.001$), coffee ($p<0.001$), and carbonated soft drinks ($p<0.001$). Among the beverages, carbonated soft drinks resulted in the greatest increase in surface roughness, followed by coffee and tea. (Table 3)

There was a significant difference in color stability between the various immersion beverages ($p<0.001$, $F=54.83$). The coffee showed the largest colour change ($\Delta E=5.78\pm1.02$), followed by carbonated soft drink and tea with small colour change, and distilled water showed very small colour change. The differences among all beverage groups were statistically significant as confirmed by post hoc analysis (Table 4). There were significant differences among composite resin materials when comparing surface degradation and discoloration after beverage exposure. The mean surface roughness and color change were the lowest for the supra-nano spherical composite, followed by the microhybrid composite, all of which showed a degree of surface roughness and color change significantly lower than that of the bulk-fill composite ($p<0.001$). (Table 5)

Two-way ANOVA revealed that the surface roughness and color stability of the composite resins were significantly different for beverage type ($p<0.001$) and composite resin type ($p<0.001$). Additionally, the composite material by beverage type interaction was significant for both outcomes, suggesting that the amounts of surface degradation and discoloration were dependent on the combination of restorative material and beverage.

The Shapiro–Wilk test showed normal distribution of the study variables, which justified the use of parametric statistical tests. (Tables 6 and 7).

Table 1. Distribution of Composite Resin Specimens According to Material Type and Beverage Exposure (N = 80)

Variable	Category	n (%)
Composite resin type	Nanohybrid composite	20 (25.0)
	Nanofilled composite	20 (25.0)
	Bulk-fill composite	20 (25.0)
	Supra-nano spherical composite	20 (25.0)
Immersion beverage	Distilled water (Control)	20 (25.0)
	Tea	20 (25.0)
	Coffee	20 (25.0)
	Carbonated soft drink	20 (25.0)

Table 2. Baseline Surface Roughness (Ra, µm) and Color Parameters (L*, a*, b*) of Different Composite Resins Before Immersion (One-way ANOVA)

Composite Resin	Surface Roughness (Ra) Mean ± SD	L* Mean ± SD	a* Mean ± SD	b* Mean ± SD
Nanohybrid	0.14 ± 0.02	76.5 ± 1.8	1.15 ± 0.42	13.6 ± 0.9
Nanofilled	0.13 ± 0.02	76.8 ± 1.6	1.10 ± 0.39	13.5 ± 1.0
Bulk-fill	0.15 ± 0.03	76.2 ± 1.9	1.19 ± 0.36	13.8 ± 0.8
Supra-nano spherical	0.13 ± 0.02	76.9 ± 1.5	1.08 ± 0.40	13.4 ± 0.7
One-way ANOVA (p-value)	**0.214**	**0.482**	**0.738**	**0.564**

Table 3. Comparison of Surface Roughness (Ra, µm) Before and After Beverage Immersion (Paired t-test)

Beverage	Baseline Mean ± SD	Post-immersion Mean ± SD	Mean Difference	t-value	p-value
Distilled water	0.14 ± 0.02	0.15 ± 0.03	0.01	1.46	0.152
Tea	0.14 ± 0.03	0.23 ± 0.04	0.09	9.74	<0.001
Coffee	0.14 ± 0.02	0.26 ± 0.05	0.12	12.31	<0.001
Carbonated soft drink	0.14 ± 0.03	0.29 ± 0.05	0.15	15.47	<0.001

Table 4. Comparison of Color Change (ΔE) Among Different Beverage Groups (One-way ANOVA with Tukey Post-hoc Test)

Beverage	ΔE Mean ± SD	Tukey Post-hoc
Distilled water	0.92 ± 0.38	a
Tea	3.46 ± 0.81	b
Coffee	5.78 ± 1.02	c
Carbonated soft drink	4.29 ± 0.87	d
F-value	**54.83**	
p-value	**<0.001**	
Different superscript letters indicate statistically significant differences ($p < 0.05$).		

Table 5. Comparison of Surface Roughness and Color Stability Among Composite Resin Types After Immersion (One-way ANOVA)

Composite Resin	Surface Roughness (Ra) Mean ± SD	Color Change (ΔE) Mean ± SD
Nanohybrid	0.23 ± 0.05	3.98 ± 1.22
Nanofilled	0.20 ± 0.04	3.12 ± 1.05
Bulk-fill	0.27 ± 0.05	4.81 ± 1.18
Supra-nano spherical	0.19 ± 0.03	2.76 ± 0.94
F-value	**12.64**	**16.52**
p-value	**<0.001**	**<0.001**

Table 6. Two-way ANOVA Showing the Effect of Composite Resin Type and Beverage Type on Surface Roughness and Color Stability

Source of Variation	Surface Roughness (Ra) F (p-value)	Color Change (ΔE) F (p-value)
Composite resin type	12.64 (<0.001)	16.52 (<0.001)
Beverage type	48.29 (<0.001)	54.83 (<0.001)
Composite × Beverage interaction	4.91 (0.002)	6.18 (<0.001)

DISCUSSION

The present in vitro study aimed to assess the surface roughness and color stability of various composite resin materials in response to commonly consumed beverages. The results showed that immersing in staining and acid drinks caused a marked increase in surface roughness and surface colour compared to distilled water. The most discolored coffee and the most surface roughened by a carbonated soft drink. Moreover, the tested composite resins were found to differ greatly in terms of resistance to surface degradation and discoloration, with the supra-nano spherical composite demonstrating the highest resistance, while the bulk-fill resin had the lowest resistance. Both the composition of restorative material and the type of beverage can affect the long-term esthetic performance of composite restorations, as indicated by these findings.

The results of the present study are similar to those of Özyurt and Kurt (2021), which showed that both surface roughness and surface discoloration of composite resin materials were significantly higher after being soaked in coffee and acidic beverages, which caused degradation of the resin matrix and loss of fillers. The beverages with low pH and high chromogenic content had a negative impact on restorative materials, as well as the results of the present study.[22]

Similarly, Chowdhury et al. (2021) assessed the effect of tea, coffee, and Coca-Cola on nanohybrid composite resin and found that significant surface roughness and colour change occurred after immersion. They found a similar trend, as surface roughness rose as a function of increasing beverage exposure, and that surface roughness was positively correlated with discoloration, consistent with the current findings.[23]

Similar findings were reported by Narayan et al. (2023) after exposing various nanohybrid composites to coffee and chlorhexidine. They determined that the coffee resulted in a much greater colour change and surface roughness than the control solution, and that composites with better filler technology had greater resistance to staining. The better performance of the supra-nano spherical composite in the present study could be attributed to optimized dispersion of the filler and the smoother polished surface.[24]

Additionally, the results were confirmed by Fidan and Çankaya (2025), who studied the effect of food-simulating liquids on microhybrid and nanohybrid composite resins. They said the nanohybrid composites showed significantly greater color stability than the conventional composites, indicating that the composition of the fillers and the quality of polishing are highly important factors in determining stain resistance.[25] This is in line with the current results showing that surface roughness and color stability were significantly affected by composite composition.

Similarly, Meniawi et al. (2025) evaluated the color stability and surface morphology of universal composite resins and found that modern universal composites with new filler technology had lower surface roughness and color stability than conventional composite materials. The results they report corroborate the current study's observations of the superior performance of the supra-nano spherical composite.[26]

More recently, Abd-Elfattah et al. (2026) evaluated flowable nanohybrid composites following 14-day immersion in coffee, cola and energy drinks. After soaking in all the staining beverages, they noted high levels of surface roughness and a decrease in color stability after the beverages were coffee and energy drinks. Their conclusions are very much supported by the present results, however, the present study went beyond the comparison of flowable composites and looked at other types of restoratives.[27]

In the same manner, Yılmaz et al. (2026) found that surface roughness, color change and bacterial adhesion were significantly higher in nanohybrid and microhybrid composites that were filled with coffee and cola. They also found that, in general, nanohybrid materials were more resistant than microhybrid materials due to smaller filler particle sizes and a better polishability of their surface.[28] The results of the present study are supported by the observation that composite composition had a significant effect on esthetic degradation following beverage exposure.

The strong interaction between composite type and beverage type found in the present study is biologically plausible due to the differences in the composition of the resin matrix, filler loading, filler size, and degree of conversion found among the various composite materials. Acidic beverages make the resin matrix soft and permit the dislodging of the filler

particles, while chromogenic beverages with tannins and pigments penetrate the resin matrix and take up on roughened surfaces. Materials that tend to have a lower water sorption, higher filler loading, and better polish retention should have better resistance to roughness and discoloration, which is what the supra-nano spherical composite shows.

While there are some differences in the degree of discoloration or roughness induced by different beverages due to the different immersion protocols, beverage composition, composite formulations, and evaluation methods, it is generally accepted that frequent exposure to staining and acidic drinks markedly affects the surface integrity and esthetic stability of composite restorations. The results of this study underscore the need to use more stain-resistant restorative materials and to inform patients of the influence of food on the durability and visual quality of composite restorations.

There were a few limitations of this study. The study was in vitro and was not able to completely replicate the complex oral environment that can affect the breakdown of restorative materials due to the presence of other factors such as buffering by the saliva, temperature changes, mastication, oral hygiene, enzymatic activity, and biofilm formation. The immersion protocol was continuous and not intermittent drinks as seen in clinical practice. The evaluation was restricted to four commonly consumed beverages and four composite resin materials, restricting the generalizability to other restorative materials and dietary agents. Furthermore, the study tested only the changes in surface roughness and color stability after short-term changes, and it did not examine long-term changes or mechanical wear and the effects of repeated polishing procedures. Further studies with artificial saliva, tooth brushing simulation, thermocycling, and longer aging time are suggested to better replicate clinical conditions.

CONCLUSION

The color stability and surface roughness of composite resin restorations were highly influenced by exposure to beverages commonly consumed in the community. Coffee caused the most discoloration, while carbonated soft drinks caused the greatest increase in surface roughness. The results showed that significant differences existed between the tested composite resins, in that the supra-nano spherical composite demonstrated the highest resistance to surface degradation and color change, whereas the bulk-fill composite exhibited the lowest resistance. The results of this study showed that the esthetic performance of long-term composite restorations is affected by both the composition of the restorative material and the patients' drinking habits. Choosing stain-resistant composite materials, combined with proper dietary counseling, could positively enhance the longevity of the restoration and patient satisfaction.

REFERENCES

1. Bompolaki, D., E.B. Lubisich, and A.P. Fugolin, Resin-based composites for direct and indirect restorations: clinical applications, recent advances, and future trends. Dental Clinics, 2022. 66(4): p. 517-536.
2. Bingül, A., et al., A Review: Resin-Based Dental Materials and Their Characterization. Polymers for Advanced Technologies, 2025. 36(6): p. e70239.
3. Ferracane, J.L., A historical perspective on dental composite restorative materials. Journal of Functional Biomaterials, 2024. 15(7): p. 173.
4. Srimaneepong, V., et al., Fixed prosthetic restorations and periodontal health: a narrative review. Journal of functional biomaterials, 2022. 13(1): p. 15.
5. Demarco, F.F., et al., Longevity of composite restorations is definitely not only about materials. Dental Materials, 2023. 39(1): p. 1-12.
6. Suryawanshi, A. and N. Behera, Dental composite resin: a review of major mechanical properties, measurements and its influencing factors. Materialwissenschaft Und Werkstofftechnik, 2022. 53(5): p. 617-635.
7. Mavrogiannidou, Z., V. Boka, and A. Arhakis, An overview of the types of soft drinks and their impact on oral health: review of literature. World Journal of Dentistry, 2023. 14(7): p. 648-654.
8. Inchingolo, A.M., et al., Damage from carbonated soft drinks on enamel: a systematic review. Nutrients, 2023. 15(7): p. 1785.
9. Floare, L., et al., Multimodal and Advanced Characterization of Dental Resin Composites: Insights into Beverage-Induced Degradation. Journal of Clinical Medicine, 2025. 14(12): p. 4080.
10. Silva, E.A., et al., Impact of high-consumption beverages on the color, and surface roughness and microhardness of resin-matrix ceramics. Dent Med Probl, 2025. 62(2): p. 299-307.
11. Alenezi, A.Y., et al., Color Stability of Tooth-Colored Restorative Materials After Exposure to Arabic Coffee and Black Tea: A Systematic Review. Cureus, 2025. 17(9).
12. Osman, M.A., et al., Biological response of epithelial and connective tissue cells to titanium surfaces with different ranges of roughness: An in-vitro study. Dental Materials, 2022. 38(11): p. 1777-1788.
13. Papa, S., et al., Key topographic parameters driving surface adhesion of Porphyromonas gingivalis. Scientific Reports, 2023. 13(1): p. 15893.
14. Mahrous, A.I., et al., Color stability of two different resin matrix ceramics: randomized clinical trial. BMC Oral Health, 2023. 23(1): p. 665.

15. Huang, W., Factors influencing color match of monochromatic resin composites: a narrative review. Frontiers in Dental Medicine, 2025. 6: p. 1742283.
16. Faris, T.M., et al., In vitro evaluation of dental color stability using various aesthetic restorative materials after immersion in different drinks. BMC Oral Health, 2023. 23(1): p. 49.
17. Alomran, W.K., et al., Evolution of dental resin adhesives—a comprehensive review. Journal of Functional Biomaterials, 2025. 16(3): p. 104.
18. Mendes, L.T., et al., Risk of failure of repaired versus replaced defective direct restorations in permanent teeth: a systematic review and meta-analysis. Clinical oral investigations, 2022. 26(7): p. 4917-4927.
19. Grachev, D.I., et al., New assessment model of financing treatment of patients with complete tooth loss. Emerging science journal, 2024. 5: p. 1898-1916.
20. Alqahtani, A.A.M., et al., Discoloration of Different Aesthetic Restorative Materials: Effects of Various Finishing Systems on Surface Roughness and Staining Susceptibility. Journal of International Crisis and Risk Communication Research, 2024. 7(S6): p. 570.
21. Alrashidi, A.S., et al., Spectrophotometric Evaluation of the Color Stability of Nanofilled Composites With and Without a Dentin Bonding Agent as a Surface Sealer Following Exposure to Common Beverages. Cureus, 2024. 16(11).
22. Özyurt, E. and A. Kurt, Effect of different beverages on color stability and surface properties of composite resin materials. Color Research & Application, 2021. 46(6): p. 1382-1391.
23. Chowdhury, D., et al., Comparative evaluation of surface roughness and color stability of nanohybrid composite resin after periodic exposure to tea, coffee, and Coca-cola–An in vitro profilometric and image analysis study. Journal of Conservative Dentistry: JCD, 2021. 23(4): p. 395.
24. Shah, N.N.M., et al., EXPLORING THE USES, STERILIZATION AND STORAGE PROTOCOLS OF EXTRACTED HUMAN TEETH FOR RESEARCH ADVANCEMENTS: A SCOPING REVIEW: Received 2024-02-21; Accepted 2024-03-04; Published 2024-03-25. Journal of Health and Translational Medicine (JUMMEC), 2024: p. 215-245.
25. Fidan, M. and N. Çankaya, Effect of food-simulating liquids and polishing times on the color stability of microhybrid and nanohybrid resin composites. Discover Nano, 2025. 20(1): p. 43.
26. Meniawi, M., N. Şirinsükan, and E. Can, Color stability, surface roughness, and surface morphology of universal composites. Odontology, 2026. 114(1): p. 149-160.
27. Abd-Elfattah, H.Y., M.E. Elawsya, and A.E. ElEmbaby, Effect of immersion in different media on the color stability, surface roughness, and microhardness of flowable nanohybrid resin composites. BMC Oral Health, 2026.
28. Yılmaz, E., et al., Investigation of the effects of different beverages on color change, surface roughness, and bacterial adhesion of nanohybrid and microhybrid composites. BMC Oral Health, 2026.

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