Exploring the Role of Mouthwash Constituents in Altering Dental Composite Microhardness and color stability: An in-vitro study

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Abstract

Background: Mouthwashes have been used to improve gingiva health, owing to their anti-bacterial and fresh effects on the oral cavity. The interactions between mouthwash additives and these composites may impact the hardness, color stability, and overall functionality of restorative materials. **Objective:** The purpose of this study was to determine how three different commercially available mouthwashes affect the toughness and color stability of two different resin-based composite restorative materials, Bulkfil and Nanohybrid. **Materials and Methods**: The study involved testing two different a polymer-based resin dental composites (RBC): Bulkfill Restorative (3M/ Filtek, ESPE,A2, USA) and Nano Hybrid Universal Restorant (3M/1 Filtek 250 XT), which are available in the United States. The specimens were divided into three subgroups (n = 9) of each composite for testing with different mouthwash additives later. Each cycle consisted of complete immersion in a mouthwash for 21 minutes (equivalent to 3 weeks of use) followed by immersion in saliva for 12 hours at 37˚C. **Results:** The results showed that color stability (ΔE) of both composites affected significantly ($p < 0.05$), while the micro hardness test didn't show significant alteration after immersion cycle ($p > 005$). **Conclusion:** Within limitation of present study, it can be concluded that despite the color stability of the composites being affected by mouthwash, surface hardness remains substantially unaffected. The results of the current study may help dentists advise patients who have restorations on the best oral hygiene products to use, extending the life and durability of the dental work.

Keywords: mouthwashes, composites, color stability, micro-hardness

Introduction

Resin-based composites are widely used in restorative dentistry due to their polymeric matrix, filler particles, and organo silane coupling agent. They are categorized into hybrid (0.5-3 um), microhybrid (0.4-1 um), and microfilled (0.04-0.4 um) based on filler particle system. These materials offer durable, aesthetically pleasing alternatives to traditional amalgam fillings and are revolutionized by advancements in resin-matrix composites.[1] In the oral cavity, various stains can affect resin composite restorations.[2,3] The two types of discoloration are typically internal and external. Internal discoloration of resin composites is caused by physical and chemical reactions in the innermost layers of the resin composite, whereas external discoloration is primarily caused by consumption of coloring agents from various sources, such as food, beverages, smoking, and frequent use of mouthwashes.[4,5]

Mouthrinses are aqueous solutions containing salts, hydrogen peroxides, antimicrobial agents, pigments, emulsifiers, solvents, acids, and alcohol. They offer benefits like plaque reduction, fresh breath, and oral hygiene. They come in various flavors to enhance user experience and encourage regular use.[6, 7] However, dental health is not only influenced by oral hygiene practices but also by the hardness and resilience of dental materials used in restorations. A vital component of oral health, dental hardness is crucial to the longevity and toughness of dental restorations.[8] Hardness is a key indicator of a material's resistance to surface penetration or persistent indentation.[9, 10]

In order to maximize oral health and extend the life of restorations, it is crucial to understand the elements that influence the hardness of dental materials.[11] Several ingredients in mouthwash, which is frequently used in oral hygiene regimens, might interact with dental materials.[12] Chlorhexidine is a well-liked antibacterial ingredient in mouthwashes because of its superior plaque-controlling abilities.[13] The absorbent qualities of activated charcoal, a recent addition to dental hygiene products, are well known, as are any potential whitening effects.[14] Because of its calming effect on oral tissues and probable antibacterial capabilities, sodium chloride, also known as common salt, is utilized in oral rinses.[15] Although each element is good for your mouth, they can all have different effects on how hard dental composites are.[16]

Dental composites are available in a variety of forms, each with specific qualities and utilized mostly in restorative dentistry.[17] A bulk-fill composite called Bulkfil is renowned for its simplicity of use and capacity to fill cavities in smaller increments, making the filling process easier.[18] Nanohybrid composites, on the other hand, offer a balance between aesthetic appeal, durability, and wear resistance to a combination of nano-sized particles and conventional filler particles.[19]

The interactions between mouthwash additives and these composites may have an impact on their hardness, color stability, and overall functionality as restorative materials.[20] The goal of this study is to determine how three distinct mouthwash additives—chlorhexidine, activated charcoal, and sodium fluoride affect the toughness and color stability of two different dental composites, Bulkfil and Nanohybrid.[21] The findings of this study may help dentists advise patients who have restorations on the best oral hygiene products to use, extending the life and durability of the dental work.

2. Material and Methods

2.1. Specimen Preparation and Grouping

The experiments involved testing two different a polymer-based resin dental composites (RBC): Bulk fill restorative (3M/ Filtek, ESPE,A2, USA), Nano Hybrid Universal Restorative (3M/ Filtek, ESPE,A2, USA). A total of 54 specimens were created using these RBCs. Each material had 27 specimens produced over an (8 mm) diameter and (4 mm) thickness metal ring placed over a celluloid band. To ensure smoothness and removing excess of composites a glass slide was utilized. The RBCs were polymerized with LED light (VALO Cordless, Ultradent Products, South Jordan, Utah, USA) for 20 seconds and light intensity was 1000 mW/cm^2 as per the manufacturer's instructions, the distance of curing tip from specimens was 1mm standardized by using a glass slide. The specimens were then polished using EVE polishing discs (ECOCOMP, RA 210, Germany) to remove any surface imperfections. For protection from dehydration, the specimens were subsequently placed in sterile boxes to be ready for hardness and color stability test.

The specimens were divided into three subgroups (n = 9) of each composite for testing with different mouthwashes later. three alcohol-free mouthwashes were used: Chlorhexidine (Wisdom, England, Bulgaria), Fresh Effect (Wisdom, England, Bulgaria), Active Whitening (Wisdom, England, Bulgaria). Details of the materials been used can be found in Table 1.

2.2. Color Stability and microhardness tests (baseline)

The initial colorimetric properties of the specimens were assessed using a spectrophotometer. A digital spectrophotometer, specifically the Vita Easyshade Compact Advance 4.0 from Vita Zahnfabrik in Bad Sackingen, Germany, was employed for color measurements. The measurements were conducted using standard illuminant based on the guidelines of the Commission Internationale d'Eclairage (CIELab) using the white baseline as a reference. The degree of color was recorded within the three-dimensional CIELab system, which includes color spaces such as white-black (L*), red-green (a*), and blue-yellow (b*).[22]

Following color stability test, the Digital Vickers hardness tester (T TEST, ZL-107B model, China) was used to determine the initial surface microhardness of each specimen by applying 300-gram load within a 15 seconds dwell time, three indentations were made on each specimen. The two diagonals of each indentation were measured by a scale microscope (under 40X magnifications). The average surface microhardness value was then calculated for each specimen.

2.3. The Protocol of Immersion

The specimens were subjected to immersion cycles in the mouthwashes and artificial saliva, with the daily dose (20 mL) and duration (1 minute) determined according to the manufacturer's recommendations. Each cycle consisted of complete immersion in a mouthwash for 21 minutes (equivalent to 3 weeks of use) followed by immersion in saliva for 12 hours at 37°C. This cycle was repeated 8 times, simulating 6 months of continuous use.[23] At the end of each cycle, the specimens were once again evaluated for microhardness and colorimetric measurements using same protocol. the color differences were reported as tristimulus values (ΔL, Δa, and Δb) based on CIELab colour scale. Then, the colorimetric changes (ΔE*) were evaluated according the following formula.[22]

$\Delta E = \sqrt[2]{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2}$ the Values of ΔE* ≥3.3 considered clinically unacceptable.[24]

Table 1: Materials used in this study

Materials	Manufactures	Compositions
Bulk fill restorative	3M/ Filtek, ESPE, A2, USA	Filler: 10-20 Nanometers 76.5% By Weight, MATRIX: AUDMA, AFM, UDMA, DDMA

Nano Hybrid Universal Restorative	3M/ Filtek Z250 XT, ESPE, A2, USA.	**Filler:** Silica particle 20 nm and Zirconia/Silica particle 10-0.1 microns (%67.8 by volume) **Matrix:** BIS-GMA, UDMA, BIS-EMA, PEGDMA and TEGDMA
Chlorhexidine/	Wisdom,England, Bulgaria	Aroma, Limonene, Sodium Saccharin, Aqua, Glycerin, PEG-40 Hydrogenated Castor Oil, 0.2% Chlorhexidine Digluconate. Alcohol free
Fresh Effect	Wisdom,England, Bulgaria	Sodium Fluoride 0.05% w/w (225 ppm F). Ingredients: Aqua, Glycerin, PEG-40 Hydrogenated Castor Oil, Sodium Saccharin, Aroma, Sodium Benzoate, Sodium 0941287 14:20 Phosphate Cetylpyridinium Chloride, Sodium Fluoride, Phosphoric Acid, CI 42051, Limonene. Alcohol free
Active Whitening	Wisdom,England, Bulgaria	Aqua, PEG-40 Hydrogenated Castor Oil, Charcoal Powder, Aroma, Zinc Ricinoleate, Tetrasodium Glutamate Diacetate, Propanediol, Sodium Saccharin, Sodium Fluoride, 2-Bromo-2-Nitropropane-1,3-Diol, Eugenol, Limonene, Linalool. Alcohol free
Artificial Saliva	KIN /Spain	Aqua, Peg-40 Hydrogenated Castor Oil, Xylitol, Sodium Saccharin, Sodium Methylparaben, Potassium Chloride, Aroma, Citric Acid, Potassium Phosphate, Menthol, Sodium Ethylparaben, Calcium Chloride, Sodium Chloride, 2-Bromo-2-Nitropropane-1, 3-Diol, Sodium Propylparaben, Potassium Thiocyanate, Magnesium Chloride,

Abbreviations: Bis-EMA, ethoxylated bisphenol A diglycidyl dimethacrylate; Bis-GMA, bisphenol A diglycidyl ether dimethacryalate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

2.4. Statistical Analysis

Statistical analyses of the data were performed using the Statistical Package for the Social Sciences, version 25 for windows (SPSS, IBM, New York, NY, USA). The comparison of the mean values between groups for microhardness, and color change (ΔE) was performed using non-parametric statistical hypothesis The Wilcoxon test. The significance level was set at $p \leq 0.05$

3. Results

Statistical results of this study revealed notable differences in the mean and standard deviations of ΔE among the RBC groups, as shown in Figure 1. Bulkfill and Nanohybrid groups differed statistically significantly in their immersion times before and after immersion (P= 0.001). According to these findings, immersion affected both groups during the experimental period, indicating changes in their color occurred.

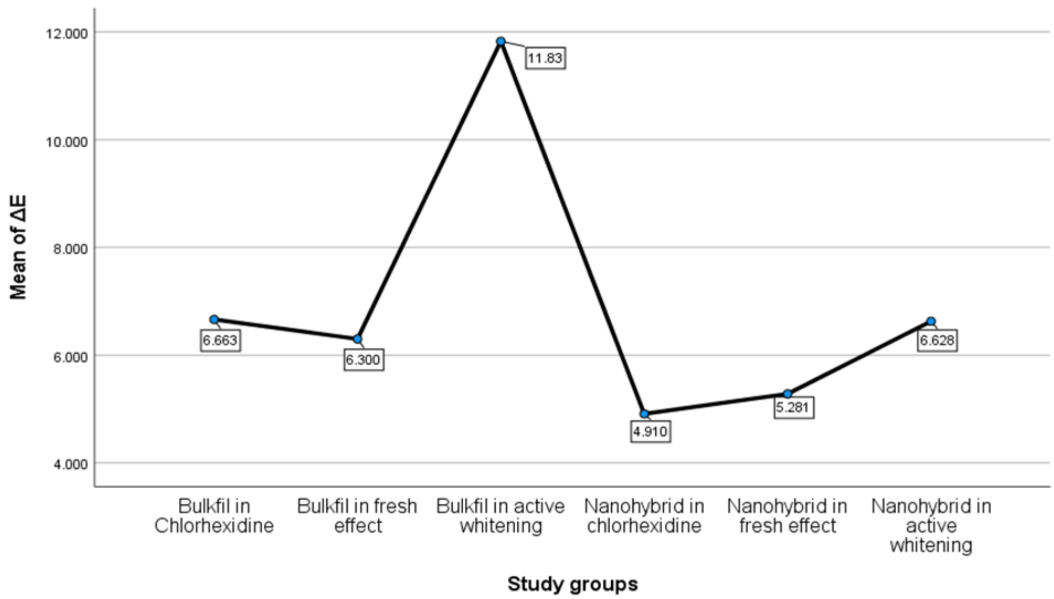

Figure 1: The mean of RBCs (ΔE) values at the end of the mouthwash immersion time

While, Table 2 presents the mean Vickers microhardness values obtained before and after immersion in solutions of both bulkfill and nanohybrid composites. The results revealed that there was no significant interaction between the tested solutions and the tested materials ($P > 0.05$). Looking at the specific values in the table, it can be observed that microhardness values for the composites was different before and after immersion in the mouthwash solutions. However, these differences were not statistically significant, as indicated by the p-values above 0.05. Before immersion in Chlorhexidine, the mean microhardness values for Bulkfill and Nanohybrid composites were 73.837 and 101.288, respectively.

Table 2: Mean and standard deviation of Vickers microhardness test of RBCs before and after immersion in the mouthwashes.

Materials	**Bulkfill**			**Nanohybrid**		
	Mean	Std. Deviation	p-value	Mean	Std. Deviation	p-value
Before Chlorhexidine	73.837	7.796	0.598	101.288	7.135	0.062
After Chlorhexidine	72.614	8.919		110.311	15.722	
Before Fresh Effect	74.903	3.864	0.706	105.570	6.489	0.220

After Fresh Effect	75.711	5.950		109.996	11.361	
Before Active Whitening	77.985	5.346	0.775	101.322	3.829	0.322
After Active Whitening	77.548	4.235		104.074	9.010	
Total	27			27		

4. Discussion

The current study assessed how three commercially available mouthwashes affected two different resin-based composite restorative materials regarding microhardness and their ability to maintain their color before and after immersion cycle. The current study's findings indicate that the null hypothesis tested was only partially rejected because daily use of mouthwashes increased a significant change in their color, while the hardness of dental composites remained unchanged.

Color stability can be evaluated visually or by using spectrophotometry and the CIE ΔL, Δb, Δa system.[25.26] This methodology is suitable for small color changes determination and offers advantages like repeatability, sensitivity, and objectivity. Previous studies used spectrophotometry for color variation evaluation.[27] Clinical detection is possible for ΔE values greater than 2. A ΔE value between 3 and 3.3 is considered clinically acceptable by Ruyter et al.,[24] Clinically acceptable variations for the Commissioned Corps of the United States Public Health Service's Healthy Lifestyles Program range between 2.2 and 4.4, though they may be higher depending on the study.[28] Figure 1 shows that the composite resins tested in this study had higher ΔE values. A higher ΔE value typically corresponds to a greater color change upto 11.83, which is bulkfil in active whitening and lowest of nanohybrid in chlorhexidine 4.90, indicating a potential discoloration or alteration of the composite material.

However, in all mouthwashes, the bulk fill composite displayed a higher color change than nanohybrid. The same outcomes were established by Khokhar et al., (1991) According to reports, resin-based materials using urethane dimethacrylate, are more stable than the others due to their lower viscosity. and water sorption qualities, resulting in more color stability.[29] This explained why bulkfill composite shows higher color changes comparing to nanohybrid in the current study. Same results were found in other studies, in which it reported that the water sorption of composite resins is affected by the resinous matrix composition. Water uptake in Bis-GMA-based composite resins increased from 3 to 6% as the amount of TEGDMA grew from 0 to 1%.[30] UDMA appears to be more stain resistant than Bis-GMA, and under normal curing circumstances, UDMA-based composite resins demonstrated reduced water sorption and higher color stability than other dimethacrylates in their resin matrix.[23] In addition, Light spreads more widely with larger filler particles, resulting in greater opacity. The smaller the filler particle, the less water is absorbed by the polymer network, resulting in less degradation of the interface matrix/particle and, therefore, less color change. Filler particles in the nanohybrid range in size from 0.1 m to 10 nm, whereas filler particles in the bulkfill range from 10 nm to 20 nm, explaining why nanohybrid is more color stable than bulkfiller composite.[23,31]

To imitate the continual washing effect of the oral cavity and to hydrate RBC specimens, artificial saliva was utilized. After the artificial saliva procedure, the specimens were immersed in the mouthwashes according to the in vitro model proposed by ArmasVega et al., who suggested that the specimens were subjected to immersion cycles in the mouthwashes tested and artificial saliva, with each cycle consisting of complete immersion in a mouthwash for 21 min (equivalent to 3 weeks of use) and then in saliva for 12 h straight.[32] Composite filler leaching was shown to be considerably higher in artificial saliva than in pure water. Furthermore, artificial saliva was used in the current investigation to deposit a pellicle layer. Saliva and the ensuing accumulation of pellicles act as a matrix for stain deposition, which can cause discoloration.[33]

Clinical success and long-term performance of dental composite restorations are affected by chemical and thermal factors. It is important to note that chemical factors play a significant role in the degradation of surface composite resins.[34] Chemical degradation affects surface roughness and microhardness.[35] The current study's findings indicate that there were no significant differences in the microhardness of the composites before and after immersion in mouthwashes. After immersion, the values decreased slightly to 72.614 for Bulkfill and increased to 110.311 for Nanohybrid. However, the p-values for these comparisons were 0.598 and 0.062, respectively, indicating no significant differences. Similar patterns can be observed for the other mouthwash solutions (Fresh Effect and Active Whitening). The mean microhardness values varied before and after immersion, but the p-values for these comparisons were all above 0.05, suggesting no significant effects.

Overall, based on these results, it can be concluded that the immersion of Bulkfill and Nanohybrid composites in the tested mouthwash solutions did not have a significant impact on their microhardness values. One possible explanation for the lack of change is that the immersion cycle used in the study, which corresponds to six months of mouthwash use, was insufficient to cause any discernible changes in the hardness of the composites. Besides in this study all three mouthwashes that were use were alcohol-free which explain that why they didn't have significant effect on surface hardness of both composites. It is worth noting that many other studies have used longer immersion times to assess the effect of mouthwashes on composite hardness, also they stated that alcohol containing mouthwashes had determinant effect on hardness of dental composites.[36,37,41] These studies most likely allowed for longer exposure to the mouthwash, which may have resulted in observable changes in the hardness of the composites. Same results were found in other study.[38]

In a study by Hamdy et al., examined the effect of different mouthwashes on the surface microhardness and color stability of dental nanohybrid resin composite. Concluded that Despite being acidic, there was no significant difference in the microhardness of resin composite between CHX and Green Tea mouthwashes and that immersed in artificial saliva.[39] This acidic PH was not thought to be a significant factor influencing resin composite surface degradation.[40, 42] As a result, the chemical composition of the mouthwash may be a more effective factor influencing the resin composite microhardness than its PH. The previous studies on microhardness supported the results of current study.[43,44]

According to the study findings, mouthwashes have a substantial impact on the color stability of dental composites. The surface microhardness of the composites, however, appears to be unchanged. This study emphasizes the need for additional research and the execution of longer-term procedures to better understand the effects of mouthwashes on the color stability and surface microhardness of dental composites.

5. Conclusion

Within limitation of present study, it can be concluded that despite the color stability of the composites being affected by mouthwash, surface hardness remains substantially unaffected.

References

1. Ferracane JL. Resin composite—State of the art Dental Materials 2011;27(1) 29-38.
2. Paolone, G.; Formiga, S.; De Palma, F.; Abbruzzese, L.; Chirico, L.; Scolavino, S.; Goracci, C.; Cantatore, G.; Vichi, A. Color Stability of Resin-Based Composites: Staining Procedures with Liquids—A **Narrative** Review. J. Esthet. Restor. Dent. **2022**, 34, 865–887.
3. Paolone, G.; Pavan, F.; Mandurino, M.; Baldani, S.; Guglielmi, P.C.; Scotti, N.; Cantatore, G.; Vichi, A. Color Stability of Resin-Based Composites Exposed to Smoke. A Systematic Review. J. Esthet. Restor. Dent. **2023**, 1, 1–13.
4. Ardu, S.; Duc, O.; Di Bella, E.; Krejci, I.; Daher, R. Color Stability of Different Composite Resins after Polishing. Odontology **2018**, 106, 328–333.
5. Nasoohi, N.; Hadian, M.; Hoorizad, M.; Hashemi, S.; Naziri saeed, S. In-Vitro Effect of Alcohol and Non-Alcohol Mouthwash on Color Change of Two Types of Bleach Shade Composite. J. Res. Dent. Maxillofac. Sci. **2019**, 4, 1–6.
6. Moran JM. Chemical plaque control—Prevention for the masses. Periodontology 2000. 1997;15 109-117.
7. Moran JM. Home-use oral hygiene products: Mouthrinses Periodontology 2000. 2008; 48 42-53.
8. Al-Ahmari MM, Alzahrani AH, Al-Qatarneh FA, Al Moaleem MM, Shariff M, Alqahtani SM et al., Effect of Miswak Derivatives on Color Changes and Mechanical Properties of Polymer-Based Computer-Aided Design and Computer-Aided Manufactured (CAD/CAM) Dental Ceramic Materials. Med Sci Monit. 2022 Jun 17;28:e936892. doi: 10.12659/MSM.936892. PMID: 35711131; PMCID: PMC9210947.
9. Arabia Js, "The Effect Of Different Pediatric Medications On Selected Physical Properties Of Different Restorative Materials." King Abdulaziz University Jeddah-Saudi Arabia, 2020.
10. Balhuc S, Campian R, Labunet A, Negucioiu M, Buduru S, Kui A. "Dental applications of systems based on hydroxyapatite nanoparticles—an evidence-based update," *Crystals*, 2021;11 (6).p. 674.
11. Çelik ZC, Çubukçu CE, Batmaz SG, "Exploring the discoloration potential of Propolis extract and Morus nigra syrup on restorative dental composites: an in vitro study," *J. Heal. Sci. Med.*2023; 6 (2), pp. 289–293.
12. Chandki R, Kala M, Kumar KN, Brigit B, Banthia P, Banthia R. "'Nanodentistry': exploring the beauty of miniature," *J. Clin. Exp. Dent.*2012; 4, (2) p. e119
13. Fakhri E, Eslami H, Maroufi P, Pakdel F, Taghizadeh S, Ganbarov K et al., Chitosan biomaterials application in dentistry. Int J Biol Macromol. 2020 Nov 1;162:956-974. doi: 10.1016/j.ijbiomac.2020.06.211. Epub 2020 Jun 26. PMID: 32599234.
14. Forouzanfar A, Hasanpour P,Yazdandoust Y, Bagheri H, Mohammadipour HS, "Evaluating the Effect of Active Charcoal-Containing Toothpaste on Color Change, Microhardness, and Surface Roughness of Tooth Enamel and Resin Composite Restorative Materials," *Int. J. Dent.*2023; 1
15. Frencken JE, Peters MC, Manton DJ, Leal SC, Gordan VV, Eden E, "Minimal intervention dentistry for managing dental caries–a review: report of a FDI task group," *Int. Dent. J.* 2012; 62, (5), pp. 223–243.
16. Golfeshan F, Ajami S, Khalvandi Y, Mosaddad SA, Nematollahi H. "The Analysis of the Differences between the Influence of Herbal Mouthwashes and the Chlorhexidine Mouthwash on the Physical Characteristics of Orthodontic Acrylic Resin," *J. Biol. Res.*

*della Soc. Ital. di Biol. Sper.*2020; 93 (10).

17. Golfeshan F, Ajami S, Khalvandi Y, Mosaddad SA, Nematollahi H, "Influence of Herbal Mouthwashes and Chlorhexidine Mouthwash on the Physical Characteristics of Orthodontic Acrylic Resin.," *J. Biol. Res. della Soc. Ital. di Biol. Sper.*2020; 93 (1).
18. Gungor AS, Donmez N, Kahya DS, Siso SH, "Impact of a Surface Sealant Application on the Color Stability of a Nano-hybrid Composite Resin/Yuzey Ortucu Uygulamasinin Nano-hibrit Kompozit Rezinin Renk Stabilitesi Uzerindeki Etkisi.," *Bezmialem Sci.*, 2022; 10 (2), pp. 219–226.
19. Huang Y, Li H, Zhu CG, Zhou X, Wang H, Han Q et al., Anti-bacterial and anti-microbial aging effects of resin-based sealant modified by quaternary ammonium monomers. J Dent. 2021 Sep;112:103767. doi: 10.1016/j.jdent.2021.103767. Epub 2021 Aug 5. PMID: 34363889.
20. Jain S, Jain AP, Jain S, Gupta ON, Vaidya A, "Nanotechnology: An emerging area in the field of dentistry," *J Dent Sci* 2013; 10, pp. 1–9.
21. H. Kermanshah, E. Ahmadi, N. Rafeie, Rafizadeh S, Ranjbar Omrani L. Vickers micro-hardness study of the effect of fluoride mouthwash on two types of CAD/CAM ceramic materials erosion," *BMC Oral Health*, 2022; 22 (1), pp. 1–8.
22. Wyszecki, G., Stiles, W.S. Color Science Concepts and Methods, Quantitative Data and Formulae, 2nd Edn. 1982; New York, NY: John Wiley & Sons, Inc.
23. Celik T AC, Coban E, Ulker HE. Effects of mouthwashes on color stability and surface roughness of three different resin-based composites. Niger J Clin Pract. 2021; 24(4):555-560. doi: 10.4103/njcp.njcp_303_20. PMID: 33851678.
24. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987; 3:246-51.
25. Cruvinel DR, Garcia LF, Consani S, Pires-de-Souza FCP. Composites associated with pulp-protection material: color-stability analysis after accelerated artificial aging. Eur.J. Dent. 2010;4:6-11.
26. Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an in vitro study. Dent Mater. 1994;10:353-62.
27. Gürdal P, Akdeniz BG, Hakan Sen B. The effects of mouthrinses on microhardness and colour stability of aesthetic restorative materials. J Oral Rehabil. 2002;29:895-901.
28. Noie F, O'Keefe KL, Powers JM. Color stability of resin cements after accelerated aging. Int J Prosthodont. 1995;8:51-5.
29. Khokhar ZA, Razzoog ME, Yaman P. Color stability of restorative resins. Quintessence Int. 1991 Sep;22(9):733-7. PMID: 1946950.
30. Kalachandra S, Turner DT. Water sorption of polymethacrylate networks: bis-GMA/TEGDM copolymers. J Biomed Mater Res. 1987 Mar;21(3):329-38. doi: 10.1002/jbm.820210306. PMID: 2951387.
31. Festuccia MS, Garcia Lda F, Cruvinel DR, Pires-De-Souza Fde C. Color stability, surface roughness and microhardness of composites submitted to mouthrinsing action. J Appl Oral Sci. 2012 Mar-Apr;20(2):200-5. doi: 10.1590/s1678-77572012000200013. PMID: 22666837; PMCID: PMC3894763.
32. Armas‑ Vega A, Casanova‑ Obando P, Taboada‑ Alvear MF, Aldas‑ Ramirez JE, Montero‑ Oleas N, Viteri‑ Garcia A. Effect of mouthwashes on the integrity of composite resin and resin modified glass ionomer: In vitro study. J Clin Exp Dent 2019;11:179‑ 84.

33. Bagis B, Baltacioglu E, Özcan M, Ustaomer S. Evaluation of chlorhexidine gluconate mouthrinse-induced staining using a digital colorimeter: an in vivo study. Quintessence Int. 2011 Mar;42(3):213-23. PMID: 21465008.
34. Yap AU, Wattanapayungkul P, Chung SM. Influence of the polymerization process on composite resistance to chemical degradation by food-simulating liquids. Oper Dent 2003; 28: 723-727.
35. Lee YK, Lu H, Oguri M, Powers JM. Changes in gloss after simulated generalized wear of composite resins. J Prosthet Dent 2005; 94: 370-376.
36. DA Silva MA, Vitti RP, Sinhoreti MA, Consani RL, Silva-Júnior JG, Tonholo J. Effect of alcoholic beverages on surface roughness and microhardness of dental composites. Dent Mater J. 2016;35(4):621-6. doi: 10.4012/dmj.2015-383. PMID: 27477228.
37. Al-Saud LM, Alolyet LM, Alenezi DS. The Effects of Selected Mouthwashes on the Surface Microhardness of a Single-shade Universal Resin Composite: In Vitro Study. Journal of Advanced Oral Research. 2022;13(2):234-244
38. Ashish Pandey*, Saurabh Dhanraj Yadav, Priyanka Tiwari and Shubham Godhani. "To Assess the Effect of Mouth Rinses on Surface Microhardness of Bulk-Fill Composite Resin". Acta Scientific Pharmacology 1.2, 2020; 14-16
39. Hamdy, T.M.; Abdelnabi, A.; Othman, M.S.; Bayoumi, R.E.; Abdelraouf, R.M. Effect of Different Mouthwashes on the Surface Microhardness and Color Stability of Dental Nanohybrid Resin Composite. *Polymers* 2023, *15*, 815.
40. Münchow, E.A.; Ferreira, A.C.A.; Machado, R.M.M.; Ramos, T.S.; Rodrigues-Junior, S.A.; Zanchi, C.H. Effect of Acidic Solutions on the Surface Degradat Ion of a Micro-Hybrid Composite Resin. Braz. Dent. J. 2014, 25, 321–326.
41. Szalewski, L.; Wójcik, D.; Bogucki, M.; Szkutnik, J.; Różyło-Kalinowska, I. The Influence of Popular Beverages on Mechanical Properties of Composite Resins. Materials 2021, 14, 3097.
42. Al-Saud LM, Alolyet LM, Alenezi DS. The Effects of Selected Mouthwashes on the Surface Microhardness of a Single-shade Universal Resin Composite: In Vitro Study. Journal of Advanced Oral Research. 2022;13(2):234-244.
43. Al-Ahmari, M. M., Alzahrani, A. H., Al-Qatarneh, F. A., Al Moaleem, M. M., Shariff, M., Alqahtani, S. M., Porwal, A., Al-Sanabani, F. A., & AlDhelai, T. A. (2022). Effect of miswak derivatives on color changes and mechanical properties of polymer-based computer-aided design and computer-aided manufactured (CAD/CAM) dental ceramic materials. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research, 28, e936892-936891.
44. Chandki, R., Kala, M., Kumar, K. N., Brigit, B., Banthia, P., & Banthia, R. 'Nanodentistry': exploring the beauty of miniature. Journal of clinical and experimental dentistry,2012; 4(2), e119.