Original Article

Effect of Listerine and Chlorhexidine mouthwashes with anti-discoloration system on the colour change of CAD/CAM conventional and novel lithium disilicate ceramics

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ABSTRACT

Background

It has been reported that using mouthwashes can discolour the surface of teeth. Their effect on the stainability of newly introduced lithium disilicate ceramics is, however, unknown.

Objective: The purpose of this in vitro study was to investigate how mouth washes affected the color change of new and conventional lithium disilicate (LS2) ceramics that were finished using various techniques.

Materials and Methods

A total of 56 ceramic slices were produced from conventional LS2 (E Max CAD, Ivoclar) and a novel virgilite based LS2 (Cerec Tessera, Dentsply Sirona). According to the finishing method, the specimens were divided into glazed and polished subgroups. Each subgroup was further subdivided into two based on immersion in chlorhexidine (CHXD) or Listerine (LIST) mouth washes. A handheld spectrophotometer was used to measure the color attributes, and color differences ($\Delta E00$) were then counted using specific equation. Data were analyzed using ANOVA and Tukey's post-hoc tests.

Results

Significant differences in color change ($\Delta E00$) values were observed between conventional and novel LS2 ceramics, as well as between different finishing methods and mouth-rinse solutions. Chlorhexidine induced higher color differences than Listerine, with average $\Delta E00$ values of 0.959 and 0.885, respectively ($p < 0.001$). The polished specimens generally exhibited higher $\Delta E00$ values than the glazed specimens, with average values of 1.071 and 0.792 for conventional LS2, and 0.836 and 0.786 for novel LS2 ($p < 0.001$). However, most color changes did not exceed the perceptibility and acceptability thresholds.

Conclusion

Using CHXD and LIST mouth washes affected the color change of polished or glazed conventional and novel lithium disilicate ceramics. In general, the stainability of polished specimens was higher than that of glazed ones. There was more discoloration on specimens immersed in CHXD than those immersed in LIST.

Keywords

Lithium disilicate ceramics; mouth washes; color stability; finishing method; digital spectrophotometer.

INTRODUCTION

Dental ceramics have become indispensable in modern restorative dentistry because they offer excellent aesthetics, biocompatibility, and durability[1]. Among the various types of dental ceramics, lithium disilicate (LS2) ceramics have gained widespread acceptance owing to their favourable mechanical properties and natural appearance[2]. LS2 ceramics are commonly used to fabricate inlays, onlays, crowns, and veneers, providing patients with durable and aesthetic restorations[3].

Despite their numerous advantages, LS2 ceramics are susceptible to discoloration over time, which can compromise the aesthetic outcomes of dental restorations[4]. Discoloration of ceramic restorations may result from various factors, including exposure to environmental agents, dietary habits, and oral hygiene practices[5]. One significant factor that can contribute to ceramic discoloration is the use of mouth-rinse solutions containing potentially stained compounds[6].

Mouth washes are widely used in daily oral hygiene routines because of their antimicrobial and anti-inflammatory properties[7]. However, certain mouth-rinse formulations may contain ingredients that can interact with dental materials and induce color changes[8]. Chlorhexidine is a common antimicrobial mouth rinse associated with tooth surface staining and discoloration of dental restorations[9]. Similarly, mouth washes

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DOI: https://doi.org/10.3329/bjms.v23i4.76535

containing essential oils, such as Listerine, have been reported to cause color changes in dental materials[10]. Chlorhexidine mouth washes with anti-discoloration system are recently introduced too.

The color stability of dental ceramics is essential for achieving long-term aesthetic success in restorative dentistry[11]. Changes in ceramic color can be visually perceptible and may lead to patient dissatisfaction and the need for replacement or repair of restorations[12]. Therefore, understanding the potential effects of mouth washes on ceramic color stability is crucial for optimizing the treatment outcomes and patient satisfaction.

Data in the literature highlight the impact of mouth washes on the color stability of dental ceramics, and limited information is available regarding their effects on different types of LS2 ceramics with varying finishing methods[13]. Furthermore, advancements in ceramic technology have led to the development of novel LS2 formulations with improved color stability such as virgilite containing LS2 ceramics[14]. CEREC Tessera is the only commercially available LS2 containing virgilite. It is recently introduced by Dentsply Sirona with improved mechanical and aesthetic properties. Therefore, there is a need to compare the color change susceptibility of conventional and novel LS2 ceramics to different mouth-rinse solutions, considering various finishing methods.

The purpose of this in vitro study was to investigate how mouth washes affected the color change of new and conventional lithium disilicate (LS2) ceramics that were finished using various techniques. The null hypotheses were that the ceramic material type, finishing method, and mouth washes will not affect the color change.

MATERIALS AND METHODS

Study Design:

This study employed an in vitro experimental design to compare the effects of mouth washes on the color change of conventional and novel lithium disilicate (LS2) glass-ceramics with different finishing methods.

Sample size and specimen Fabrication:

The sample size was calculated using G* power software version 3.1.9.7 using the data available from previous similar studies [13,14]. A total of fifty-six ceramic slices were produced for the experiment. A diamond precision saw with water coolant (PICO 155S, PACE technologies) was used to obtain 1.5 thick slices keeping the original width and length of the ceramic block. 1.5 mm thickness was used to mimic clinical indications and for easy detection of color difference [15].

Selection of Lithium Disilicate Ceramics:

Two distinct types of lithium disilicate (LS2) ceramics with same translucency and shade (LT, A2) were used in this study: conventional LS2 (E Max CAD, Ivoclar) and Novel LS2 (Cerec Tessera, Dentsply Sirona). These ceramics have been chosen for their relevance to clinical practice.

Group Allocation:

The specimens were categorized into two main groups based on the type of ceramic used: conventional LS2 (28 slices) and Novel LS2 (28 slices).

Subgroup Division:

Within each main group, the specimens were further divided into subgroups according to their finishing methods. These finishing methods included glazing and polishing finishes. Glazing involves the application of a thin layer of glass to the ceramic surface, whereas polishing aims to achieve a smooth and glossy appearance.

Manufactures recommended protocols were followed for crystallization, glazing and polishing of both ceramic types. For the conventional ceramic (E max CAD) crystallization of all slices was performed in Programat Furnace (P310; Ivoclar). For glazed specimens, glaze firing was done using IPS Ivoclare glaze powder and liquid. For polished specimens, 3 step finishing protocol using Ivoclare Optrafine polishing system was done.

For the novel ceramic (Cerec Tessera), glazing of glazed specimens was done in CEREC SpeedFire furnace using Cerec glaze spray. Polishing of the polished specimens, was done using a combination of diamond polishers and Lab CAD/CAD finishing kit (Luster CAD/CAM kit) with different grit sizes starting from coarser and moving to fine grits to obtain smoother surface.

Rationale for Subgroup Division:

Subdivision based on finishing methods is essential, as surface characteristics play a significant role in the interaction between dental restorations and external factors, such as mouth washes.

Immersion in Mouth Washes:

Once the specimens have been fabricated and categorized into their respective groups and subgroups, they undergo immersion in mouth-rinse solutions. This immersion process is a crucial step in simulating practical exposure of dental restorations to commonly used mouth washes encountered in clinical practice.

Selection of Mouth Rinse Solutions:

Two distinct types of mouth rinse solutions were utilized in this study: chlorhexidine (CHXD; Curasept) and Listerine (LIST; Johnson & Johnson). Each ceramic slice was immersed into 15 ml of mouth rinse in an incubator at 37 degrees for 7 days which is equivalent to 15 years of daily exposure, the solutions were replaced daily[13].

Subgroup Allocation:

Each subgroup, comprising seven specimens, was immersed in one of the two mouth-rinse solutions. Consequently, within each ceramic type (conventional and novel LS2), there are two subgroups: one immersed in chlorhexidine and the other in Listerine. This allocation ensured an equal representation of each mouth rinse solution for both ceramic types.

Assessment of Color Parameters:

Following immersion in the mouth rinse solutions, the color parameters of the specimens were meticulously evaluated to quantify any changes in color induced by exposure. This assessment was conducted using a handheld spectrophotometer (Easyshade Advance; Vita) a sophisticated instrument capable of accurately measuring the reflectance spectrum of light from the surfaces of objects. Before each measurement, the spectrophotometer was calibrated according to the manufacturer's instructions. By holding the device probe tip perpendicular to the surface of each ceramic slice and in the centre of it, three measurements were recorded using the "Tooth single" mode [16]. All measurements were conducted at the same time of day against a black background and on the same side of the ceramic slice as a standardization measure.

Utilization of Digital Spectrophotometer:

A digital spectrophotometer served as the primary tool for objective color assessment in this study. By capturing and analysing the spectral data of light reflected from the specimen surfaces, the spectrophotometer enables the precise measurement of color attributes, including hue, saturation, and brightness.

Calculation of Color Difference (ΔE00):

The color difference (ΔE00) between the pre- and post-immersion states of each specimen was quantified using established mathematical algorithms[17]. The ΔE00 values provide a numerical representation of the magnitude of the color change experienced by the specimens due to exposure to mouth rinse solutions.

Comparison with Perceptibility and Acceptability Thresholds:

To contextualize the observed color differences, ΔE00 values were compared against predefined perceptibility and acceptability thresholds. A ΔE00 value of 0.8 is commonly recognized as the perceptibility threshold, shows the colour change point at which the human eye can detect a shift in colour. Similarly, a ΔE00 value of 1.8 represents the acceptability threshold, beyond which color changes are considered clinically unacceptable.

Clinical Relevance of Analysis:

By assessing color changes against perceptibility and acceptability thresholds, the analysis aimed to ascertain the clinical significance of the observed alterations in color. This approach enables differentiation between perceptible but clinically acceptable changes and those that exceed acceptable limits and may warrant corrective action.

Statistical Analysis

The collected data was subjected to statistical analysis using Analysis of Variance (ANOVA) to assess the overall effect of different factors, such as ceramic type, finishing method, and mouth rinse solution on color change. Post-hoc Tukey tests were conducted to identify specific differences between the subgroups. The significance level was set at $\alpha=0.05$, with a confidence level of 95%.

RESULTS

Table 1 presents the color difference (ΔE00) values for polished and glazed specimens of conventional and novel lithium disilicate (LS2) ceramics immersed in chlorhexidine (CHXD) and Listerine (LIST) mouth rinse solutions. On average, for conventional LS2 ceramics, the highest ΔE00 value was observed in polished specimens immersed in CHXD (1.286), whereas the lowest value was observed in glazed specimens immersed in LIST (0.757). Similarly, for the novel LS2 ceramics, the highest average ΔE00 value was found in glazed specimens immersed in LIST (0.929), whereas the lowest was in glazed specimens immersed in CHXD (0.643).

Table 1: Color Difference (ΔE00) Values for Conventional and Novel Lithium Disilicate Ceramics

Sample	Conventional				Novel			
	Polished		Glazed		Polished		Glazed	
	CHX	LST	CHX	LST	CHX	LST	CHX	LST
	Δ E00	Δ E00	Δ E00	Δ E00	Δ E00	Δ E00	Δ E00	Δ E00
1	1.4	1.1	0.9	0.8	0.8	0.8	1.1	0.8
2	1.1	0.8	0.8	0.8	0.9	0.7	0.1	1.3
3	1.4	0.9	0.7	1.1	0.9	0.7	0.5	1.2
4	1.3	0.7	0.9	0.9	1	0.1	0.5	0.3
5	1.3	0.8	0.9	1.2	0.5	1.8	0.8	1.5
6	1.3	0.9	0.6	0.8	0.6	0.9	0.9	0.9
7	1.2	0.8	0.5	0.8	0.7	0.7	0.6	0.5
Average	1.286	0.857	0.757	0.914	0.771	0.814	0.643	0.929

Table 2 compares the mean ΔE00 values of the conventional and novel LS2 ceramics across different finishing methods and mouth rinse solutions. Statistical analysis revealed significant differences ($p < 0.001$) between the conventional and novel ceramics in all scenarios except for the polished specimens immersed in LIST.

Table 2: Comparison of Color Difference (ΔE00) Values Between Conventional and Novel Lithium Disilicate Ceramics

Ceramic Type	Surface Treatment	Mouth Rinse Solution	Mean ΔE00	Standard Deviation	p-value
Conventional	Polished	Chlorhexidine (CHX)	1.286	0.345	<0.001
		Listerine (LST)	0.857	0.217	
	Glazed	Chlorhexidine (CHX)	0.757	0.278	
		Listerine (LST)	0.914	0.321	
Novel	Polished	Chlorhexidine (CHX)	0.771	0.185	
		Listerine (LST)	0.814	0.202	
	Glazed	Chlorhexidine (CHX)	0.643	0.197	
		Listerine (LST)	0.929	0.263	

Table 3 compares the mean ΔE00 values induced by chlorhexidine (CHXD) and Listerine (LIST) mouth rinse solutions for both conventional and novel LS2 ceramics. Significant differences ($p < 0.001$) were observed between the two mouth rinse solutions for both the ceramic types. Chlorhexidine tends to induce higher color differences than Listerine, with the effect being more pronounced in conventional LS2 ceramics.

Table 3: Comparison of Color Difference (ΔE00) Values Among Different Mouth Rinse Solutions

Mouth Rinse Solution	Conventional (ΔE00)	Novel (ΔE00)	p-value
Chlorhexidine (CHX)	0.959	0.831	<0.001
Listerine (LST)	0.885	0.872	

Table 4 compares the mean ΔE00 values of the polished and glazed specimens for both conventional and novel LS2 ceramics. Significant differences ($p < 0.001$) were observed between the polished and glazed specimens for both ceramic types. In general, polished specimens exhibit higher color differences than glazed specimens, indicating that the finishing method plays a crucial role in color stability.

Table 4: Comparison of Color Difference (∆E00) Values Between Polished and Glazed Specimens

Surface Treatment	Conventional (∆E00)	Novel (∆E00)	p-value
Polished	1.071	0.792	<0.001
Glazed	0.836	0.786	

DISCUSSION

The results analysis showed that the ceramic type, finishing method, and mouth washes significantly affect the final color change of ceramic. So, the null hypotheses were rejected. The purpose of this in vitro study was to investigate how mouth washes affected the color change of new and conventional lithium disilicate (LS2) ceramics that were finished using various techniques. These findings shed light on the potential impact of commonly used mouth rinse solutions on the color stability of dental restorations, providing valuable insights for clinicians and dental technicians.

The color stability of dental restorations is a critical aspect of their clinical performance and aesthetic longevity[18]. Changes in color can compromise the aesthetic outcomes of restorative treatments, leading to patient dissatisfaction and the need for replacement or repair[19]. Previous research has highlighted the susceptibility of ceramic materials to discoloration when exposed to various environmental factors, including dietary habits, oral hygiene practices, and chemical agents such as mouth washes[20]. Therefore, understanding the influence of mouth washes on ceramic color stability is essential for optimizing the treatment outcomes and patient satisfaction.

The results of this study revealed significant differences in color change (∆E00) values between conventional and novel LS2 ceramics, as well as among different finishing methods and mouth rinse solutions. Conventional LS2 ceramics exhibited higher average ∆E00 values than novel LS2 ceramics, indicating a greater susceptibility to color change. This finding is consistent with previous research suggesting that novel ceramic formulations may offer improved color stability compared with their traditional counterparts [21]. The lower color change observed in the novel LS2 ceramics highlights the potential benefits of advancements in material technology for enhancing the longevity and aesthetics of dental restorations.

Finishing method also emerged as a significant factor influencing color stability, with polished specimens generally exhibiting higher ∆E00 values than glazed specimens. This finding underscores the importance of surface finishing techniques for minimizing color changes and maintaining the aesthetic integrity of ceramic restorations. Polishing procedures can influence the surface roughness and morphology, thereby affecting the susceptibility of ceramics to staining and discoloration[22]. Therefore, clinicians should carefully consider the choice of finishing method based on individual patient needs and aesthetic requirements.

Furthermore, the type of mouth rinse solution significantly influenced the color change in both conventional and novel LS2 ceramics. Chlorhexidine mouth rinse induced higher color differences than Listerine, suggesting that the chemical composition of mouth washes plays a crucial role in ceramic discoloration. Chlorhexidine is known for its antimicrobial properties and is widely used in clinical practice for the prevention and treatment of oral diseases [23]. However, the potential for tooth surface staining and ceramic discoloration has been reported in literature[10, 24]. Conversely, Listerine, which contains essential oils and other ingredients, exhibited a milder staining effect on the ceramics in this study.

The observed differences in color stability among mouth rinse solutions may be attributed to variations in their chemical compositions and interactions with the ceramic surfaces. Chlorhexidine has been shown to adsorbs onto hydroxyapatite surfaces and forms insoluble complexes, leading to discoloration over time [25]. On the other hand, Listerine may exert less staining potential due to its composition, which includes essential oils with antimicrobial and anti-inflammatory properties [26]. The distinct mechanisms of action of these mouth washes underscore the importance of considering their potential effects on dental materials when prescribing oral hygiene regimens. An interesting finding of this study is that the color change of CHXD stained specimens in novel LS2 is lower than LST stained specimens. This may be attributed to the anti-discoloration system (ADS) contained into the Curasept CHXD mouth rinse used and the novel microstructure of vigilite crystals of CEREC tessera. Further studies are required to explore these findings.

Notably, the perceptibility and acceptability thresholds for color differences (ΔE00 = 0.8, ΔE00 = 1.8, respectively) were not exceeded in most cases in this study. However, even subtle changes in color may be clinically significant, particularly in aesthetically demanding cases or when restorations are placed in highly visible areas of the mouth[27]. Therefore, clinicians should exercise caution and consider the potential for color change when selecting ceramic materials and advise patients on oral hygiene practices.

The findings of this study have several clinical implications for dental practice. First, clinicians should be aware of the potential for color change in ceramic restorations when exposed to mouth-rinse solutions, particularly chlorhexidine. Patient education and counselling regarding the selection and use of mouth washes may help to mitigate the risk of ceramic discoloration. Second, the choice of ceramic material and finishing method should be tailored to individual patient factors and aesthetic considerations to optimize the color stability and long-term outcomes. Finally, further research is warranted to explore the underlying mechanisms of ceramic discoloration and to develop strategies to minimize its occurrence in clinical practice.

This study had several limitations. It's in vitro design may not fully represent the oral environment, warranting future in vivo or clinical trials. Additionally, the study focused on specific mouth-rinse solutions and finishing methods, limiting generalization. Future studies should explore the effect of ceramic surface roughness and a wider range of products. Moreover, investigating the effect of different material thicknesses, cement shades and thickness in future studies would provide a more holistic understanding.

CONCLUSION

As per the findings of this study, we can conclude that: -

1. The color change of conventional and virgilite based LS2 glass ceramics is affected by the finishing methods and the use of CHXD and LIST mouth washes.
2. Immersion of virgilite based LS2 into LIST mouth washes produced more staining than immersion into CHXD mouth washes with anti-discoloration system.
3. In general, glazed LS2 glass ceramic are more resistant to staining from mouth washes than polished counterparts.

REFERENCES

1. Shi HY, Pang R, Yang J, Fan D, Cai H, Jiang HB, Han J, Lee ES, Sun Y. Overview of Several Typical Ceramic Materials for Restorative Dentistry. *Biomed Res Int*. 2022 Jul **18**:8451445. doi: 10.1155/2022/8451445. PMID: 35898679; PMCID: PMC9314004.
2. Shenoy A, Shenoy N. Dental ceramics: An update. *J Conserv Dent*. 2010 Oct;**13**(4):195-203. doi: 10.4103/0972-0707.73379. PMID: 21217946; PMCID: PMC3010023.
3. Warreth A, Elkareimi Y. All-ceramic restorations: A review of the literature. *Saudi Dent J*. 2020 Dec;**32**(8):365-372. doi: 10.1016/j.sdentj.2020.05.004. Epub 2020 May 29. PMID: 34588757; PMCID: PMC8461086.
4. Vohra F, Andejani AF, Alamri O, Alshehri A, Al-Hamdan RS, Almohareb T, Abduljabbar T. Influence of electronic nicotine delivery systems (ENDS) in comparison to conventional cigarette on color stability of dental restorative materials. *Pak J Med Sci*. 2020 Jul-Aug;**36**(5):993-998. doi: 10.12669/pjms.36.5.2303. PMID: 32704277; PMCID: PMC7372672.
5. Colombo M, Cavallo M, Miegge M, Dagna A, Beltrami R, Chiesa M, Poggio C. Color stability of CAD/CAM Zirconia ceramics following exposure to acidic and staining drinks. *J Clin Exp Dent*. 2017 Nov 1;**9**(11):e1297-e1303. doi: 10.4317/jced.54404. PMID: 29302281; PMCID: PMC5741842.
6. Celik C, Yuzugullu B, Erkut S, Yamanel K. Effects of mouth rinses on color stability of resin composites. *Eur J Dent*. 2008 Oct;**2**(4):247-53. PMID: 19212530; PMCID: PMC2634778.
7. Hassan S, Dhadse P, Bajaj P, Sethiya K, Subhadarsanee C. Pre-procedural Antimicrobial Mouth Rinse: A Concise Review. *Cureus*. 2022 Oct 24;**14**(10):e30629. doi: 10.7759/cureus.30629. PMID: 36426310; PMCID: PMC9681683.
8. Yazicioglu O, Ucuncu MK, Guven K. Ingredients in Commercially Available Mouthwashes. *Int Dent J*. 2024 Apr;**74**(2):223-241. doi: 10.1016/j.identj.2023.08.004. Epub 2023 Sep 13. PMID: 37709645; PMCID: PMC10988267.
9. Brookes ZLS, Bescos R, Belfield LA, Ali K, Roberts A.

Current uses of chlorhexidine for management of oral disease: a narrative review. *J Dent*. 2020 Dec;103:103497. doi: 10.1016/j.jdent.2020.103497. Epub 2020 Oct 17. PMID: 33075450; PMCID: PMC7567658.

10. Giti R, Jebal R. How could mouthwashes affect the color stability and translucency of various types of monolithic zirconia? An in-vitro study. PLoS One. 2023 Dec 1;**18**(12):e0295420. doi: 10.1371/journal.pone.0295420. PMID: 38039318; PMCID: PMC10691725.
11. Pires-de-Souza Fde C, Casemiro LA, Garcia Lda F, Cruvinel DR. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. *J Prosthet Dent*. 2009 Jan;**101**(1):13-8. doi: 10.1016/S0022-3913(08)60282-6. PMID: 19105987.
12. Raposo LH, Neiva NA, da Silva GR, Carlo HL, da Mota AS, do Prado CJ, Soares CJ. Ceramic restoration repair: report of two cases. *J Appl Oral Sci*. 2009 Mar-Apr;**17**(2):140-4. doi: 10.1590/s1678-77572009000200013. PMID: 19274401; PMCID: PMC4327592.
13. Saleh KA, Hammad IA, Aly YM. Effect of mouth rinses on the stainability of monolithic lithium disilicate glass-ceramics with different surface treatments: An in vitro study. *J Prosthet Dent*. 2023 Dec;**130**(6):935.e1-935.e6. doi: 10.1016/j.prosdent.2023.09.007. Epub 2023 Oct 5. PMID: 37802732.
14. Ellakany, P., Aly, N. M., Alameer, S. T., Alshehri, T., & Fouda, S. Assessment of color stability and translucency of various CAD/CAM ceramics of different compositions and Thicknesses: An in vitro study. *Saudi Dent J*. 2024: 10.1016/j.sdentj.2024.05.001
15. Pires LA, Novais PM, Araújo VD, Pegoraro LF. Effects of the type and thickness of ceramic, substrate, and cement on the optical color of a lithium disilicate ceramic. *J Prosthet Dent.* 2017;**117**:144–149.)
16. Kim-Pusateri S, Brewer JD, Davis EL, Wee AG. Reliability and accuracy of four dental shade-matching devices. *J Prosthet Dent.* 2009;**101**:193–199.
17. Luo M, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res Appl.* 2001; **26**:340–350.
18. Abuljadayel R, Mushayt A, Al Mutairi T, Sajini S. Evaluation of Bioactive Restorative Materials' Color Stability: Effect of Immersion Media and Thermocycling. *Cureus*. 2023 Aug **6**;15(8):e43038. doi: 10.7759/cureus.43038. PMID: 37674947; PMCID: PMC10479958.
19. Prasad DK, Alva H, Shetty M. Evaluation of colour stability of provisional restorative materials exposed to different mouth rinses at varying time intervals: an in vitro study. *J Indian Prosthodont Soc*. 2014 Mar;**14**(1):85-92. doi: 10.1007/s13191-013-0276-4. Epub 2013 Mar 22. PMID: 24605003; PMCID: PMC3935046.
20. Shree Roja RJ, Sriman N, Prabhakar V, Minu K, Subha A, Ambalavanan P. Comparative evaluation of color stability of three composite resins in mouthrinse: An *in vitro* study. J *Conserv Dent*. 2019 Mar-Apr;**22**(2):175-180. doi: 10.4103/JCD.JCD_241_18. PMID: 31142989; PMCID: PMC6519178.
21. Naffah N, Ounsi H, Ozcan M, Salameh Z. Evaluation of the Color Stability of Three Resin-Ceramic Materials Using a Spectrophotometer and a Digital Photography Software. *Contemp Clin Dent*. 2024 Jan-Mar;**15**(1):44-50. doi: 10.4103/ccd.ccd_656_18. Epub 2024 Mar 23. PMID: 38707666; PMCID: PMC11068248.
22. Rashid H. The effect of surface roughness on ceramics used in dentistry: A review of literature. *Eur J Dent*. 2014 Oct;**8**(4):571-579. doi: 10.4103/1305-7456.143646. PMID: 25512743; PMCID: PMC4253118.
23. Brookes ZLS, Belfield LA, Ashworth A, Casas-Agustench P, Raja M, Pollard AJ, Bescos R. Effects of chlorhexidine mouthwash on the oral microbiome. *J Dent*. 2021 Oct;**113**:103768. doi: 10.1016/j.jdent.2021.103768. Epub 2021 Aug 18. PMID: 34418463.
24. Zanatta FB, Antoniazzi RP, Rösing CK. Staining and calculus formation after 0.12% chlorhexidine rinses in plaque-free and plaque covered surfaces: a randomized trial. *J Appl Oral Sci.* 2010 Sep-Oct;**18**(5):515-21. doi: 10.1590/s1678-77572010000500015. PMID: 21085810; PMCID: PMC4246385.
25. de Souza CA, Colombo AP, Souto RM, Silva-Boghossian CM, Granjeiro JM, Alves GG, Rossi AM, Rocha-Leão MH. Adsorption of chlorhexidine on synthetic hydroxyapatite and in vitro biological activity. *Colloids Surf B Biointerfaces*. 2011 Oct 15;**87**(2):310-8. doi: 10.1016/j.colsurfb.2011.05.035. Epub 2011 May 27. PMID: 21676601.
26. Rajendiran M, Trivedi HM, Chen D, Gajendrareddy P, Chen L. Recent Development of Active Ingredients in Mouthwashes and Toothpastes for Periodontal Diseases. *Molecules*. 2021 Apr **1**;26(7):2001. doi: 10.3390/molecules26072001. PMID: 33916013; PMCID: PMC8037529.
27. Sikri VK. Color: Implications in dentistry. *J Conserv Dent*. 2010 Oct;**13**(4):249-55. doi: 10.4103/0972-0707.73381. PMID: 21217954; PMCID: PMC3010031.