COMPARATIVE EVALUATION OF SURFACE AND OPTICAL PROPERTIES OF EXTRINSICALLY STAINED CAD CAM MILLED GLASS CERAMIC: AN IN-VITRO STUDY

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Abstract:
Background: To analyze the effect of toothbrushing on extrinsically stained glass ceramic.
Aims: This study assesses the optical and surface property of extrinsically stained cad cam milled leucite-reinforced glass ceramic after tooth brushing over a time interval of 3,6,9,12 years.
Settings and Design: This in-vitro study was conducted in the Department of Prosthodontics and Crown & Bridge, Subharti Dental College, and Hospital, Meerut.
Methods and Material: The material leucite-reinforced glass ceramic (IPS Empress CAD) cad cam milled was used in this study. It was studied in the form of disc-shaped specimens (n=30), 10mm diameter and 3mm thickness. Three different methods of applying extrinsic stain were performed on each material: Glazed (n=10); Stain then Glaze (n=10); Stained and Glazed together (n=10). Above specimens were brushed using a multi-station brushing machine for 72, 144, 216, and 288 hours. Surface roughness, shade, and gloss were evaluated and compared.
Statistical analysis used: One way ANOVA-F, Two way ANOVA-F test, unpaired-t test.
Results: Statistically significant differences were found in shade change, surface roughness and gloss in all groups after 12 years of simulated toothbrushing.
Conclusions: The study concluded that for the shade change method of stained and glazing together was found to be most effective followed by stained and glazed together and glazed only. Method of stained then glazing was found most effective followed by glazed only and stained and glazed together in surface roughness. Method of stained and glazed together was found most effective followed by glazed only and stained then glazed for gloss.

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INTRODUCTION:

Ceramic restoration has become more accessible around the world due to advances in restorative materials.[1] Like previously used materials, ceramics were able to overcome many drawbacks, such as corrosion in saliva, discoloration, and poor aesthetics.[2] This study focuses on one such material introduced in the early 1990s a glass-ceramic, leucite-reinforced glass ceramic (IPS Empress CAD). It closely reproduces the natural tooth structure due to its distinct chameleon effect and lifelike fluorescence also demonstrates excellent light-optical properties.

The above striking properties are important to be maintained in the long-term performance of the all-ceramic systems under an oral environment which leads to the purpose of the study to analyze the performance of the ceramic material leucite reinforced glass ceramic cad cam[3] milled.

Many studies have been conducted, Anil and Bolay showed that, the extrinsic stain should be placed as deeply as possible in the restoration to ensure its durability and also reported a significant change in shade and decreased surface roughness of extrinsically stained feldspathic porcelain restorations after an equivalent of 8.5 years of toothbrushing.[4] Aker et al demonstrated that the use of a normal toothbrush with a common dentifrice could wear away the porcelain stains applied to the surface of feldspathic porcelain.[5] Bativala et al found that extrinsic stain layer on feldspathic porcelain restorations was resistant to significant loss from the use of a fluoride dentifrice applied with a soft multi-tufted toothbrush for at least 8.5 years of simulated brushing.[6] Garza et al reported no statistically significant difference in the shade change and surface roughness of the extrinsically stained ceramics after 12 years of simulated toothbrushing.[7] However, no studies have reported the effect of toothbrushing on extrinsically stained cad cam-milled ceramic materials.

The objective is to find if the aesthetic properties of the ceramic material that alter or remain the same when undergoing toothbrushing effect simulating the oral environment with a gradual increase in time i.e. shade, roughness, and gloss under three methods.

Therefore, this study investigates the effect of tooth brushing on surface roughness and optical property of extrinsically stained cad cam milled leucite-reinforced glass ceramic for 3,6,9, and 12 years. The null hypothesis of this study is that no change would be observed in the surface roughness, gloss, and shade after toothbrushing in between the three groups: Group A, B, and C after the brushing at different time interval.

MATERIAL AND METHODS:

The CAD-CAM milled blocks of leucite based glass ceramic, IPS Empress CAD were tested. Millable blocks were cut to prepare 30 specimens of each type, with each disk-shaped specimen having a diameter of 10.0 mm and a thickness of 3.0 mm. Thickness was confirmed using with a digital caliper. Specimens were then ground down from 3 mm to 2.90 mm using silicon carbide 420 grit paper to allow for the addition of 100 μm of extrinsic characterization material which was followed by surface preparation.[Table 1]

The brush strokes for stain application were made parallel to that mark on sample created using the fiducial mark. After the addition of stain and/or glaze materials, samples were measured again and ground using silicon carbide paper through 420 grits until a final thickness of 3 mm was achieved. This method allowed for the addition of 1.0 mm of glaze or stain and glaze to each specimen.

Simulated toothbrushing was performed using a multi-station brushing (toothbrushing cycle test rig. ID No. PRAJ/INST/031, designed by Praj Metallurgical Laboratory, India).The machine contained three arms and a reservoir that allowed the brushing of 3 specimens simultaneously. A soft, straight toothbrush (Oral-B cross-section power) was used for the brush heads. The reservoir was filled with a solution made from 150 g of medium abrasive 70 RDA toothpaste (Colgate Total) suspended in 150 mL of distilled water (1:1 ratio). Specimens were fixed in place using custom-made polymer holders and positioned so that the fiducial mark and the brush strokes were parallel with each other. Each specimen was brushed for 288 hours with a load of 200 grams at a rate of 90 strokes per minute with interruptions at 72, 144, 216, and 288 hours. Brushes and toothpaste were replaced after every 3 years of simulated brushing. Forty-eight thousand strokes in the multi-station brushing machine were determined to be equivalent to 3 years of twice-daily toothbrushing for 2 minutes. Specimens were rinsed with water and dried after brushing and before measurements.

Evaluation for shade changes was carried out with a spectrophotometer (Make: VITA Easyshade Advanced V, Germany VITA Zahnfabrik H. Rauter GmbH and CO.KG, Germany) at 5 different intervals: baseline and after 72, 144, 216, and 288

hours of brushing. The spectrophotometer measured the reflected or transmitted light from a specific object and provided measurements corresponding to visible light wavelengths. Samples and spectrophotometer were positioned in a customized holder which allowed repeatable positioning.

The surface gloss was evaluated with a glossometer (Make: Photoelectric Instruments, India Sr.No. M. 1970) at 5 intervals as above. The gloss reading was made before and after brushing, by using a glossmeter with a 2×2 mm spot area and a 60-degree geometry (light incidence), with values expressed in Gloss Units (GU). The specimens were protected from environmental light during the readings by using a black opaque plastic cover, readings were made for each specimen, and used for the statistical analysis.

Surface roughness was evaluated with a profilometer (Mitutoyo, Japan Model: SJ 210)at 5 intervals. The instrument was calibrated using a standard reference specimen,and set to travel at a speed of 0.10 mm per second with a range of 600 μm during testing. A diamond stylus (5 μm tip radius) was used under a constant measuring force of 3.9 mN. Surface roughness (Ra) was measured 3 times by orienting the fiducial mark at the 11, 12, and 1 o'clock positions. The detector moved across the sample, and perpendicular to the direction of the toothbrushing direction.

Once all the readings were evaluated at different time intervals using readings obtained from the change in surface and optical properties of the material used before and after toothbrushing. Further, the data was statistically analyzed using SPSS software followed by a comparative analysis between the three groups. To test the significance between the groups, unpaired-T test, one-way and two way ANNOVA F test was carried out.

RESULT:

Shade change (ΔE) for each subgroup is summarized in the Table 1 and 2 with the mean (SD) values of during the 12 years of toothbrushing. The value of shade change increases in all the three groups with respect of time.

Surface roughness mean and SD values are listed in Table 3 of the three distinct groups during the 12 years of toothbrushing with increasing values over the time. Table 4 describes between group comparison for surface roughness at different time points which was found to have significant difference at 0.05 level of significance.

Table 5 summarise the mean and SD value of gloss for the three groups during 12 years of toothbrushing. Table 6 describes between group comparison for gloss at different time points which was found to have significant difference at 0.05 level of significance.

Table 1: Distribution of sample

GROUPS	MATERIAL	SAMPLE NUMBER
GROUP A	IPS EMPRESS-Glazed With IPS Empress® universal glaze paste	**n = 10**
GROUP B	IPS EMPRESS-Stained then Glazed With IPS Empress® universal shade A2	**n = 10**
GROUP C	IPS EMPRESS- Stained and Glazed together With Empress universal shade A2 and Empress universal glaze paste	**n = 10**

Table 2: MEAN, STANDARD DEVIATION, MAXIMUM & MINIMUM SCORES AND COEFFICIENT OF VARIATION IN CHANGE IN Δ E AT DIFFERENT TIME-POINTS OF BRUSHING CYCLES IN THREE DIFFERENT GROUPS

Δ E				
TIME POINTS OF BRUSHING CYCLES	**GROUP-A - - GLAZED**	**GROUP- B-- STAINED THEN GLAZED**	**GROUP- C- STAINED & GLAZED TOGETHER**	**P- VALUE BY TWO-WAY ANVOA-F TEST**
AFTER 72 hrs BRUSHING CYCLES	2.29	0.37	0.11	1)P=.0002* P<.05 (SIGNIFICANT DIFFERENCE AMONG **TIME-POINTS**)
AFTER 144 hrs BRUSHING CYCLES	6.21	2.37	1.57	
AFTER 216 hrs BRUSHING CYCLES	15.52	8.33	6.81	2)P=.0446*P<.05 (SIGNIFICANT DIFFERENCE AMONG **GROUPS**)
AFTER 288 hrs BRUSHING CYCLES	28.73	15.89	14.35	
MEAN	**13.188**	**6.740**	**5.710**	----------
S.D.	**11.754**	**6.974**	**6.438**	----------

Table 3:COMPARATIVE STUDY OF COLOR STABILITY AMONG l*,a* & b* AT EACH TIME POINTS IN THREE DISTINCT GROUP (BY ONE WAY ANOVA-F TEST)

Sr.NO.	TIME-POINTS	GROUP A--GLAZED	GROUP B -- STAINED THEN GLAZED	GROUP C -- STAINED & GLAZED TOGETHER
		AMONG L & a& b	AMONG L & a& b	AMONG L & a& b
1	AT BASE LINE	P=.0004*P<.05 (SIG.)	P=.0003*P<.05 (SIG.)	P=.0004*P<.05 (SIG.)
2	AFTER 72 HRS OF BRUSHING CYCLES	P=.0011*P<.05 (SIG.)	P=.0011*P<.05 (SIG.)	P=.0000*P<.05 (SIG.)
3	AFTER 144 hrs OF BRUSHING CYCLES	P=.0002*P<.05 (SIG.)	P=.0003*P<.05 (SIG.)	P=.0000*P<.05 (SIG.)
4	AFTER 216 hrs OF BRUSHING CYCLES	P=.0003*P<.05 (SIG.)	P=.0021*P<.05 (SIG.)	P=.0005*P<.05 (SIG.)
5	AFTER 288 hrs OF BRUSHING CYCLES	P=.0001*P<.05 (SIG.)	P=.0007*P<.05 (SIG.)	P=.0006*P<.05 (SIG.)

*SHOWS A SIGNIFICANT DIFFERENCE AT.05 LEVEL OF SIGNIFICANCE. (P<.05)

Table 4: MEAN, STANDARD DEVIATION AT DIFFERENT TIME –POINTS AND % CHANGE B/W BASELINE - AFTER 288 hrs BRUSHING CYCLES FOR SURFACE ROUGHNESS--Ra μm)

ROUGHNESS						
	BASE LINE	AFTER 72 hrs BRUSHING CYCLES	AFTER 144 hrs BRUSHING CYCLES	AFTER 216 hrs BRUSHING CYCLES	AFTER 288 hrs BRUSHING CYCLES	% CHANGE B/W BASE LINE- AFTER 288 hrs BRUSHING CYCLES
GROUP- A – GLAZED Mean(SD)	0.133 (0.009)	0.146 (0.010)	0.158 (0.010)	0.168 (0.009)	0.175 (0.009)	75.875 %
GROUP-B- STAINED THEN GLAZED--- SURFACE Mean(SD)	0.093 (0.008)	0.101 (0.006)	0.108 (0.005)	0.114 (0.006)	0.118 (0.006)	78.201 %
GROUP-C- STAINED & GLAZED TOGETHER Mean (SD)	0.305 (0.011)	0.328 (0.011)	0.343 (0.012)	0.356 (0.010)	0.366 (0.011)	83.144 %

Table 5:- B/W GROUP COMPARISON FOR SURFACE ROUGHNESS (Ra μm) AT DIFFERENT TIME POINTS

Sr.NO.	PAIR OF GROUPS	PROBABLE VALUES OF UNPAIRED" t "TEST B/W GROUPS				
		AT BASE LINE	AFTER 72 hrs BRUSHING CYCLES	AFTER 144 hrs BRUSHING CYCLES	AFTER 216 hrs BRUSHING CYCLES	AFTER 288 hrs BRUSHING CYCLES
1	GLAZED AND STAINED THEN GLAZED	.0000* P<.05(SIG.)	.0001* P<.05(SIG.)	.0011* P<.05(SIG.)	.0009* P<.05(SIG.)	.0013* P<.05(SIG.)
2	STAINED THEN GLAZED AND STAINED& GLAZED TOGETHER	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0004* P<.05(SIG.)	.0002* P<.05(SIG.)
3	GLAZED&STAINED& GLAZED TOGETHER	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)

***SHOWS A SIGNIFICANT DIFFERENCE AT.05 LEVEL OF SIGNIFICANCE. (P<.05)**

Table 6: MEAN, STANDARD DEVIATION AT DIFFERENT TIME –POINTS AND % CHANGE B/W BASELINE - AFTER 288 hrs BRUSHING CYCLES FOR SURFACE GLOSS

GLOSS						
	BASE LINE	AFTER 72 hrs BRUSHING CYCLES	AFTER 144 hrs BRUSHING CYCLES	AFTER 216 hrs BRUSHING CYCLES	AFTER 288 hrs BRUSHING CYCLES	% CHANGE B/W BASE LINE- AFTER 288 hrs BRUSHING CYCLES
GROUP- A – GLAZED Mean(SD)	36.59 (1.240)	34.37 (1.198)	32.86 (1.100)	31.72 (1.090)	30.72 (1.135)	83.96%
GROUP-B- STAINED THEN GLAZED---SURFACE Mean(SD)	35.83 (0.814)	33.63 (0.863)	31.47 (0.910)	29.53 (0.926)	28.44 (0.825)	79.37%
GROUP-C- STAINED & GLAZED TOGETHER Mean (SD)	60.91 (1.811)	58.79 (1.733)	56.72 (1.642)	55.49 (1.588)	54.44 (1.613)	89.38%

Table 7:B/W GROUP COMPARISON FOR GLOSS AT DIFFERENT TIME POINTS.

Sr.NO.	PAIR OF GROUPS	PROBABLE VALUES OF UNPAIRED" t "TEST B/W GROUPS				
		AT BASE LINE	AFTER 72 hrs BRUSHING CYCLES	AFTER 144 hrs BRUSHING CYCLES	AFTER 216 hrs BRUSHING CYCLES	AFTER 288 hrs BRUSHING CYCLES
1	GLAZED AND STAINED THEN GLAZED	.0000* P<.05(SIG.)	.0001* P<.05(SIG.)	.0067* P<.05(SIG.)	.1321** P>.05(NOT SIG.)	.1253** P>.05(NOT SIG.)
2	STAINED THEN GLAZED AND STAINED& GLAZED TOGETHER	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)
3	GLAZED AND STAINED& GLAZED TOGETHER	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)	.0000* P<.05(SIG.)

*SHOWS A SIGNIFICANT DIFFERENCE AT.05 LEVEL OF SIGNIFICANCE. (P<.05)

DISCUSSION

The in vitro study demonstrated that simulated tooth brush abrasion significantly changed color, reduced glossyness, and increased roughness of stained and glazed ceramic materials. Therefore, the null hypothesis was rejected that no change would be observed in the surface roughness, gloss, and shade after toothbrushing in between the three groups: Group A ,B and C after the brushing at baseline and 72, 144, 216, and 288 hours.

The ΔE value is the measure of the total color difference between two objects. This study represents the mean and standard deviation of Group A – glazed , Group B - stained then glazed and Group C- stained & glazed together for color difference at different time points b/w base line after 72, 144, 216, and 288 hours brushing cycles for shade change. The p-value was found to be significant for different time point and among the groups. [Table 2] Comparative study of color stability among the color coordinated l*,a* & b* at each time points in three distinct group (by one way anova-f test) showed significant difference. [Table 3]

From the above-mentioned results, the values for color difference ΔE seemed to be increasing over a time period. Similar results have been found associated with a study by Kanat Erturk B., examined the effect of surface finishing procedures on glass ceramic and found significant differences between the color stability.[8] Mühlemann S et al, Pouranfar FL et al, Yuan JC et al and Sehovic E, noticed a significant color change after toothbrushing of ceramic material. The probable reason of it is the abrasive effect of toothbrushing, potentially wear ceramic stains. It was recommended to apply staining ceramics as deeply as possible to avoid changes in color over time. [9-12]

Seghi et al. in a study performed with translucent color porcelain disks, and dental professionals reported a color difference of ΔE = 2.[13] Ragain et al. also evaluated color difference acceptability in translucent porcelain disks and reported an average acceptability threshold of ΔE = 2.72.[14] Johnston et al. in 1989 published a study which established this limit as ΔE = 3.7; barely acceptable matches were found to have ΔE of 6.[15] Vichi et al proposed that an ΔE value < 1 unit is considered not identifiable by the human eye, ΔE value >1 - < 3.3 units are considered appreciable by skill operator and clinically acceptable, and finally an ΔE value >3.3 units are detectable by patients.[16] Douglas et al reported the first in vivo study where they concluded perceptibility values were 2.6 units, as compared to acceptability values of 5.5 units, proving that perceptibility tolerances are less than acceptability tolerances for shade matching on denture teeth.[17]

In relation to the above-mentioned studies this study showed an increase in the ΔE value which was clinically acceptable in Group A- glazed till 72(2.29) hours but beyond this time interval, appreciable loss of color stability was noticed. For Group B and Group C – stained and glazed together color stability(0.37,2.37,0.11,1.57) was clinically acceptable till 144 hours and beyond it was lost. A statistically significant shade change ΔE was noted after 12 years of toothbrushing in all groups.

The results of the present study showed that surface roughness of ceramic materials increased. In terms of surface roughness, Anil and Bolay found a significant decrease in the roughness of extrinsically stained feldspathic dental porcelain after an equivalent of 8.5 years of toothbrushing.[4] This could be attributed to the loss of the glazed surface over time or the difference in thermal expansion coefficients of the core and the glazed material.

Garza et al reported that mean Ra values increased slightly over time.[7] The wear produced by brushing, instead of removing the nanoclusters from the surface, cause them to fracture, keeping a part of them on the surface of material resulting into

roughness. De Andrade evaluated the effect of simulated toothbrushing on surface roughness of chairside CAD-CAM materials promoted a increase in the value for all the materials tested.[18] The inconsistency in the studies may be the result of differences in testing methods. These results are also supported by Yuan JC et al work ie. the surface roughness effect of simulated years alone on surface roughness showed that simulated 5, 10, and 15 years all resulted in significantly different surface roughness.[11]

The average mean is found to be 0.133, 0.146, 0.158, 0.168 and 0.175 µm for Group A – glazed at baseline and at 72, 144, 216, and 288 hours. The average mean is found to be 0.093, 0.101, 0.108, 0.114 and 0.118 µm Group B – stained then glazed at baseline and at 72, 144, 216, and 288 hours. The average mean is found to be 0.305, 0.328, 0.343, 0.356 and 0.366 µm Group C – stained and glazed together at baseline and at 72, 144, 216, and 288 hours.[Table 4]

Between group comparison for surface roughness at different time points was found to have significant difference at 0.05 level of significance. [Tables 5]

The present study determined a mean Ra value after 12 years toothbrushing not clinically perceived for any of the groups. Least change was noted in Group B- stained then glazed. These numbers are below the clinical thresholds noted above. Even though the groups demonstrated a statistically significant change in roughness as a function of brushing time and techniques.

Within the limitations from this study, we can evaluate that there is a general trend of loss of gloss in all the groups. The gloss difference of 35.7 GU is clinically perceived the simulated toothbrushing promoted a clinically significant decrease in gloss in all tested materials.[19] According to the American Dental Association (ADA) recommendations, a polished restoration should have a surface gloss ranging from 40 to 60 GU.[20]

In this study, mean of Group A(glazed) at different time –points b/w base line- after 288 hrs brushing cycles for gloss was found to be 36.59, 34.37, 32.86, 31.72 and 30.72 respectively. For Group B(stained then glazed) at different time interval, the mean recorded was 35.83, 33.63, 31.47, 29.53, and 28.44. Mean for Group C(stained & glazed together) at different time 60.91, 58.79, 56.72, 55.49, and 54.44 respectively. [Table 6]The test conducted between group comparison for gloss at different time points which was found to be significant difference at .05 level of significance but at time interval 216 hours and 288 hours for inter group difference Group A – glazed and Group B – stained then glazed was found to be not significant.[Table 7] Gloss was noted to be meaningfully lost with the time interval for all the three groups. Only Group C had the better clinically perceived property for gloss even after reduce at various time interval at baseline and after 72, 144, 216, and 288 hours of brushing. In group a and b difference in gloss could be noted after 144 hours of tooth brushing.

Gloss was noted to be meaningfully lost with the time interval for all the three groups. Only Group C had the better clinically perceived property for gloss even after reduce at various time interval at baseline and after 72, 144, 216, and 288 hours of brushing. In group a and b difference in gloss could be noted after 144 hours of tooth brushing.

These results are in accordance to an in vitro study that evaluated different CAD CAM materials by Mormann WH were brasive toothbrushing reduced the gloss value of the ceramic material tested.[21] Sehovic E measured the durability of the gloss of stained monolithic ceramic materials subjected to artificial tooth brush abrasion resulted decreased values after aging. [12]Similar results were found in the study by Labban et al which showed decrease in gloss after tooth brushing.[22]

CONCLUSION:

1. For shade change method of stained and glazing together was found to be the most effective followed by stained and glazed together and glazed only.
2. For surface roughness method of stained then glazing was found to be most effective followed by glazed only and stained and glazed together.
3. For gloss method of stained and glazed together was found to be most effective followed by glazed only and stained then glazed.

REFERENCE :

1. AGARWAL S, TRIVEDI A, KUSUM CK, GOSWAMI R, MOWAR A. A Three-dimensional Finite Element Analysis of Effect of Abutment Materials on Stress Distribution around Peri-Implant Bone in Immediate and Delayed Loading Conditions. Journal of Clinical & Diagnostic Research. 2022 Jun 1; 16(6).
2. Johnson WW. The history of prosthetic dentistry. J Prosthet Dent. 1959;9(5):841-6.

3. Dadoo A, Jain S, Mowar A, Bansal V, Trivedi A. 3D Printing Using CAD Technology or 3D Scanners, A Paradigm Shift in Dentistry—A Review. Int. J. Med. Dent. Res. 2021;1:35-40.
4. Anil N, Bolay S. Material Loss, Roughness, and Used in Metal Ceramic Restorations : An In Vitro Study. Int J Prosthodont. 2002;15 (5): 483–8.
5. Aker DA, Aker JR, Sorensen SE. Toothbrush abrasion of colorcorrective porcelain stains applied to porcelain-fused-to-metal restorations. J Prosthet Dent. 1980;44(2):161-3.
6. Bativala F, Weiner S, Berendsen P, Vincent GR, Ianzano J, Harris WT Jr. The microscopic appearance and effect of toothbrushing on extrinsically stained metal-ceramic restorations. J Prosthet Dent. 1987;57(1):47-52.
7. Garza LA, Thompson G, Cho S-H, Berzins DW. Effect of toothbrushing on shade and surface roughness of extrinsically stained pressable ceramics. J Prosthet Dent. 2016; 115(4):489–94.
8. Kanat-Ertürk B. Color Stability of CAD/CAM Ceramics Prepared with Different Surface Finishing Procedures. J Prosthodont. 2020; 29(2):166-172.
9. Mühlemann S, Stromeyer S, Ioannidis A, Attin T, Hämmerle CH, Özcan M. Change in Color and Gloss Parameters of Stained Monolithic Resin-Ceramic CAD/CAM Materials After Simulated Aging: An In Vitro Study. Int J Prosthodont. 2021;34(1):79-87.
10. Pouranfar FL, Sheridan R, Salmon C, Vandewalle KS. Effect of Toothbrushing on Surface Color of Ceramic-polymer Materials: An In Vitro Study. J Contemp Dent Pract. 2020;21(9):1054-1058.
11. Yuan JC, Barão VAR, Wee AG, Alfaro MF, Afshari FS, Sukotjo C. Effect of brushing and thermocycling on the shade and surface roughness of CAD-CAM ceramic restorations. J Prosthet Dent. 2018;119(6): 1000-1006.
12. Sehovic E, Ioannidis A, Hämmerle CH, Özcan M, Mühlemann S. Effect of tooth brush abrasion on the color, gloss and surface roughness of internally and externally stained monolithic ceramic materials. J Prosthodont Res. 2022;66(2):303-311.
13. Seghi RR, Johnston WM, O'Brien WJ. Performance assessment of colorimetric devices on dental porcelains. J Dent Res. 1989 ;68(12):1755-9.
14. Ragain JC Jr, Johnston WM. Minimum color differences for discriminating mismatch between composite and tooth color. J Esthet Restor Dent. 2001;13(1):41-8.
15. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res. 1989;68(5): 819-22.
16. Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. Dent Mater. 2011;27(1) :97– 108.
17. Douglas RD, Brewer JD. Acceptability of shade differences in metal ceramic crowns. J Prosthet Dent. 1998;79(3):254–60.
18. de Andrade GS, Augusto MG, Simões BV, Pagani C, Saavedra GSFA, Bresciani E. Impact of simulated toothbrushing on surface properties of chairside CAD-CAM materials: An in vitro study. J Prosthet Dent. 2021;125 (3):469-74
19. Jones CS, Billington RW, Pearson GJ. The in vivo perception of roughness of restorations. Br Dent J. 2004;196(1):42-5.
20. American Dental Association. Product review: polishing systems. Chicago: American Dental Association; 2010. p. 16.
21. Mörmann WH, Stawarczyk B, Ender A, Sener B, Attin T, Mehl A. Wear characteristics of current aesthetic dental restorative CAD/CAM materials: two-body wear, gloss retention, roughness.
22. Labban N, Al Amri MD, Alnafaiy SM, Alhijji SM, Alenizy MA, Iskandar M, Feitosa S. Influence of Toothbrush Abrasion and Surface Treatments on Roughness and Gloss of Polymer Infiltrated Ceramics. Polym 2021 Oct 27;13(21):3694