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Spectrophotometric Evaluation of Color Stability of CAD/CAM Monolithic Zirconia Following Exposure to Betel Leaf, Slaked Lime, Areca Catechu, and Tobacco

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KEYWORDS

Monolithic zirconia, Color stability, Polishing, Glazing

ABSTRACT:

Background and Aim: Discoloration is a major concern with use of tooth colored restotations. Type of restorative marerial and surface treatment are belived to play a major role in this regards. This study sought to compare the color stability of glazed and polished monolithic zirconia ceramic after exposure to betel leaves with slaked lime, areca catechu and tobacco solutions.

Materials and Method: A total number of 64 discs with 10 mm diameter and 2 mm thickness were fabricated from commercially available CAD/CAM zirconia blanks [Aidite (Qinhuangolao) Technology Co. Ltd.] and divided into two groups of 32. Glazing was done in group 1 samples and group 2 was polished using a polishing kit. The CIE L*a*b* color parameter of the samples were measured using a spectrophotometer. The specimens in each of the two groups Group 1 and Group 2 was further divided into 4 sub-groups i.e. 1A, 1B, 1C, 1D for Group 1 and 2A, 2B, 2C, 2D for Group 2 based on immersing in staining solutions used for immersion. After 28 days of immersion period, spectrophotometer recordings were taken. Colour change (ΔE) values were determined by using the Commision Internationale de l'Eclairage L*a*b* (CIELab) colorimetric system. The colour difference (ΔE) values was evaluated by calculating the difference in colour by using spectrophotometer. Results were statistically analysed using ANOVA One way test, Tuckey's Post Hoc test, One Sample t test and Independent sample t test.

Results: Color measurements revealed that immersion of both group 1 and group 2 in tobacco solution and mixture of betel leaves, areca catechu, slaked lime and tobacco solution resulted in significantly higher color change values($p<0.05$). These changes were not significantly different between the 2 groups ($p>0.05$) when immersed in different staining solutions.

Conclusion: No significant difference in staining observed for both polished and glazed groups. The maximum staining potential was shown by combined mixture of betel leaves with slaked lime, areca catechu and tobacco solution followed by tobacco solution and least by betel leaves with slaked lime and areca catechu solution.

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1. Introduction

The demand for aesthetic dental services is on a constant upsurge due to an aesthetic conscious society.[1] Aesthetic dental practice has brought numerous innovative clinical procedures and a revolution in dental materials. Indirect restoration constructed from various all-ceramic materials is widely practiced in contemporary dental practice. Different materials are used for fabrication of prosthetic restorations; among which, porcelain is highly popular due to its excellent esthetics, natural look and high translucency as well as its inertness and biocompatibility.[2]

Zirconia or zirconium dioxide (ZrO) is a highly attractive ceramic material in prosthodontics due to its good chemical properties, dimensional stability, high mechanical strength, toughness, and a Young's modulus (210 GPa) similar to that of stainless steel alloy (193 GPa).[3]

Zirconia has superior mechanical properties but its opaque white color and insufficient translucency require glassy porcelain veneering on the framework to get a natural appearance and acceptable esthetics.[4] However, cracking or chipping of the porcelain veneer has been reported to be a major complication of these restorations.[5,6] Non-veneered zirconia restorations were developed as an alternate solution to the layered zirconia. Due to increase in translucency of zirconia and advances in CAD/CAM technology full-contoured, monolithic zirconia restorations without veneering porcelain have become increasingly popular.[4,7] In order to eliminate the veneer cracking monolithic zirconia has been used in posterior region especially for single crowns.[8,9] It has been suggested for use in patients with limited interocclusal space because of its ability to resist high loads with only 0.5 mm occlusal thickness.[10]

The milling process induces surface and subsurface damages in CAD/CAM ceramics for this reason, the surface finishing of CAD/CAM ceramics must be conducted after the milling process. Generally in ceramics, surface finishing is performed by glazing. For in-office restorations, surface finishing using rotary instruments is a convenient option.[11] In addition, the need for possible occlusal adjustment may require the removal of the glaze surface layer and prevent future color change; therefore, a polishing kit may be a simpler alternative for dentists. Finishing and polishing protocols is aimed to create a smooth and shiny surface with same optical properties to those of natural enamel.[11,12]

Prosthesis must not only have the dimensions, texture and contours of the teeth to be replaced but should also have similar light behaviour. Furthermore, the color stability of the restoration is critical for the long-term success of the aesthetic restorations.

Surface degradation of ceramics are reported by extrinsic factors like beverages, mouthwashes, acid solutions, tooth brushing and higher temperature. The extrinsic pigment absorption or adsorption from the oral cavity is affected by the composition and surface morphology of ceramic materials.[13-15] Intrinsic discoloration is related to innate characteristics of the materials in composition of porcelain while extrinsic discoloration is due to the accumulation of stains on the porcelain surface, which depends on the level of smoothness of the surface and presence/absence of porosities.

The chewing of betel quid, a combination of areca nut, Kattha, betel leaf, slaked lime, and region-dependent flavouring ingredients, is a uniquely Asian, culturally derived lifestyle habit. Bred from ancient tradition, its use is socially accepted in all groups, including women and young children.[16]

Various studies have been done on the effect of beverages such as tea, coffee, carbonated drinks, and alcohol, on the color stability of different esthetic restorative materials. However, a research on the effect of betel leaves with slaked lime, areca catechu and tobacco on the esthetic restorative materials is yet to be documented. Therefore, the present study was conducted to investigate the effect of betel leaves with slaked lime, areca catechu and tobacco on color stability of different surface treated (glazed & polished) monolithic zirconia ceramics.

2. Materials and Method

This present in vitro experimental study was conducted on CAD/CAM fabricated 64 discs shaped zirconia samples of 10 mm diameter and 2 mm thickness. Monilithic zirconia blanks were cut and ground in their green stage. The specimens were sintered according to the manufacturers' instructions using the manufacturer's furnace. The specimens were equally divided into 2 groups (figure 1) as follows:

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Group 1: The samples of group 1 were polished. The polishing was done with Eva kit (Eva Silicon Polishers; Ernst Vetter GmbH, Pforzheim, Germany) using straight hand piece connected to the electric control unit at a constant speed of 10,000 rpm, under constant pressure and standard time in a single direction motion, following manufacturers' instructions. Coarse-grit polisher was first used, followed by medium grit, fine grit and extra fine grit polishers under water coolant.

Group 2: The samples of group 2 were glazed. A thin layer of glazed material was applied on the surface of porcelain samples and they were transferred to a furnace with initial temperature of 600°C. The temperature was reached to 940°C within three minutes and the samples were kept at this temperature for one minute. The samples were then cooled down.

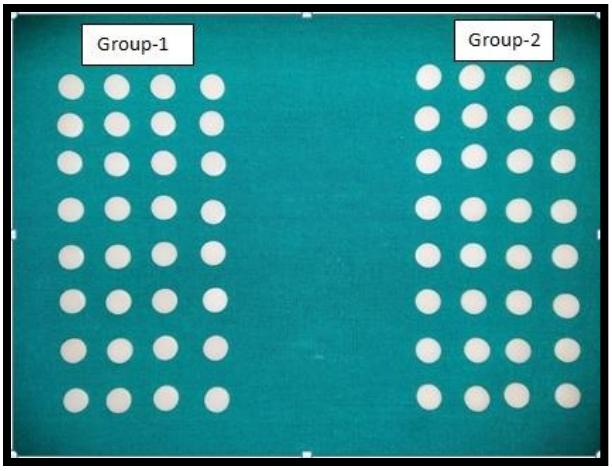

Figure 1: Samples before immersion in immersion solutions

All surface treatment were applied on 1 side of the specimen and other side were left untreated. All glazing and polishing procedures were performed by same operator. Specimens were stored for 24 hours in distilled water at 37°C and air dried before base line spectral radiance measurements.

Sub-Groups: The specimens in each of the two groups Group 1 and Group 2 was further divided into 4 sub-groups i.e. 1A, 1B, 1C, 1D for Group 1 and 2A, 2B, 2C, 2D for Group 2 (Table 1) based on immersing in staining solutions used for immersion.

Table 1: Sub-groups according to the staining agent used

Sub-Groups	Solution	Sample Size
1A/2A	Artificial saliva	1A=8 2A=8
1B/2B	Tobacco + Artificial saliva	1B=8 2B=8
1C/2C	Betel Leaves + Catechu + Slaked Lime + Artificial saliva	1C=8 2C=8
1D/2D	Betel Leaves + Catechu + Slaked Lime + Tobacco +Artificial saliva.	1D=8 2D=8

Initial Color Evaluation:

The initial color evaluation (CIE L*a*b* value) for each group was done by color spectrophotometer (KONICA MINOLTA) on day 0.

Staining Solution Preparation:

Solutions were prepared in the following manner:

1) Artificial saliva solution: It was used as control solution. Its composition was as follows- carboxymethylcellulose sodium (.10%), potassium chloride (.12%), potassium dihydrogen phosphate (.03%), calcium chloride (.014%), magnesium chloride (.005%) and purified water (99.3%).

2) Tobacco + Artificial saliva Solution: 3 gm of dried tobacco leaves were ground in a grinder with 10 ml of artificial saliva to form a solution.

3) Betel Leaves + Catechu + Slaked Lime + Artificial saliva Solution: 4 gm of betel leaves + 3 gm of catechu + 3 gm of slaked lime were ground in 10 ml of artificial saliva.

4) Betel Leaves + Catechu + Slaked Lime + Tobacco +Artificial saliva solution: 4 gm of betel leaves + 3 gm of catechu + 3 gm of slaked lime + 3 gm of tobacco were ground in 10 ml of artificial saliva.

Immersion in Staining Solutions:

The samples of control sub-groups 1A & 2A were immersed in artificial saliva. The staining sub-groups 1B & 2B were immersed in tobacco solution, sub-groups 1C

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& 2C were immersed in solution of betel leaves and slaked lime and sub-groups 1D & 2D were immersed in solution of betel leaves and catechu, slaked lime and tobacco (figure 2).

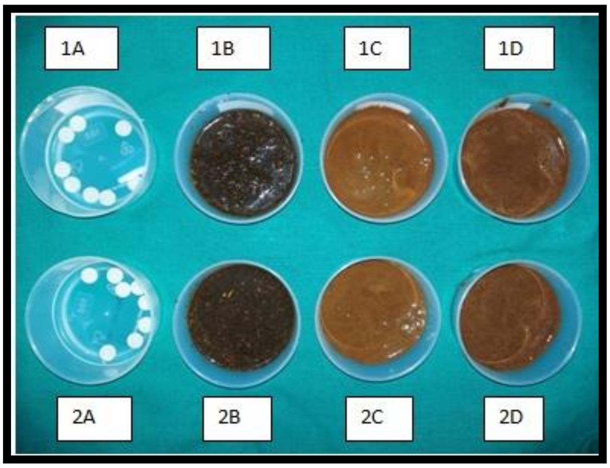

Figure 2: Samples immersed in various immersion solutions

All samples immersed in staining solutions for 12 hours every day followed by rinsing and dipping in 10 ml artificial saliva for 12 hours at 37°C to simulate mouth conditions.

All staining solutions were changed every day for 28 days. After the period of immersion of 28 days, all the samples were washed with distilled water and dried with paper for colorimetric evaluation according to the CIE $L^*a^*b^*$system.

Final Color Evaluation:

After 28 days of immersion period (figure 3), spectrophotometer recordings were taken. Colour change (ΔE) values were determined by using the Commision Internationale de l'Eclairage L*a*b* (CIELab) colorimetric system. The colour difference (ΔE) values was evaluated by calculating the difference in colour by using spectrophotometer.

$$\Delta E\ (L^*a^*b^*) = [(L^*1-L^*2)^2 + (a1^*-a2^*)^2 + (b1^*-b2^*)^2]^{1/2}$$

Where, numbers '1'and '2' refer to the colour coordinates before and after staining respectively.

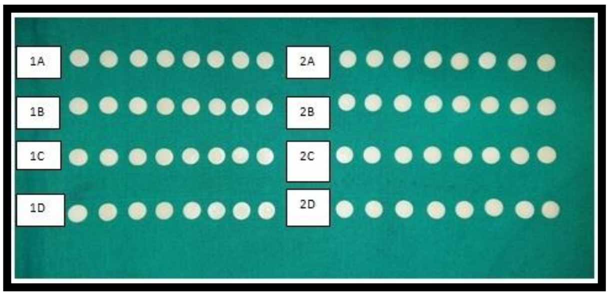

Figure 3: Samples after 28 days of immersion in staining solutions

The data was collected and analyzed using the statistical software SPSS 16.0. Descriptive statistics were calculated for each variable of the groups. ANOVA One way test was used for mean comparison of color change (ΔE) among the subgroups. Tuckey's Post Hoc test was applied for mean comparison of color change (ΔE) between the sub groups and One Sample t test was applied for mean comparison of color change (ΔE) between subgroups and standard values. Independent sample t test was applied for mean comparison of color change between 2 groups. For analysis of data 5% level of significance was used.

3. Results

Color Change:

Figure 4 shows the comparison of color change (ΔE) among the sub-groups of polished group using ANOVA one way test. The result were found to be statistically significant ($p<0.05$) among the sub-groups of group 1. The order of color change in different sub-groups were as follows:

Sub-group D>Sub-group B>Sub-group C>Sub-group A

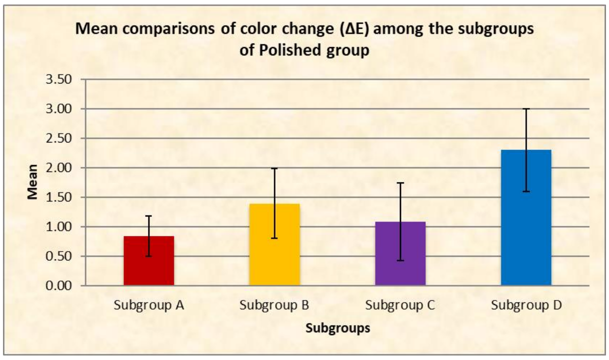

Figure 4: Comparison of color change among the sub-groups of polished group

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Table 2 shows the comparison of color change (ΔE) between the sub-groups of polished group using Tukey's post hoc test. The comparison results between subgroups A-D, subgroups B-D and subgroups C-D were statistically significant ($p<0.05$).

Table 2: Mean comparison of color change (ΔE) between the sub-groups of Polished group

Sub-groups	Mean	SD	Mean difference	p value
Sub-group A	0.84	0.34	0.55	0.254 NS
Sub-group B	1.39	0.59		
Sub-group A	0.84	0.34	0.24	0.842 NS
Sub-group C	1.08	0.66		
Sub-group A	0.84	0.34	1.46	0.000 S
Sub-group D	2.30	0.70		
Sub-group B	1.39	0.59	0.31	0.711 NS
Sub-group C	1.08	0.66		
Sub-group B	1.39	0.59	0.91	0.023 S

Figure 5 shows the comparison of color change (ΔE) among the subgroups of glazed groups using ANOVA one way test. The results were found statistically significant ($p < 0.05$). The order of color change in different sub-groups were as follows:

Sub-group D>Sub-group B>Sub-group C>Sub-group A

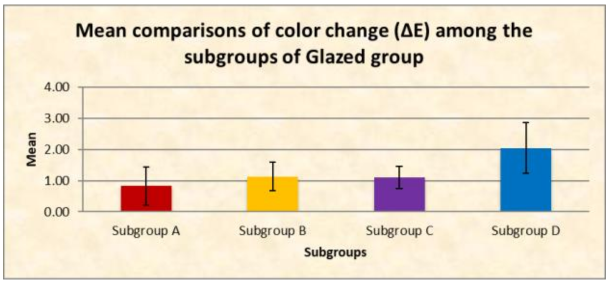

Figure 5: Comparison of color change among the sub-groups of glazed group

Table 3 shows mean comparison of color change (ΔE) between the sub-groups of glazed group using Tukey's post hoc test. The comparison results between subgroups A-D, subgroups B-D and subgroups C-D were statistically significant ($p<0.05$).

The comparison of color change (ΔE) between polished and glazed groups using independent sample t test were found to be statistically insignificant ($p>0.05$).

Table 3: Mean comparison of color change (ΔE) between the sub-groups of Glazed group

Sub-groups	Mean	SD	Mean difference	p value
Sub-group A	0.83	0.61	0.30	0.743 NS
Sub-group B	1.13	0.46		
Sub-group A	0.83	0.61	0.27	0.799 NS
Sub-group C	1.10	0.36		
Sub-group A	0.83	0.61	1.22	0.001 S
Sub-group D	2.05	0.82		
Sub-group B	1.13	0.46	-0.03	1.000 NS
Sub-group C	1.10	0.36		
Sub-group B	1.13	0.46	0.92	0.019 S
Sub-group D	2.05	0.82		
Sub-group C	1.10	0.36	0.95	0.015 S
Sub-group D	2.05	0.82		

4. Discussion

The present study evaluated the effect of exposure to betel leaves with slaked lime, areca catechu and tobacco on the color stability of CAD-CAM monolithic zirconia restorations using spectophotometric analysis. Optical properties, color stability and translucency throughout the functional lifetime of a restoration are important parameters because color and translucency affect the esthetic outcome of ceramic restorations. Polishing and glazing are two common surface treatment methods to improve the esthetic appearance of ceramic restorations. The milling process induces surface and subsurface damages in CAD/CAM ceramics. The finishing and polishing protocols aim to create a smooth and shiny surface with optical properties similar to those of natural enamel.[12]

Dental restorations are exposed to coloring agents from various nutrition and beverages in the oral cavity.[17] The color change is clinically important and can be measured using visual and instrumental means. The present study utilized reflectance spectrophotometer (Konica Minolta) which uses the CIE Lab (CIELAB) color system.

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Although there was statistically significant color difference between sub groups A-D, B-D and C-D of both polished and glazed groups due to different staining potential of immersion solutions but ΔE value for all the sub-groups was at an acceptable level (ΔE <3.7). This was in accordance to study conducted by Gawriolek et al.[18] who reported that different groups of lithium disilicate ceramics demonstrated color change below the clinically perceptible level (ΔE<3.7) when immersed in commonly consumed beverages like coffee, black tea and red wine.

Derafshi et al.[13] documented that both monolithic zirconia and feldspathic porcelain underwent color changes after immersion in Chlorhexidine and Listerine® mouthrinses. The color changes of both materials were within clinically acceptable ranges and not visually perceptible. It was hypothesized that high physical properties in the zirconia group, may influence relative color stability of the material compared to feldspathic porcelain. However both materials included grain and small particles which might reduce surface roughness and susceptibility to discoloration. In addition, the crystalline structure of zirconia might decrease color changes compared to the feldspathic groups which contained more glass matrix.

Sulaiman et al.[19] investigated the surface topography and optical properties of monolithic zirconia after immersion in simulated gastric acid and reported that there is minimum effect on zirconia's optical properties plus monolithic zirconia materials showed smoother surfaces after an acidic challenge.

Palla et al.[20] evaluated color variations of lithium disilicate ceramics after immersion in commonly consumed beverages and thermal cycling (TC). It was found that glazed samples conferred color stability in comparison to unglazed samples. This supports the fact that the rough surface of the unglazed pressed ceramic allows water infiltration and enhance in the absorption of coloring pigments. Whereas glazed-pressed ceramics, prevent the water penetration due to lack of surface irregularity and micro-cracks.

Alencar-Silvaet al.[21] reported that mean color change for both glazed and polished CAD-CAM lithium disilicate ceramic due to beverages was below the perceptibility threshold of 1.30.

In a systematic review by Alencar et al.[22], it was reported that both mechanical polishing and glaze application could prevent significant color variations in CAD/CAM ceramic surfaces. Also, coffee and red wine proved to have the greatest pigmentation potential for ceramic materials.

Norbakhsh et al.[23] compared the color change of glazed and polished dental porcelain after 30 days of immersion in chlorhexidine (CHX). It was documented that both polishing and glazing confer optimal color stability to dental porcelain within the clinically acceptable range.

Patterson et al.[24] reported that glazed ceramics have a smoother surface and higher color stability compared to polished ceramics.

In contradiction to the results of the present study, Haralur et al.[17] reported that monolithic zirconia displayed least color stability as compared with lithium disilicate and bilayered zirconia when immersed in the tested discoloring agents. After immersion into solution of Chlorhexidine gluconate (CHG) coffee and tea ΔE values for MZ were 4.86 5.60 and 5.19 respectively. It was hypothesized that monolithic zirconia, without an overlaying ceramic veneer, is directly exposed to the water and body fluids and results in structural disintegration, surface roughness and the development of micro-cracks.

Based on the findings of the present study it can be clinically inferred that if the dietary habits of the patient already present a potential discoloration risk to the restoration, then the treatment option must take into consideration the appropriate type of material along with optimum surface treatment technique. Also on occasion, porcelain restorations require adjustment after insertion in circumstances that preclude reglazing. Roughness created by adjusting the porcelain must be polished to confer color stability similar to the glazed surface of the ceramic restorations apart from rendering it minimally abrasive to opposing natural tooth substance or restorative materials.

However, there are certain limitations in the study. The present in vitro study did not reflect clinical situations. In the current study artificial saliva was used to simulate an in vivo study. However, color change susceptibility might influenced by salivary pellicle and consumption of different foods and beverages. Polishing process was

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another limitation of the present study because this process is performed by a technician, and expertise of the technician can affect the results. Moreover, type and quality of polishing kits can affect the results. Future studies are required to assess the effect of longer storage times and different polishing kits and glazing procedures on color change of different types of dental porcelains.

5. Conclusion

Within the limitations of the study, the following conclusions can be drawn:

1. Both polished and glazed monolithic zirconia ceramic were stained when immersed in betel leaves with slaked lime and areca catechu solution, tobacco solution and combined mixture of betel leaves with slaked lime, areca catechu and tobacco solution. However, there was no significant difference in staining observed for both polished and glazed groups.
2. The maximum staining potential was shown by combined mixture of betel leaves with slaked lime, areca catechu and tobacco solution followed by tobacco solution and least by betel leaves with slaked lime and areca catechu solution.

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