"A COMPARATIVE EVALUATION OF COLOUR STABILITY OF MONOLITHIC ZIRCONIA AND LAYERED ZIRCONIA CERAMICS AFTER IMMERSION IN COMMERCIALLY AVAILABLE MOUTHWASH AND FOOD SIMULATING LIQUIDS: AN IN-VITRO STUDY"

Dr. Anubhuti Dubey, Post Graduate Student, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Dr. T. Mohan Kumar, Former Professor and Head of the Department, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Dr. Indrakumar. HS, Professor and Head of Department, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Dr. Pragya Kotnala, Senior Lecturer, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Dr. Kirana S, MDS, Department of Prosthodontics Crown, Bridge and Implantology, Coorg Institute of Dental Sciences, Bangalore

Dr. Rajani Mamadapur, Post Graduate Student, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Corresponding author: Dr. Anubhuti Dubey, Post Graduate Student, Department of Prosthodontics Crown, Bridge and Implantology, College of Dental Science and Hospital, Rau, Indore

Abstract

Background: The aim of this study is to compare the colour stability of Monolithic Zirconia and layered Zirconia after immersion in commercially available mouthwash and food-simulating liquids (FSLs).

Material and Methods: 40-disc shaped specimen, 20 discs of each material with diameter of 10 mm and thickness 2 mm were prepared with CAD/CAM techniques following standard set protocols. Two groups, Group NA: Specimens fabricated from monolithic Zirconia (MZ), (UPCERA INDIA CAD ST, SHADE A2) 2. Group NB: Specimens fabricated from monolithic Zirconia veneered/layered with lithium Disilicate (LZ), (UPCERA INDIA CAD

ST, SHADE A2 veneered with IPS e.max) were divided into 4 sub-groups; All the samples were immersed in different staining solutions over a 28-day test period. Acolorimetric evaluation according to the CIE L*a*b* system was performed by a trained operator at 28 days of the staining process. Kruskal-Wallis and Mann Whitney U test were applied to assess significant differences among restorative materials.

Results: ΔE values for MZ with the immersion of saliva, mouthwash, coffee, cola were 0.4, 2.23, 4.98, 3.72 respectively. Corresponding ΔE values for LZ were 0.34, 0.84, 1.8 and 1.02; MZ has marginally higher values than the clinically acceptable level of 3.5 in coffee and cola.

Conclusion: Both monolithic zirconia and layered Zirconia underwent colour changes after immersion in FSLs and commercially available mouthwash.

Keywords: Colour stability, Monolithic Zirconia, Layered Zirconia, Mouthwash, Coffee, Cola

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Introduction: The increased demand for aesthetics in dentistry has led to changes in restorative treatment protocols utilizing new and improved restorative materials and techniques[1]. Zirconia exists in three allotropic forms i.e., monoclinic, tetragonal, and cubic structures, Yttrium stabilized tetragonal polycrystalline zirconia (Y-TZP) is most used because of its excellent biocompatibility and increased fracture resistance. In Y-TZP Zirconia, yttria (Y_2O_3) or cerium (CeO_2) is added as stabilizers. Y-TZP has a white opaque appearance and hence they are restricted mostly for posterior restoration. Thus, it needs to be veneered with a more translucent ceramic layer in areas requiring high aesthetics. Latest improvements in translucency and staining technologies have allowed researchers to mimic natural tooth colour. Several ceramic materials are currently used to veneer zirconia e.g., Lithium disilicate, feldspathic ceramic, fluorapatite, etc.

Lithium Disilicate ceramics are most veneered to zirconia to provide exceptional optical properties and strength. Other benefits of Lithium Disilicate include better edge integrity, less porosity, and net-like forming by pressing[4].

Absorption of external pigment or adsorption from the oral cavity is influenced by the composition and morphology of the surface ceramic materials[4]. Non-enzymatic browning and formation of pigmented metal sulphides of CHX is attributed to discoloration of teeth restorations[3]. The advent of the Anti-Discoloration CHX System has helped drastically reduce the appearance of brown spots that can form on teeth as a result of regular Chlorhexidine use, however, their effectiveness has not yet been sufficiently tested. Tea, coffee, and energy drinks, often stain restorative materials owing to their organic dye contents that either enter the nano pores of ceramics and polymers or adsorbs to the surface. Soft drinks contain different types of acids such as tartaric acid, lactic acid, maleic acid, and phosphoric acid. In addition to this they also contain various colouring pigments such as caffeine, caramel colour, etc. The synergistic action of acid and the dyes results in discoloration of the teeth or restoration. The harmful effect of soft drinks is determined by the acids present in it, i.e., drinks based on phosphoric acid cause more damage than citric acid-based drinks. CIE L*a* b* (Commission Internationale de l'Eclairage) system ensured quantitative representation of colour. The difference in colour before and after beverage insult can be calculated using Nickerson's colour difference formula which is as follows: $[\Delta E= ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{½}]$, where $\Delta L^*=L_1-L_0$; $\Delta a^*=a_1-a_0$; and $\Delta b^*=b_1-b_0$, where L_0, a_0, and b_0 are colour values measured before immersion.

Therefore, this in vitro study was planned to evaluate the colour change of the monolithic Zirconia and veneered monolithic zirconia after immersion in coffee, cola, and Chlorhexidine solutions.

Materials and Methods

Materials

Group N_A: Specimens fabricated from monolithic Zirconia (UPCERA INDIA CAD ST, SHADE A2)

Group N_B: Specimens fabricated from monolithic Zirconia veneered/layered with lithium Disilicate (UPCERA INDIA CAD ST, SHADE A2 veneered with IPS e.max)

40-disc shaped specimen, 20 discs of each material with diameter of 10mm and thickness 2mm were prepared with CAD/CAM techniques following standard set protocols.

Food simulating liquids - Artificial Saliva, 0.2% Chlorhexidine ADS (CLOHEX ADS, DR. REDDY'S LAB, INDIA), Coffee (NESCAFE CLASSIC, NESTLE INDIA Ltd., MYSORE, INDIA), Cola (COCA COLA, HINDUSTAN COCA COLA BEVERAGESPVT Ltd., PUNE).

Armamentarium

For sample fabrication: - CAD/CAM and milling unit, CAD/CAM Zirconia blank, Silicon carbide paper.

For testing: Spectrophotometer (VITA Easy shade Advance 4.0)

Miscellaneous: Distilled water, Graduated closed containers, Blotting paper

Methodology

Fabrication of Samples by CAD/CAM System: The group A, 20 Monolithic zirconia discs were milled from pre sintered blank using CAD/CAM system. The milled specimens of diameter 10mm and thickness 2mm were fired at 1450 C for 6 hours and trimmed. A standardized polish was performed using wet 320-400-600-800-1200 grit silicon carbide paper. The polished specimens were ultrasonically cleaned with distilled water for 5 minutes. For group B - 20 core specimen for veneered/layered Zirconia was fabricated following similar process to that of monolithic Zirconia. One side of Zirconia core was covered with lithium Disilicate veneer with a layering technique following the manufacturer's instructions. The thickness of the veneering glass ceramic was kept at 1mm for all the samples and was confirmed with digital calliper.

Method of Study: The samples from each ceramic material were randomly divided into two groups. Each group was divided into four subgroups each depending on the staining solutions (artificial saliva, coffee, cola, Chlorhexidine). Both groups had 20 samples each with 5 specimens in each immersion media (subgroups). So, all the samples were ultrasonically cleansed and dried with blotting paper before storage in the immersion media.

The coffee staining solution was prepared by adding 15g to 300ml of boiled distilled water. For the purpose of immersion, 0.2% Chlorhexidine gluconate oral mouthwash was used. The initial values of L, a, b for each group and subgroup was noted before immersing in the staining solutions with the dental spectrophotometer. Then the ceramic discs were immersed in 15ml of test solution for 28 days at a controlled temperature of 37±10ºC in a dark environment in an incubator. The test solutions were changed daily and stirred once every 12 hours to maintain homogeneity of solution. After immersion period of 28 days, the samples were taken out from solution, rinsed with distilled water and blot dried with blotting paper.

Sample Testing: A dental spectrophotometer was used to record the CIELAB factors (L, a, b) of the specimens. L* represents the lightness between 0 (black)-100 (white), a* represents the point on a red-green scale, and b* on a yellow-blue scale. The colour differences (Δ E) between two objects can be determined by the equation: $\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$, where ΔL* is the variation of L*, Δa* is the variation of a*, and Δb* is the variation of b*. ΔL∗ = (L black – L white), Δa∗ = (a black – a white), Δb*= (b black – b white).

On each occasion, the disc colour is measured three times against a light background. The average value from 3 repeated colour measurements will be considered the colour of the disc. The data was entered into the excel sheet. The data was analysed using SPSS (Statistical Package for Social Sciences) 20.0 version. The nonparametric Kruskal Wallis test was applied which shows that the mean value of ΔE of four different subgroups ($P<0.05$).

Individual subgroups comparison was performed by Mann-Whitney U test as Post Hoc test for non-parametric variables.

Results and Observation: This in – vitro study was planned to investigate the effect of FSLs and commercially available mouthwash on the colour stability of monolithic Zirconia and veneered zirconia. Statistically significant difference was found among the materials regarding the outcome of spectral properties. To investigate the effects of independent variables (FSLs and mouthwash) on the dependent variables (ΔE) were performed by Kruskal Wallis test for intergroup comparison and Mann-Whitney U Test for intragroup comparison.

The null hypothesis (H0): There is no significant difference in the colour stability of monolithic Zirconia and layered Zirconia ceramics. There is no significant effect of immersion in artificial saliva, food simulating liquids and commercially available mouthwash on colour stability of monolithic zirconia and layered zirconia ceramics.

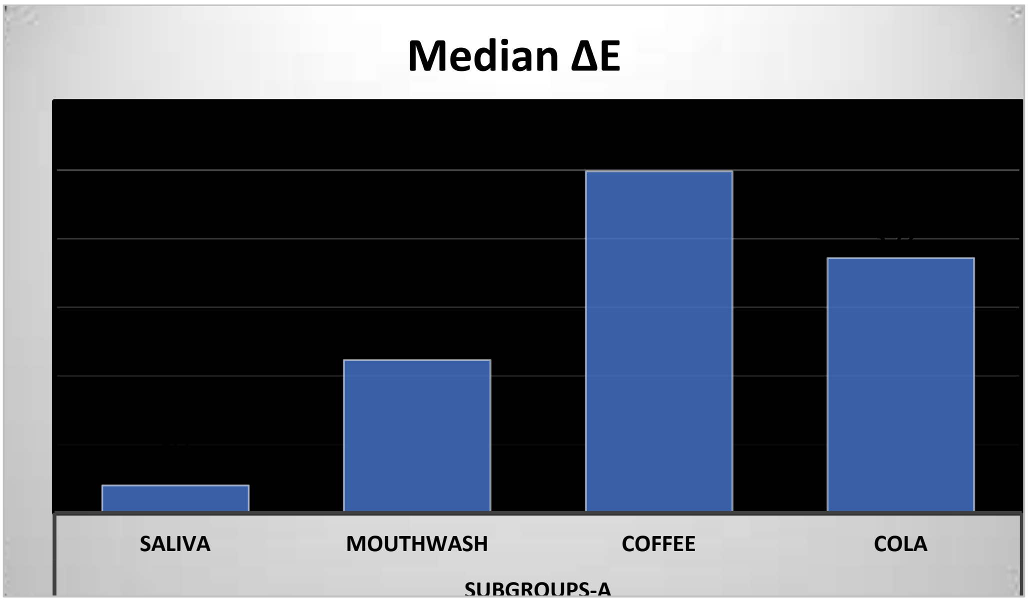
The Alternative Hypothesis (H1): There is significant difference in the colour stability of monolithic Zirconia and layered Zirconia ceramics. There is significant effect of immersion in artificial saliva, food simulating liquids and commercially available mouthwash on colour stability of monolithic Zirconia and layered Zirconia ceramic.

There is difference between the colour stability of monolithic Zirconia and layered Zirconia. There is effect of FSLs and commercially available mouthwash on colour stability of monolithic Zirconia ceramics. There is effect of FSLs and commercially available mouthwash on colour stability of layered monolithic Zirconia ceramics. There is difference between the colour stability of monolithic Zirconia and layered Zirconia on exposure to FSLs and commercially available mouthwash. Once the results obtained were analysed, the alternative hypothesis was accepted and the null hypothesis was rejected as significant differences were found among the groups based on the results of colour stability.

Subgroups-A		**N**	**Mean Rank**	**Median**	**Kruskal-Wallis H**	
Δ E	Subgroup A – Saliva	5	3.00	0.4	Value	17.331
	Subgroup A - Mouthwash	5	8.40	2.23	Df	3
	Subgroup A –	5	18.00	4.98	P Value	0.001

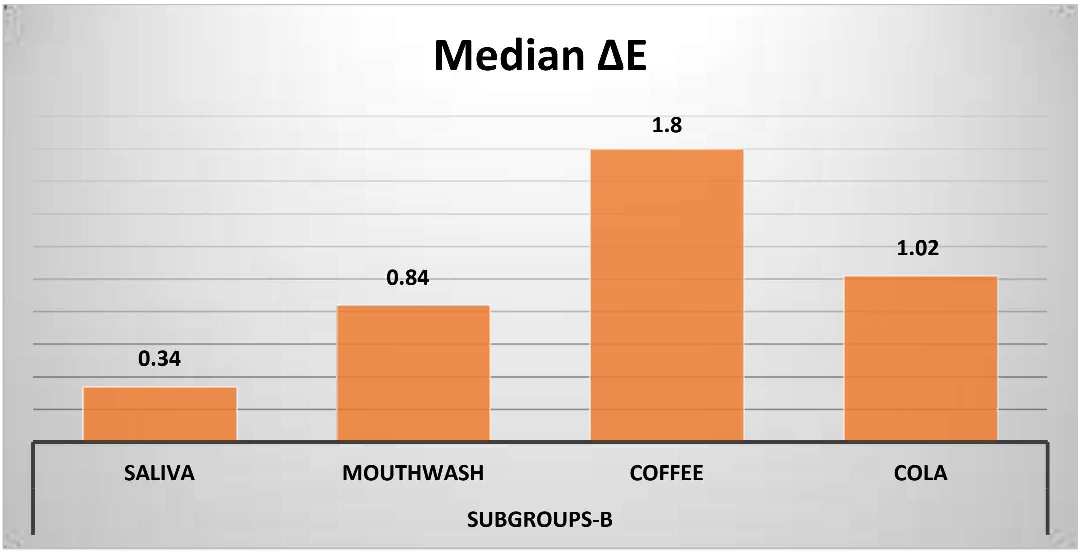
	Coffee					
	Subgroup A – COLA	5	12.60	3.72	Significant	
	Total	20				

Table 1 - Comparison of Mean value of ΔE among Subgroups of Group A



Subgroups-B		N	Mean Rank	Median	Kruskal-Wallis H	
Δ E	Subgroup B - Saliva	5	4.00	0.34	Value	11.594
	Subgroup B - Mouthwash	5	9.80	0.84	Df	3
	Subgroup B - Coffee	5	16.60	1.8	P Value	0.009
	Subgroup B – COLA	5	11.60	1.02	Significant	
	Total	20				

Table 2 - Comparison of Mean Rank among Subgroups of Group B



Discussion: Since decades, fixed dental prostheses (FDPs) are the treatment of choice to restore function and aesthetics, after loss of a single tooth when implants cannot be placed due to anatomic restrictions. Long-term clinical data on metal–ceramic FDPs are available and reveal excellent survival rates even after observation periods exceeding 10 years[28]. Lately, all-ceramic materials are of growing importance in restorative dentistry, as they provide superior aesthetics due to their tooth-like colour and translucency, high biocompatibility and are of lower cost compared to precious alloys.[29] With the introduction of advanced computer-aided manufacturing /computer- aided design (CAD/CAM)technologies various high-strength ceramic materials have evolved and are increasingly being used for anterior and posterior FDP situations.[29, 30] The success of dental restoration depends on their ability to restore function and aesthetics. Accurate colour matching to adjacent teeth, along with other aesthetic goals such as position, texture, and contour, are critical to a good aesthetic outcome. Due to the deeper translucency near the natural tooth, allceramic restorations are preferred in the anterior region[4]. The stability of the introduced colour is decisive for the long-term success of prostheses. In order to interpret the influence of frequently consumed beverages such as coffee, tea, and chlorhexidine mouthwash on the colour fastness of the ceramic samples before and after immersion in above mentioned FSLs with a spectrophotometer. The spectrophotometer was used for colour measurement because it offers better accuracy, numerical representation of colour, and is free of subjective bias [4,5,6]. Colour in this study was expressed in CIELAB because it includes all perceptible colours and was developed to serve as a device-independent reference. The "L" coordinate represents the lightness of the colour, while "a" and "b" indicate the chromatic range of green-red and blue-yellow respectively. Since the three coordinates are measured independently, it allows the measurement of an infinite number of possible colours in the three-dimensional space of real numbers [6]. Based on the results of this investigation, the null hypothesis that there is no significant difference in the colour stability of monolithic zirconia and veneered zirconia after immersion in food simulating liquids and commercially available mouthwash was rejected. According to the previously established standards, an ΔE between 1–3.3 units represent an important difference, but it is clinically acceptable; however, an ΔE > 3.3 is perceivable even by an untrained observer and is considered unacceptable [44,45]. Our results indicated that most colour changes were detected when the zirconia samples were immersed in coffee (ΔE > 3.3 was observed for some samples).Surface disintegration of ceramics depends on material composition, manufacturing methods, surface treatment and measurement methods. Palla et al.[1] found Coffee caused the least discoloration of pressed glazed lithium disilicate e-max restorations. They also reported that the rough surface of unglazed pressed ceramics allows water infiltration and subsequent disintegration of the silica network. This leads to reduced crystallinity and increased absorption of colour pigments. While glazed pressed ceramics, thanks to the absence of surface irregularities and microcracks, prevent water penetration and dissolution of the silica network. The conclusions from their study were consistent with the results of our study. Gawriolek et al.[57] reported a similar IPS e-max mean colour parameter after soaking in coffee for 72 hours at 1.71. Alencar-Silva et al.[67] reported a mean colour change for both glazed and polished CAD-CAM lithium disilicate ceramics caused by beverages that is below the perceptibility threshold of 1.30. The findings of this study showed that monolithic zirconia was susceptible to greater staining from coffee, cola, chlorhexidine ADS and artificial saliva. The corresponding ΔE values were 4.98, 3.72, 2.23 and 0.4, respectively. These results are congruent with those of Kurt et al.[63] who showed that colour changes due to aging are higher for monolithic zirconia. They also found that lithium disilicate ceramics were more aesthetically pleasing in terms of colour stability and translucency. Monolithic zirconia (LTD) by a phase transformation from a tetragonal to a monoclinic structure [60,61]. The phase transformation to monoclinic resulted in a 4% increase in volume; it subsequently results in structural disintegration, surface roughness and the formation of microcracks. Manufacturers of monolithic zirconia reduce the alumina content to improve its translucency. Fathy et al.[62] suggest that the alumina content is responsible for the resistance to degradation at low temperatures. They reported that monolithic Zirconia is more prone to low temperature degradation (LTD) than core zirconia due to lower alumina content. Surface porosity due to monoclinic phase transformation also increases incident light scattering and reduces translucency. LZ with lithium disilicate veneering ceramics showed less discoloration across the entire storage solution compared to monolithic zirconia. The corresponding ΔE values of coffee, cola, Chlorhexidine ADS and saliva were 1.8, 1.02, 0.84 and 0.34, respectively. Prior reports[64] have also shown that the surface texture of the finished restoration affects colour stability, hence researchers advocate polishing or glazing to achieve a smoother surface and to improve the colour stability. The mean colour change observed with layered/veneered Zirconia in the present study was less than 3.5. Previous research suggests that colour changes (ΔE) less than 3.5 are indiscernible and clinically acceptable. The monolithic zirconia showed mean colour changes that were marginally higher than the clinically acceptable level.

The limitation of the present in vitro study is:

i. The samples were not subjected to thermocycling regimen and hence was unable to simulate real time oral conditions.
ii. The complementary effects of brushing, micro-surface roughness and colouring agents in nutrition were not considered in the study.
iii. Only one thickness of the material was evaluated. Factors such as cement shade, dentin colour, different thickness, etc should be investigated.
iv. Additionally, the study did not include the effect of UV light on the discoloration process. Further studies are recommended to evaluate the effect of sunlight exposure, salivary proteins, nutritional colouring agent, and smoking on the colour stability of all-ceramic restorations.

Conclusion: Within the limitations of the present study, it may be concluded that both monolithic zirconia and layered Zirconia underwent colour changes after immersion in FSLs and commercially available mouthwash. Discoloration from coffee was more significant in monolithic Zirconia as compared to layered/veneered Zirconia followed by discoloration due to cola. Majority of the layered/veneered Zirconia specimen presented slight colour changes ($\Delta E<2$).

Hence, layered Zirconia displayed better colour stability than monolithic Zirconia among all the tested discolouring agents.

Summary: The present study was done to comparatively evaluate colour stability of monolithic Zirconia and layered Zirconia ceramics after immersion in commercially available mouthwash and food simulating liquids.

For both the groups, the greater ΔE was observed after immersion into the coffee followed by cola and Chlorhexidine gluconate. No significant colour change was observed in samples immersed in artificial saliva.

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