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To Evaluate and Compare the Effect of Number of Firings on the Color Stability of All-Ceramic System Using a Spectrophotometer: An in Vitro Study

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Abstract:
Background: Ceramic restorations have been advocated for superior esthetics, and various materials have been used to improve ceramic core strength, but there is a lack of information on how color is affected by fabrication procedures. This study was designed to compare the effect of no. of firings on color stability in all ceramic restoration.
Methods and materials:
Thirty-disc shaped specimens were made of 7mm diameter with 2mm thickness (All-ceramic- ivoclar IPS e-max press). Repeated firing cycles (5, 7, or 9) was performed, and associated color change was compared. Color differences among the specimens was measured using a spectrophotometer. A portable reflectance spectrophotometer is used. Values of the color change are recorded in the CIELAB color system. Data expressed in Commission Internationale de 1'Eclairage (CIE)LAB system coordinates. The CIELAB color space provides L*a*b* values for each sample. Statistical analysis of data was done to draw conclusions.
Result: The L*a*b* values of all ceramic system were affected with increase number of firings (5,7,9) on veneering porcelain material. L* value non-significantly increase. For veneering porcelain, the a* value decreased after repeated firings and the b* value decreased after repeated firings.
Conclusion: Too many firings give a lifeless over translucent porcelain in a clinical situation, a comparative analysis will help a clinician to choose a restoration that is best suited for a patient and which will also restore the esthetics.
Key words: All ceramic crowns, Esthetics, Firing

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I. Introduction:

The main considerations for people who seek prosthetic treatments is esthetics. The appearance affects the dental as well as the overall facial esthetics. There is a need to restore the color naturally, focus on the translucency and have a good relationship with the facial appearance. [1] An essential aspect of this is shade. The challenge for a clinician is not only the functional aspect but also the longevity and esthetic part. Ceramic crowns are the best answer to this. Ceramics have a long history in fixed prosthodontics for achieving optimal esthetics. Yttria-stabilized tetragonal zirconia(Y-TZP) is gaining use in dentistry due to its good mechanical properties and superior biocompatibility. It is currently used as core material in all ceramic dental restorations, implant superstructures, and orthodontic brackets. Its superior mechanical properties compared to other dental ceramics, such as higher strength and fracture toughness, which are due to the transformation toughening mechanism, are similar to that observed in quenched steel. Ceramics have certain issues like chipping of the ceramic, metal exposure, lack of translucency. Some of them may cause “Graying” of the gingival margin also. So, this challenges the regular usage of the material. [2] Heat- pressed ceramic restorations are an answer to this since they create a much better-quality esthetic result. The translucency which this material provides minimizes the shadowing of the gingival. Studies are seldom reported on the way of manipulation of the material especially in terms of firing and its effect on the color stability of the material on the long run. [3] Many factors like color, light source, the core material, the natural shade of the tooth, the post in the root, luting cement used affects the overall esthetics.[4] Ceramic restorations have been advocated for superior esthetics, and various materials have been used to improve ceramic core strength, but there is a lack of information on how color is affected by different core substructures and fabrication procedures. Color matching between a restoration and natural teeth is a common clinical problem. Despite of careful shade selection, color of the restoration may be affected by fabrication procedure. According to Rosenstiel And Johnston (1998)[5] study, restoration conducted from different kinds of porcelain showed significant color difference, while parameters such as firing temperature and condensation technique have little impact on the color of porcelain. The purpose of this an in vitro study was carried out to evaluate the effect of repeated firings on color stability of all ceramic (IPS e-max ® Ivoclar, Vivadent, Lichtenstein) using a reflectance spectrophotometer.

II. Materials and Methods

The study was carried out in the Department of prosthodontics and was prior reviewed and approved by the ethical committee. Thirty discs shaped specimens are made, (figure 1) 7mm diameter with 2mm thickness of All-ceramic (Ivoclar IPS e-max press) (n=30). The shade employed for fabrication of specimens was A2. Shade from the group of a shade guide (VITA Classical Shade Guide; VITA Zahnfabrik) was selected, as this group accounts for at least 65% of clinical shade selections. (figure 2)

Figure 1 All Ceramic Specimens (n=30)

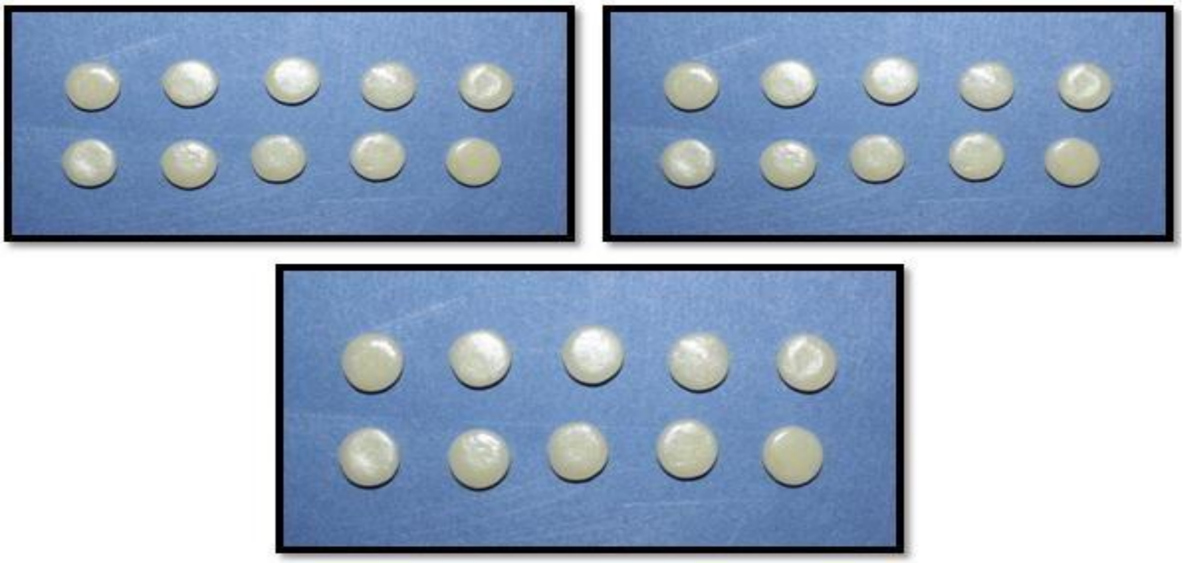

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Figure 2 **All Ceramic –IPS e-max Ceram (IvoclarVivadent) (Shade A2)**

III. Fabrication of specimen:

In disc shaped specimen, the core thickness and the veneering thickness was kept constant at 0.5 mm and 1.5mm as given in literature and recommended by the manufacturer. Metal dies (figure 3) were fabricated to facilitate standardization of core thickness. After the cores were finished, a micrometer of 1µm sensitivity was used to ensure the accuracy of the core thickness. An instrument (specially fabricated for die) was made to help in veneering of the cores (figure 4). The internal diameter was wider of the first piece by 30% i.e 1.5 mm to compensate for volumetric shrinkage. The cores were placed in the hollow of the instrument and lowered to a required depth. The veneering was carried out by dentin and enamel ceramic as dentine determined the tooth color and enamel scattered at wavelengths in the blue range. The discs were then fired according to the respective manufacturer's recommendation. The fired discs did not have an even smooth surface, so the veneered surface was finished flat at the thickness of correct dimension (2mm) with a diamond impregnated finishing point of 25µ grit. Specimen was checked with digital Vernier caliper (Mitutoyo, Japan) (figure 5) for the desired thickness. As the desired thickness was achieved, specimens were cleaned, and glazing was done and tested.

Figure 3 **Die (I) For Core Fabrication**

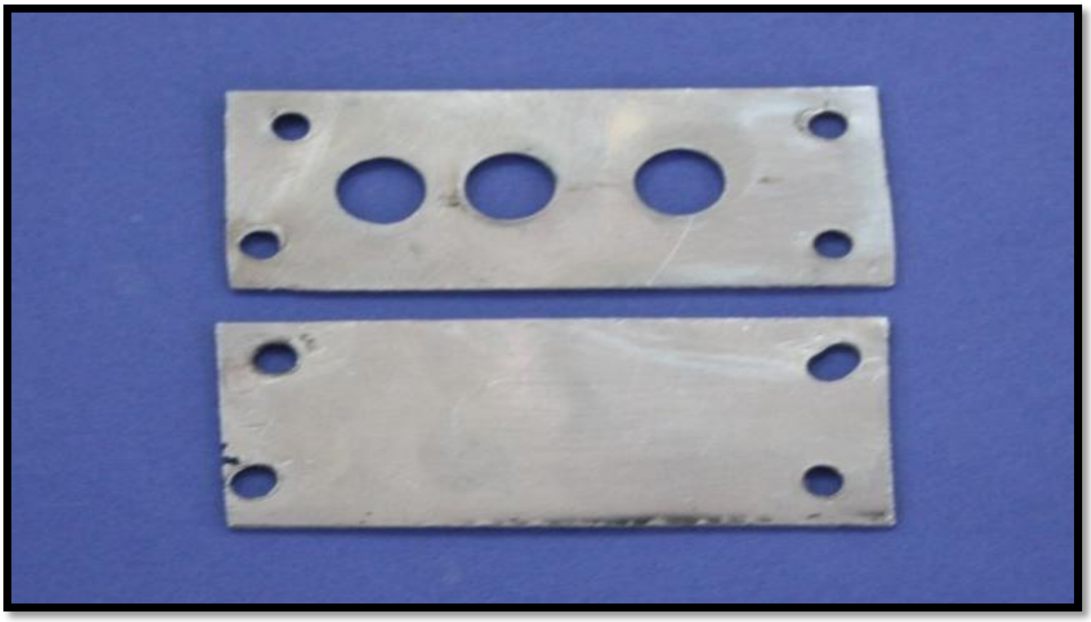

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Figure 4 Specially Fabricated Stainless-Steel Die (II) For Veneering

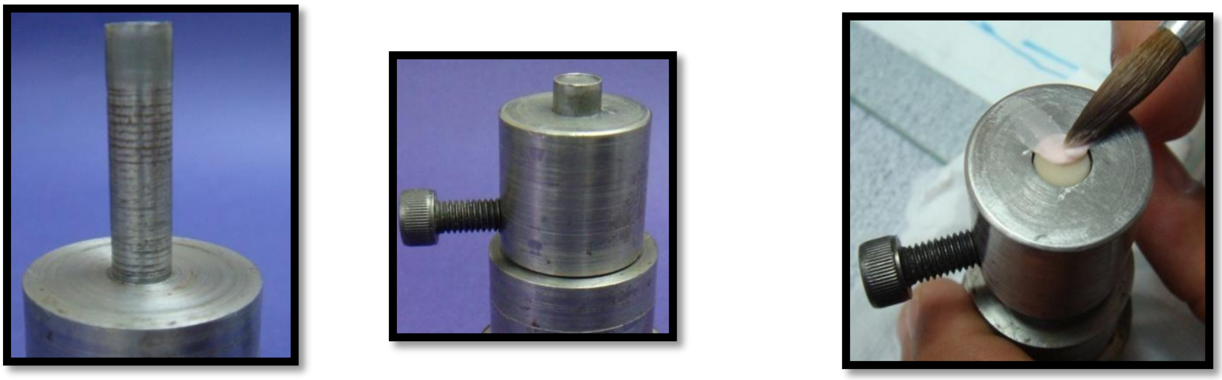
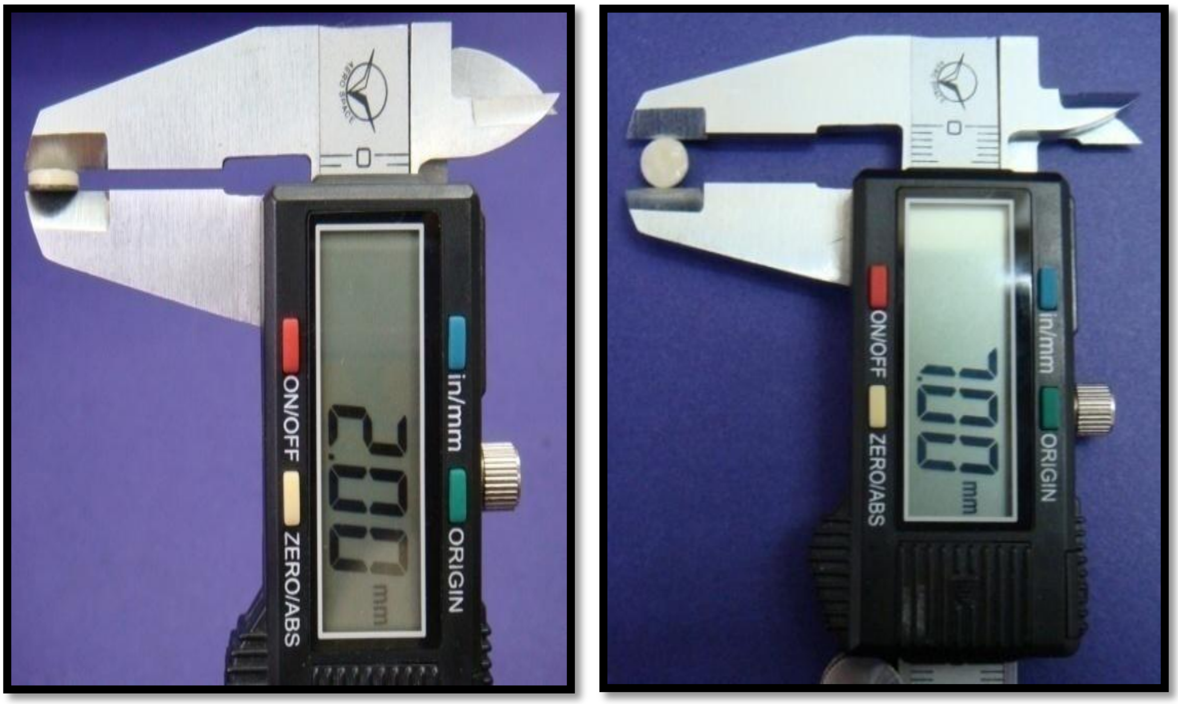


Figure 5 Dimensions of The Specimen (Thickness & Diameter)



IV. Color measurement and statistical analysis:

The color of each specimen was measured with a reflectance spectrophotometer (techkon Gmbh, Germany) (figure 6) using D45 illumination standard and a 100 observer. The CIE lab units (L* a* b* values) were recorded and were used for subsequent comparisons. 30 samples were fired 9 times and 3 set of readings were available of each group and that is at the end of 5,7 and 9 firings. Quantity of color change (ΔE*) was calculated each time. The total color difference (ΔE*) of each specimen was calculated with the following equation:

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

The readings obtained were statically analyzed and mean and standard deviations were calculated. The results of the testing were analyzed with statistical software (SPSS, PC, Version 17.0; SPSS, Inc, Chicago, IL, USA). Repeated measurements of the data (number of firings and ceramic thicknesses) were analyzed with analysis of variance (ANOVA) for significant differences. Bonferroni post hoc test was used to perform pairwise comparisons (α=.05). The results of the testing were analyzed with statistical software (SPSS, PC, Version 17.0; SPSS, Inc, Chicago, IL, USA). Repeated measurements of the data (number of firings and ceramic thicknesses) were analyzed with analysis of variance (ANOVA) for significant differences. Bonferroni post hoc test was used to perform pairwise comparisons (α=.05).

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Figure 6 Portable Reflectance Spectrophotometer-Techkon

V. Results:

Results of the testing were analyzed with statistical software (SPSS, PC, Version 17.0; SPSS, Inc, Chicago, IL, USA). Repeated measurements of the data (number of firings and ceramic thicknesses) were analyzed with analysis of variance (ANOVA) for significant differences. Bonferroni post hoc test was used to perform pairwise comparisons (α=.05).

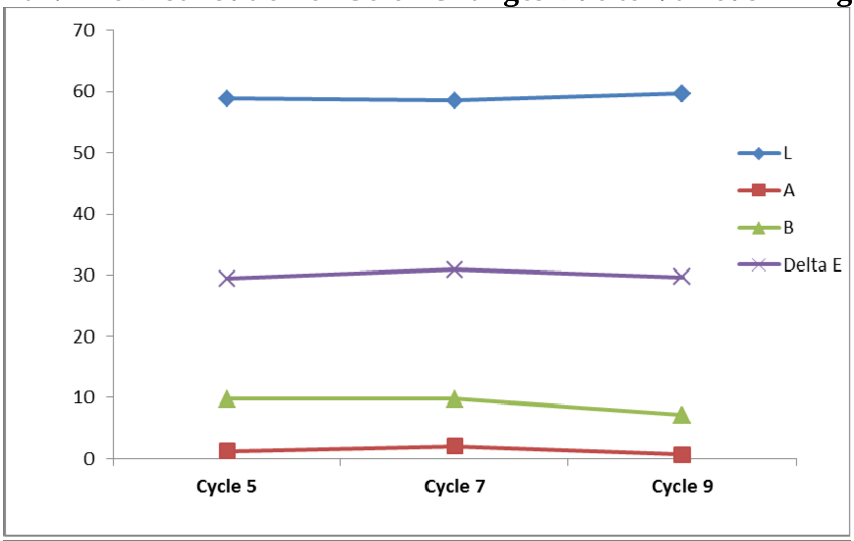
An increase in number of firings resulted in significant increase in L*, a and b values from cycles 5 to 9 firings. There was no significant change seen with that of the L values between cycles 7 and 9 firings. Overall, there was an appreciable change seen from the baseline to the cycles 7 and 9 firings. The mean E value was the least with cycle 5 and increased with cycle 7 (Table 01, Graph 01).

Table 01: The distribution of color changes with varying number of firing cycles

	All Ceramic (A)			**P-values**		
System co-rdinates	**Cycle 5**	**Cycle 7**	**Cycle 9**	**5 Vs 7**	**5 Vs 7**	**5 Vs 7**
L	58.8±1.7	52.6±1.4	50.3±0.9	0.04*	0.04*	0.04
a	1.3±0.07	2.1±0.6	0.73±0.1	0.001*	0.003*	0.001*
b	9.8±0.7	7.9±0.7	7.2±1.1	0.01*	0.001*	0.001*
ΔE	29.4±1.6	30.9±1.4	29.7±0.8	0.050*	0.873	0.138

*Denotes significant difference.

Graph 01: The Distribution of Color Changes Due to Various Firing Cycles



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VI. Discussion:

Veneering of Pressable all-ceramic is favored for greater esthetics. Furthermore, the opacity of all core specimens increases after veneering because of the structure of the veneering porcelain, increased specimen thickness, reflectance at the interface between core and veneering porcelain, porosity between the layers, and any changes in the constituent core material with additional firing cycles.[6] The ultimate translucency of the core and veneer system is important for optimal esthetics. Ceramic translucency can be affected by thickness, crystalline structure, and number of firings. Reduced crystalline content and a crystal refractive index close to that of the matrix cause less scattering of light. [7]Douglas and Przybylska tried to predict the ceramic thickness to get the desirable color for Vintage and VMK 95 porcelain. [8] They were reported that the thickness of ceramic is less or equal to 2mm in all the porcelain systems to have better color match. While 2mm corresponds to the thickness that would be achieved after an adequate tooth reduction at the occlusal and incisal surfaces. It involves core thickness (0.5 mm) [9, 10]and the veneering thickness (1.5mm) as given by the manufacturer. [11] For fabrication of the specimens, the manufacturers' recommendations[5] were followed. Core thickness and veneering thickness were kept constant as the thickness is one of the confounding factors and has major effect on the color of restoration. Color can be evaluated with various instruments as well as by visual assessment. Barnagi et al stated that by visual assessment, variability may result due to several factors including observed object, illuminant position relative to the observer and to each other, color characteristic of the illuminant, metamerism, fatigue, aging and emotional state of the observer. [12] According to another study the influence of the background substrate on the definitive appearance of ceramic specimens is well established. [13]Neutral white was selected as a background to minimize the influence of background hue on the color measurement of the specimens. [14] Results of the current study indicated imperceptible color changes for the tested all ceramic subjected to a repeated number of firings. The first firing serves to eliminate micro-cracks and release the stresses associated with grinding and polishing procedures, as recommended by the manufacturers. The second and third firings are necessary steps for producing the restoration using the staining or layering technique. The fourth and subsequent firings are necessary when shape and color corrections are needed. After the third firing, an all-ceramic restoration is ready for installation in the mouth by the dentist. The additional 4 firings were assumed to be necessary only if the dentist needs further shape and color corrections.[15]Mulla and Weiner, concluded that marked color changes occurs due to repeated firings compared to the initial firing of porcelain stains. [16] Another investigation on the effect of multiple firings on to flexural strength of zirconia ceramics reported that three firing processes significantly increased the strength. They suggested that to do 3 times baking instead of one baking, and also added that 5 times baking would be applied to achieve better esthetics [17] and this did not significantly decrease the strength compared to 3 times baking.[18] Celik et al[19] reported that an increase in the number of firings resulted in a decrease in L* and an increase in a* and b* color values of In-Ceram and IPS Empress specimens with different veneering ceramic thicknesses. Antonson and Anusavice studied the effect of change in the thickness of ceramics on the contrast ratio of dental core and veneering ceramic and concluded that the contrast ratio was dependent on the type of the material tested. [20] Gonuldas evaluated effects of repeated firings on the color stability and surface roughness of zirconia ceramics. They reported that increased number of firing caused to more rough surfaces and differentiation in the color. The authors concluded that the technicians should avoid multiple baking processes, when manufacturing the restorations. [21] Yilmaz investigated effects of different number of firing and various polishing techniques on the color features of all ceramic restorations. They found that the multiple firings caused to transformations in the crystalline structure. Thus, the authors reported that differentiations in the color of restoration might occur regardless of polishing techniques. [22] Heffernan et al. described the influence of core material thickness on its translucency and the influence of core plus ceramic veneer thickness on the overall translucency of specimens. In our study, we believe that the thickness of the layered ceramic influenced the final shade, partially due to the translucency, as the thicker ceramic disks were less translucent. In the current study, repeated firings resulted in a statistically non-significant increase in L* value but significant decrease in a* and b* resulted in less reddish and yellowish specimens for the veneering porcelain A2 shade. Results of Celik G et al [19] study investigating the color changes of a zirconia ceramic system with 2 different veneering porcelain shades

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after repeated firings indicated an increase in the L* value and a decrease in the a* value for both A1 and A3 veneering porcelain shades, resulting in lighter and greener specimens; however, the b* value was not influenced by the number of firings for the A1 veneering porcelain shade and increased for the A3 veneering porcelain shade, resulting in more yellowish specimens. The differences between these 2 previous studies and the current study may be attributed to the optical properties of different core materials, as a zirconia ceramic system was found to be the least translucent ceramic system and opaquer than the IPS e-max system. In addition, the VITA instrument usedin the current study, which was found to have both reliability and accuracy values greater than 90%, may be sensitive to translucency changes, and some change may be related to the vitrification of the veneering porcelain. As the porcelain is fired, its translucency may change, and the measurements may be slightly altered. The result of our study suggests that L*a*b* values of the ceramic systems were affected by the number of firings (5, 7, or 9 firings) and veneering porcelain materials. The translucency of the specimen is increasing, and opacity is decreased. Overall, the specimen becoming lighter than the desired shade due to repeated firings. Color change after repeated firings may also be attributed to the color instability of metal oxides during firing, which can affect the resulting color of ceramic. Ceramic consists of pigments and opacifiers. Pigmenting oxides are added to obtain various shades needed to simulate natural teeth. The pigments are prepared by fusing metallic oxides together with glass and feldspar. Different coloring pigments used in dental porcelain are iron /nickel oxide (brown); copper oxide (green); titanium oxide (yellowish brown); manganese oxide (lavender) and cobalt oxide (blue). Opacity may be achieved by the addition of cerium oxide, zirconium oxide, titanium oxide or tin oxide. Several studies have suggested that certain metal oxides are not color stable after they are subjected to firing temperatures.[23, 24] Studies examining color changes of surface colorants after firing have demonstrated pigment breakdown at firing temperatures. IPS e-max® Press, Ivoclar vivadent has an unusual microstructure. Lithium disilicate ($Li2Si2O5$) consists of many small interlocking plate-like crystals that are randomly oriented. This ceramic is highly translucent due to optical compatibility between the glassy matrix and the crystalline phase, which minimizes internal scattering of light as it passes through it. Zirconium oxide and other oxides are added as opacifiers. A varying percentage of these opacifiers in the ingots could be the reason for varying color differences between the groups and so varying shade reproduction.[25] Crispin et al and Lund et al[23, 24] reported that yellow- and orange hued stains were the least color stable at the manufacturers' recommended firing temperatures. However, Mulla and Weiner [16] reported that blue was the most unstable stain, while orange demonstrated the greatest color stability at higher firing temperatures. Clinical success and color stability of ceramic restorations depend on laboratory and clinical variables. Ceramic systems in this study exhibited color differences that could not be detected by the human eye under firing conditions following the manufacturers' instructions. Finally, ceramic restorations should be luted to the tooth substrate using a luting agent with a shade and thickness that contribute to the aesthetic appearance of the restorations. Therefore, further studies on the interaction of ceramic materials with luting agents and other substrates are needed.

VII. Conclusion

This in-vitro study was carried out to evaluate and compare the effect of number of firings on the color all-ceramic system. Within the limitations of this in vitro study, the following conclusion were drawn: Lesser the number of firings, higher is the strength and better is the esthetics. Too many firings give a lifeless over translucent porcelain. In a clinical situation, a comparative analysis will help a clinician to choose a restoration that is best suited for a patient and which will restore the esthetics also. Number of firings should be carefully considered to obtain an acceptable color match of the definitive restorations.

VIII. Limitations of This Study:

Although a strict protocol for sample fabrication and testing was followed throughout the study, following factors impose certain limitations on the study that include the in vitro use of a spectrophotometer to evaluate shade differences of only a single A2 shade (Vitapan Classic). The other shades available for ceramics also need to be tested for color stability. Furthermore, the specimens were disc shaped rather than crown shaped. Specimens used in this study were dry. The study was carried out extra orally.

Additional studies are needed to evaluate the color stability after repeated firings intraorally with the thin film of saliva and the effect of the various luting cements on the color stability of ceramic.

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