EGYPTIAN
DENTAL JOURNAL

VOL. 66, 2633:2639, OCTOBER, 2020

PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360

FIXED PROSTHODONTICS AND DENTAL MATERIALS

www.eda-egypt.org • Codex : 117/2010 • DOI : 10.21608/edj.2020.42266.1253

EFFECT OF MULTIPLE FIRING CYCLES ON THE PHYSICAL PROPERTIES OF THREE PRESSABLE LITHIUM SILICATE GLASS CERAMICS

Ahmed Shawky Ali Radwan*, Ingy Mohamed Nouh* *and* Ahmed Thabet*

ABSTRACT

Statement of the problem: To achieve esthetic perfection with dental ceramics, ceramic dental restorations may need to undergo multiple firing cycles for characterization. The behavior of lithium silicate ceramics when exposed to those firing cycles is not well understood, the way it might affect the optical and mechanical properties of restorations.

Purpose: The aim of this in-vitro study was to investigate the effect of multiple firing cycles on translucency and biaxial flexure strength Of 3 different types of pressable lithium silicate ceramics. Materials and methods.

A total of 72 disc shape specimens (10mm diameter and 1mm thickness) were fabricated by heat pressing of LT A1 shaded ingots. 24 specimens of Celtra press and the same number of IPS e.max press and Livento press lithium silicates materials.

Each material group were subdivided in to three subgroups (8 samples per group) according to the number of firing cycles. One, three, and five firing cycles' protocols were constructed, to simulate the firing protocols of the three common laboratory fabrication techniques (staining, cutback, and layering) of glass ceramic restorations. Translucency parameters and biaxial flexural strength were evaluated for specimens to detect the effect of multiple firing cycles.

Results: All tested materials showed statistically significant decrease in translucency parameters values with multiple firing cycles. No significant effect was detected on the biaxial flexural strength values after repeated firing.

Conclusion: Translucency of tested materials is negatively affected by multiple firing cycles. Multiple firings have no effect on the biaxial flexural strength of lithium silicate ceramics.

KEYWORDS: Pressable ceramics, Biaxial flexural strength, Translucency, Multiple firing cycles, lithium silicate.

* Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Cairo, Egypt

INTRODUCTION

The clinical success of all-ceramic dental restoration is largely relied on the mechanical and optical properties of ceramic material, and they play the major role in decision making during selection of the most appropriate ceramic restoration material. [1, 2]

The hot-pressing technique has become a common technique to produce glass-ceramic dental restorations,[3] as heat-pressed glass-ceramic restorations have better fitting accuracy, marginal edge quality, low porosity, as well as high mechanical properties when compared to computer aided design/computer aided manufacture (CAD/CAM) milled materials. [4-6]

Due to the limitations in ingots shades, the heat-pressed glass ceramic restorations may need to undergo additional firing cycles to improve the esthetic outcome, either for glazing, characteristic dying or even surface veneering. The consequent heat treatments of glass ceramic restoration were associated with changes in material mechanical and optical properties, which affect final clinical results. [7, 8]

MATERIALS AND METHODS

Samples preparation:

Ingots of A1 shade were used to fabricate disc specimen of 1mm thickness and 10mm diameter. Wax patterns design were created digitally using 3D design software, discs of slightly higher thickness 1.2 mm were designed to compensate for final finishing and polishing procedures. The virtual 3D model were imported as STL file to dental CAM software and it was milled out of wax blanks using K4 milling machine. The milled wax patterns were sprued, invested and burned out. The resulted mold were hot pressed by A1 shaded ingots of the different lithium silicates materials. After divesting the pressed discs were unsprued, finished and polished using sandpapers to result in a flat and even 1mm thickness discs (figure 1).

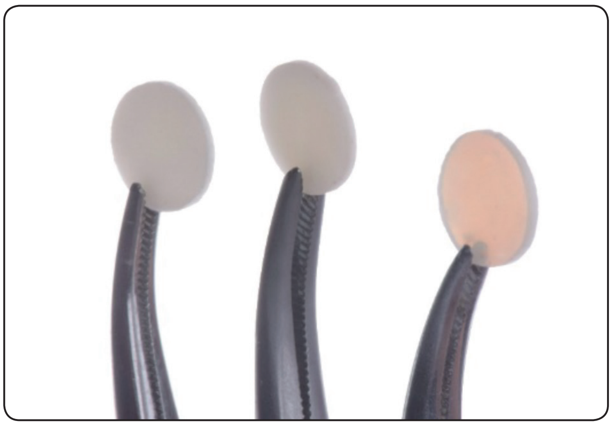

Fig. (1): Livento press, Emax press and Celtra press ceramic discs

Samples grouping:

A Total Number of 72 ceramic discs were prepared and constructed in this study. Discs were divided into three main groups according to material

Group CP: All ceramic discs of Celtra press (24 Discs)

Group EP: All ceramic discs of IPS.emax press (24 Discs)

Group LP: All ceramic discs of Livento press (24 Discs)

Each group was further sub divided into three subgroups according to number of firing cycles

Subgroup (1): 1 firing cycles (8 discs)

Subgroup (3): 3 firing cycles (8 discs)

Subgroup (5): 5 firing cycles (8 discs)

Multiple firing cycles:

After polishing, the discs were ready for the firing cycles. Three firing protocols were established to mimic the firing cycles of the three different ceramic restoration fabrication techniques which are staining, cut-back and layering techniques. Each group of material was subjected to the three firing protocols (one for each subgroup). The manufacturer firing instruction was followed according to the corresponding feldspathic porcelain system of each material.

Translucency parameters measurements

A double-beam spectrophotometer (Cary 5000 UV-Vis-NIR.) was used to measure translucency. The specular reflectance component was excluded (SCE mode). Relative reflectance data was recorded in visible range from 380 to 780 nm at 5 nm intervals.

Color coordinates, CIE L*, a* and b* were determined from the transmittance and reflectance date using a computer software (Carry WIN UV). Each value was measurement on five different area of each specimen including the center of specimen by moving it 1 mm toward each quadrant direction. Average L*, a* and b* values were used to calculate needed parameters.

The translucency parameter (TP) was obtained by calculating the difference of the specimen over the black and white background with the following equation:

$$TP= [(L^*w-L^*b)^2 + (a^*w-a^*b)^2 + (b^*w-b^*b)^2]\ ½$$

Biaxial Flexural Strength measurement

The biaxial flexure strength test was done for the all the samples in all the groups. The test was done using piston on three balls technique with cross head speed of 1mm/min in an Instron testing machine model 3345* according to ISO 6872 specification for testing ceramic materials (figure 16). The data recorded using computer software Bluehill version 3.3. The fracture load for each specimen was recorded and the biaxial flexure strength was calculated using the following equation.

$$\boldsymbol{\sigma} = \frac{-0.2387P\ (X - Y)}{b^2}$$

Where:

σ = Maximum center tensile stress (MPa), P = Maximum load (N),

b = Specimen thickness at fracture origin (1mm)

$X = (1+v)\ \ln\ (B/C)^2 + [(1-v)/2]\ (B/C)^2$

$Y = (1+v)\ [1+\ln\ (A/C)^2] + (1-v)\ (A/C)^2$

Where:

v = Poisson ratio (0.22)

A = radius of support circle (4mm)

B = radius of piston (0.6mm)

C = radius of the specimen (5mm)

Statistical analysis:

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Two-way ANOVA was used to study the effect of different tested variables and their interaction on biaxial flexural strength and translucency. Comparison of main and simple effects were done utilizing pairwise t-tests with Bonferroni correction. Spearman rank order correlation coefficient was used to study the correlation between biaxial flexural strength and translucency. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM® SPSS® Statistics Version 26 for Windows.

* Instron, Norwood, MA, USA
® IBM Corporation, NY, USA.
®SPSS, Inc., an IBM Company.

RESULTS

Translucency (TP)

There was a significant difference between TP values found in samples made of different materials ($p<0.001$). The highest value was found with Celtra press (15.95±1.40), followed by Emax press (10.07±0.96), while the lowest value was found in Livento press samples (8.92±0.57). The three materials showed decrease in TP values with multiple firing cycles (figure 2). The highest value was found in samples that were subjected to one cycle (12.89±3.60), followed by samples subjected to 3 cycles (11.36±3.05), while samples with 5 firing cycles had the lowest value (10.69±2.82).

Biaxial flexural strength (Mpa)

There was no significant difference between samples subjected to different number of firing cycles ($p=0.295$).Only type of material had a significant effect on biaxial flexural strength ($p<0.001$). The highest value was found with Emax press (221.58±30.82) MPa, followed by Livento press (199.76±27.84) MPa, while the lowest value was found in Celtra press samples (169.78±28.39) MPa.

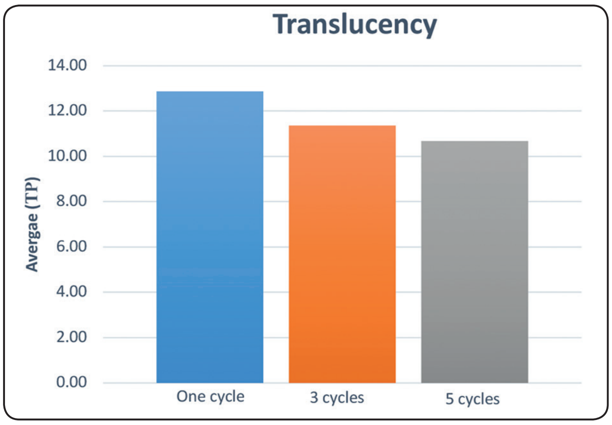

Fig. (2): Bar chart showing average translucency (TP) of different number of cycles

DISCUSSION

Lithium silicate glass ceramics became increasingly popular in the clinical use especially in anterior esthetic areas, as they offer a combination of adequate translucency and improved mechanical properties.[9] although the studies which investigate the effects of multiple firing on lithium silicate glass ceramics are diversified, but it remain in question, as the variety of products is also increasing steadily.

This in vitro study aimed to compare the effect of firing cycles on translucency and biaxial flexural strength of three pressable lithium silicate glass ceramics.

Translucency of dental materials depends on many factors such as the ratio of the crystalline/glass phases and the difference in the refractive index between these phases, the morphology of crystals, grain boundaries, pores, second phase component, additives, and light scattering from the surface.[10]

It has been established in the literature that translucency is a material specific property, and it has an inverse relationship with its thickness and surface roughness.[11, 12] That's why specimens in this study were polished and prepared with even thickness.

The results of this study showed that, with repeated firing cycles all tested materials showed significant decrease in TP values ($p<0.001$). As the highest value was found in samples that were subjected to one cycle (12.89±3.60), followed by samples subjected to 3 cycles (11.36±3.05), while samples with 5 firing cycles had the lowest value (10.69±2.82). This finding could be attributed to the increase in crystal size, the orientation of the crystals and perhaps to the change of the glass matrix of tested materials. **Hallmann et al. 2019**[13] also attributed their results to the same cause, trying to interpret the increased opacity of lithium silicate ceramics after heat treatments.

Dongdong et al. 2015[14] concluded that repeated firing negatively affected the color and translucency of Emax press material.

Emam et al 2020[15] found significant changes in color coordinates of Emax press and Celtra press after repeated firing. They attributed results to the lower glassy content in the microstructure of tested materials, which need compensating additives (metal oxides, coloring ions) to control optical properties like opalescence, color and opacity. These oxides tend to be unstable when the material undergoes repeated firing cycles, which result in increased color changes in all ceramics compared to the control group color.

Milmine et al 2014[16] found significant change in CIE lab color parameters of lithium disilicate after repeated firing, and their finding were also attributed to crystals growth and the instability of metal oxides coloring agents at high temperatures.

The smaller silicate crystals in the lithium silicate glassy matrix of Celtra Press result in high glass content. In contrast, IPS emax press, consists of needle shape interlocked lithium disilicate structure with around 70% by volume.[12] This can account to high TP value found with Celtra press (15.95±1.40), over Emax press (10.07±0.96), and Livento press samples (8.92±0.57), when statistical data of this study were pooled by material.

Although the different parameters used to describe translucency, such as the contrast ratio or the translucency parameter, made it difficult to compare studies. Many studies found to be in accordance with our results.

Bukhari et al. 2020[17] found that, Celtra Press had a significantly higher contrast ratio than the rest of the materials. While E.max CAD and E.max Press values were not significantly different (p=0.9949); however, Celtra Duo had significantly the lowest values.

Awad et al 2015[12] found that Celtra Duo attained higher absolute translucency values than IPS e.max CAD in case of a polished samples.

Oraby et al. 2018[10] found that translucency values of ZLS are either the same or inferior to that of LDS at the same thicknesses.

Flexural strength is one property to guide in material selection for restorations. Microstructure, surface cracks, and porosity are important factors affecting the flexural strength and clinical longevity of all-ceramic materials.[18]

The biaxial flexural strength is commonly used in the studies to evaluate the flexural strength of dental ceramics. Its use over uniaxial flexural strength were justified, as the dental materials are generally subjected to multiaxial loading rather than uniaxial during functioning in the oral cavity. Piston-on-three-ball test is commonly used to study the biaxial flexural strength of ceramic dental materials in comparison to ring-on-ring test, as fixture does not require the two disc surfaces to be absolutely flat and slightly warped specimens can be accommodated by the three-ball supports.[19]

Statistical analysis of this study showed that Emax press had the highest biaxial flexural strength (221.58±30.82), followed by Livento press (199.76±27.84), while the lowest value was found in Celtra press samples (169.78±28.39).

Bukhari et al. 2020[17] discussed the flexural strength of lithium silicate ceramics . All groups had significant differences in strength ($p<.0001$); IPS e.max CAD showed the highest flexural strength followed by IPS e.max Press, then Celtra Press, then Celtra Duo. The results were attributed to E.max high crystalline content and its homogeneity.

This finding comes in accordance to the study of **Stawarczyk et al. 2020**[20] who discussed four point flexural strength of lithium silicate ceramics. Emax press showed the highest values followed by livento press and Celtra press. These results were difficult to explain by the material compositions, As Celtra press and Emax press have a higher percentage of

ZrO2, but this does not seem to have a positive influence on the mechanical properties.

Conversely, **Elsaka et al. 2013**[21] compared the mechanical properties of two types of CAD/CAM lithium silicates glass ceramics; Vita Suprinity and IPS e.max CAD and reported that, zirconia reinforced lithium silicate ceramics show higher flexural strength compared to lithium disilicate ceramics. These conflicting reports may be attributed to a different type of material used

Moreover, the lower flexural strength values recorded for Celtra Press are in agreement with the results of **Apel et al. 2007** [22] According to these authors, the addition of zirconium dioxide (ZrO2) in the glass matrix does not enhance the flexural strength. However, the high ZrO2 content in the glass ceramics results in increasing the viscosity and is associated with a reduction in the crystal growth. In the case of the platelet-shapes crystals, the flexural strength is depended on the orientation of these crystals to the load beam.

The results are in agreement with a study by **Hallmann et al. 2019**[8] who evaluated the biaxial flexural strength of IPS e.max Press and Celtra Press. IPS e.max Press showed higher biaxial flexural strength than Celtra press, which agrees with our findings.

CONCLUSION

Within the limitation of this study the following conclusion can be drawn

1- The translucency of lithium silicate materials decrease with increase in number of firing cycles.

2- The biaxial flexural strength of lithium silicate materials is not affected by firing cycle

3- Celtra press had a statistically significant higher translucency value than the rest of the materials regardless of the number of cycles.

REFERENCES

1. Fehmer V., Mühlemann S., Hämmerle CHF., Sailer I. Criteria for the selection of restoration materials. Quintessence Int (Berl). 2014;45(9).
2. Rekow ED., Silva N., Coelho PG., Zhang Y., Guess P., Thompson VP. Performance of dental ceramics: challenges for improvements. J Dent Res. 2011;90(8):937-952.
3. EL-Etreby AS., Ghanem L. The Effect of Repeated Heat-Pressing On The Biaxial Flexural Strength and Surface Roughness of Lithium Dislilicate Glass-Ceramics. Dent J. 2017;63(53):60.
4. Ledić K., Majnarić I., MILARDOVIĆ ORTOLAN S., Špalj S., Štefančić S., Mehulić K. Analysis of translucency parameter of glass-ceramics fabricated by different techniques. Acta Stomatol Croat. 2015;49(1):27-35.
5. Gorman CM., McDevitt WE., Hill RG. Comparison of two heat-pressed all-ceramic dental materials. Dent Mater. 2000;16(6):389-395.
6. Wang F., Yu T., Chen J. Biaxial flexural strength and translucent characteristics of dental lithium disilicate glass ceramics with different translucencies. J Prosthodont Res. Published online 2019.
7. Meng H., Xie H., Yang L., et al. Effects of multiple firings on mechanical properties and resin bonding of lithium disilicate glass-ceramic. J Mech Behav Biomed Mater. 2018;88:362-369.
8. Hallmann L., Ulmer P., Gerngross M-D., et al. Properties of hot-pressed lithium silicate glass-ceramics. Dent Mater. 2019;35(5):713-729.
9. Makhija SK., Lawson NC., Gilbert GH., et al. Dentist material selection for single-unit crowns: Findings from the National Dental Practice-Based Research Network. J Dent. 2016;55:40-47.
10. Oraby Haa. Translucency Evaluation of Zirconia Lithium Silicate and Lithium Disilicate Glass Ceramic With Different Thicknesses Pre And Post Cementation. Egypt Dent J. 2018;64 (2-April (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)):1623-1630.
11. Wang F., Takahashi H., Iwasaki N. Translucency of dental ceramics with different thicknesses. J Prosthet Dent. 2013;110(1):14-20.
12. Awad D., Stawarczyk B., Liebermann A., Ilie N. Translucency of esthetic dental restorative CAD/CAM materials

and composite resins with respect to thickness and surface roughness. J Prosthet Dent. 2015;113(6): 534-540.

13. Hallmann L., Ulmer P., Gerngross MD., et al. Properties of hot-pressed lithium silicate glass-ceramics. Dent Mater. 2019;35(5):713-729.

14. Dongdong Q., Lei Z., Xiaoping L., Wenli C. Effect of repeated sintering on the color and translucency of dental lithium disilicate-based glass ceramic. West China J Stomatol. 2015;33(1).

15. Emam Z., El Sayed SM. Color stability and Microstructure Changes of Two Pressable Ceramics after Repeated Firing protocols. Egypt Dent J. 2020;66(1-January (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)):453-568.

16. Milmine HJ. Effects of multiple firing on the physical properties of CAD/CAM produced lithium disilicate for dental restorations. Published online 2014.

17. Bukhari AF. Mechanical and optical properties of machinable and pressable glass ceramic. Published online 2020.

18. Kang S-H., Chang J., Son H-H. Flexural strength and microstructure of two lithium disilicate glass ceramics for CAD/CAM restoration in the dental clinic. Restor Dent Endod. 2013;38(3):134-140.

19. Ritter Jr JE., Jakus K., Batakis A., Bandyopadhyay N. Appraisal of biaxial strength testing. J Non Cryst Solids. 1980;38:419-424.

20. Stawarczyk B., Dinse L., Eichberger M., Jungbauer R., Liebermann A. Flexural strength, fracture toughness, three-body wear, and Martens parameters of pressable lithium-X-silicate ceramics. Dent Mater. 2020;36(3):420-430.

21. Elsaka SE., Elnaghy AM. Mechanical properties of zirconia reinforced lithium silicate glass-ceramic. Dent Mater. 2016;32(7):908-914.

22. Apel E., van't Hoen C., Rheinberger V., Höland W. Influence of ZrO2 on the crystallization and properties of lithium disilicate glass-ceramics derived from a multi-component system. J Eur Ceram Soc. 2007; 27(2-3): 1571-1577.