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The Effect of Different Acidic Beverages on the Chemical Solubility and Biaxial Flexural Strength of Lithium Disilicate Ceramics

Thesis: Submitted for Partial Fulfilment of Master Degree Requirements in fixed prosthodontics, Faculty of dentistry, Ain Shams University

*Aya Allah Mohsen Hamed Mohamed**

Supervisors

Dr.Marwa Mohamed Wahsh Associate professor of fixed Prosthodontics Fixed prosthodontics department Faculty of Dentistry Ain Shams University

Dr. Fatma Adel Mohamed Lecturer of fixed Prosthodontics Fixed prosthodontics department Faculty of Dentistry Ain Shams University Faculty of Dentistry Ain Shams University

Abstract:

Aim:

The aim of this study was to evaluate effect of different acidic beverages on the chemical solubility and biaxial flexural strength of lithium disilicate glass ceramics.

Methods:

Two lithium disilicate glass ceramic materials were used in this study: IPS e.max Press (e.max; Ivoclar Vivadent) and GC Initial LiSi Press (LiSi; GC). Chemical solubility and biaxial flexural strength tests were conducted according to ISO 6872:2015 for all the disc specimens. The chemical solubility test with acids (phosphoric and citric acid) was done by analysis via measurement of the mass loss (μg/cm2). The biaxial flexural strength test was conducted using a universal testing machine. Finally, the results were analyzed via one-way ANOVA ($\partial = 0.05$).

* B.D.S. Ain Shams University

Results:

The chemical solubility of LiSi was lower than that of e.max but the difference was not significant. The flexural strength of e.max was slightly higher than that of LiSi but didn`t differ significantly.

Conclusion: e.max and LiSi have good mechanical properties and chemical stability as a lithium disilicate glass ceramic restorative materials.

INTRODUCTION

In the past years of life the porcelain fused to metal restorations were our first option to obtain appropriate mechanical properties [1, 2]. But nowadays all ceramic restorations have been used for their superior esthetics [2-5] accompanied with the acceptable mechanical characteristics. IPS Empress 1 (Ivoclar Vivadent, Schaan, Liechtenstein) is a leucite reinforced glass ceramic was launched to dental market. Thereafter e.max (empress 2) consists of 70 volume % of lithium disilicate crystals higher than other glass ceramics, leads to highly interlocked lithium disilicate crystals under microscope results in multiple crack deflections [6, 7], reinforcing fillers increasing in e.max making the main strengthening effect comes within crack bridging and deflection [8]. Recently Pressable ceramics as IPS e.max are popular dental restorative systems because of occlusal accuracy, fabrication technique easier, marginal integrity higher, translucency, net shaped, less porosity and high mechanical properties [9]. Challenge nowadays to obtain ceramic material with sufficient translucency and strength [10]. Finally, initial LiSi press which is a lithium disilicate glass ceramic with high density micronization technology showed a revolutionary new pressable ceramic material combined unparalleled strength and exceptional aesthetics claimed to have higher biaxial flexural strength and lower chemical solubility than IPS e.max press. Different test methods have been established to evaluate the mechanical properties of monolithic ceramics as biaxial flexural test. As the measurement of strength of brittle materials under the biaxial flexure conditions rather than the uniaxial flexure (3 or 4-point flexural tests) is often considered much more reliable [10]. Therefore, the objective of this study is to evaluate and compare two pressable lithium disilicate glass ceramic materials fabricated by different manufacturers in terms of their flexural strength and acid resistance. Toward this end, we hypothesize that these materials do not differ in terms of the above-mentioned physical properties.

MATERIALS AND METHODS

Sample preparation

Table 1: summarizes the details of the two pressable lithium disilicate glass ceramic materials investigated in this study, namely GC Initial LiSi Press (LiSi; GC) and IPS e.max Press (e.max; Ivoclar Vivadent). Forty-two disc shaped specimens were prepared according to each manufacturer's instructions. More specifically, for LiSi, the specimens were invested using LiSi Press Vest (GC), while Panamat Press (GC) was used as a press furnace for press molding the LiSi specimens with the heating and pressing programs recommended by the manufacturer. Similarly, for the e.max specimens, IPS Press VEST Speed (Ivoclar Vivadent) and Programat EP 5000 (Ivoclar Vivadent) were used for investing and press molding, respectively, according to the manufacturer's instructions. The size of each ceramic specimen to be subjected to each test was confirmed with a caliper.

Table 1: Material used in this study.

Materials – Technique	Product	Manufacturers
Heat-pressed; lithium disilicate glass-ceramic	IPS e.max Press	Ivoclar Vivadent AG, Germany, Schaan, Liechtenstein
Heat-pressed; lithium disilicate glass-ceramic	initial LiSi Press	GC, America, USA

Chemical Solubility Test

The chemical solubility test with acid was performed for each lithium disilicate glass ceramic specimen according to ISO 6872:2015. Disk-shaped ceramic specimens were prepared by press molding wax patterns (15mm diameter*1mm thicness) according to the manufacturer's instructions. Eventually, all 42 disc-shaped specimens having a surface area of 30cm^2 or more were prepared and subjected to the chemical solubility test with phosphoric acid, citric acid and artificial saliva. In the chemical solubility test, the specimens were washed with distilled water, dried at 150 °C for 4 h, then each specimen was weighed with an electronic balance and subsequently immersed in phosphoric acid, citric acid and artificial saliva at 80 °C for 16 h. Then, the specimens were removed from the solutions, rinsed with distilled water, and dried thoroughly at 150 °C. Each specimen was reweighed with an electronic balance; then, its chemical solubility was determined from the acid-induced mass loss.

$$\text{Chemical solubility} = \frac{(Wb - \mathrm{Wa})}{\text{Surface area of the specimen}}$$

Mechanical Properties

The biaxial flexural strength test was conducted for each lithium disilicate glass ceramic specimen according to ISO 6872:2015. A universal testing machine was used to perform the biaxial flexural strength test at a crosshead speed of 1.0 mm/min. The biaxial flexural strength (MPa) was calculated using the following equation:

$$S= -0.2387\ P\ (X - Y)/d2$$

$$X = (1 + v)\ \ln\ (r2/r3)2 + ((1\text{-}v)/2)\ (r2/r3)2$$

$$Y = (1 + v)\ [1 + \ln\ (r1/r3)2) + (1\text{-}v)\ (r1/r3)2$$

where S is the maximum center tensile stress (MPa), P is the total load causing fracture (N), ν is Poisson's ratio (ν=0.25), d is the specimen thickness (mm), r_1 is the radius of the supporting circle (mm), r_2 is the radius of the piston (mm), and r_3 is the radius of the specimen (mm).

RESULTS

Statistical Analysis

The means and standard deviations were calculated from the numerical results of each test, and the data were statistically analyzed via one-way ANOVA (∂=0.05) and Bonferroni's multiple comparison tests.

Acid resistance

Table 2: Descriptive statistics and results of Mann-Whitney U test for comparison between chemical solubility (μg/cm^2) of the two ceramic types.

Immersion medium	e.max		Initial LiSi		*P*-value	Effect size *(d)*
	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)		
Cola	0.0100 (0.0191)	0.0027 (0.0013-0.0531)	0.0027 (0.0017)	0.0013 (0.0013-0.0053)	0.462	0.382

Orange	0.0036 (0.0043)	0.0027 (0.0013-0.0133)	0.0017 (0.0006)	0.0013 (0.0013-0.0027)	0.276	0.568
Artificial saliva	0.0011 (0.0014)	0.0013 (0-0.0531)	0.0009 (0.0006)	0.0013 (0-0.0013)	0.944	0.034

*: Significant at P ≤ 0.05

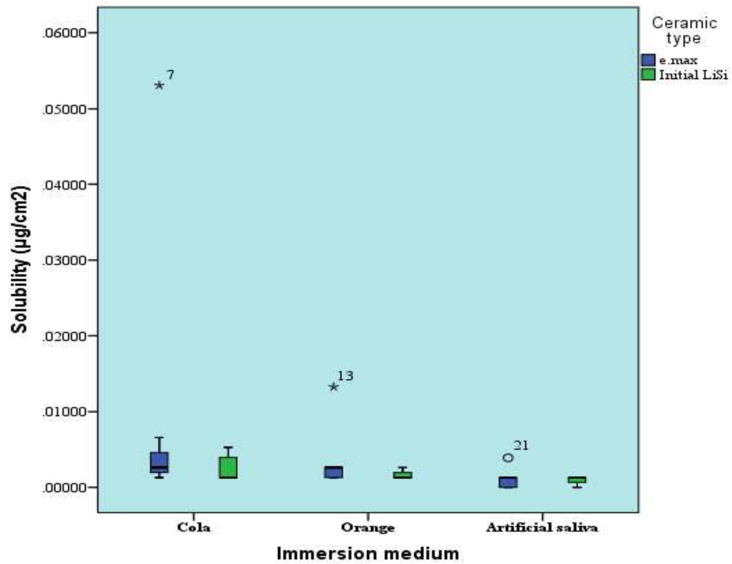

Figure 1: Box plot representing median and range values for chemical solubility of the two ceramic types (Circle and stars represent outliers).

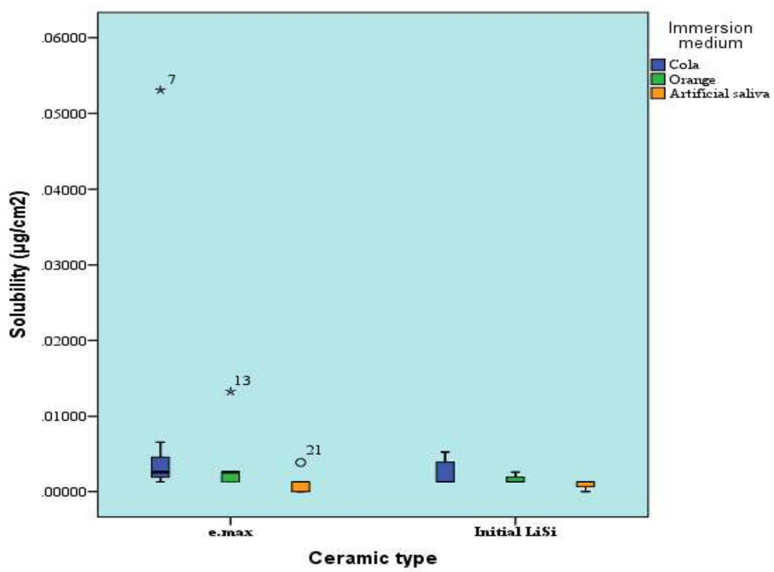

Figure 2: Box plot representing median and range values for chemical solubility of different immersion media (Circle and stars represent outliers).

Flexural Strength

Table 3: The mean, standard deviation (SD) values and results of two-way ANOVA test for comparison between biaxial flexural strength (MPa) of the two ceramic types regardless of immersion medium.

e.max		Initial LiSi		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD		
415.6	35.8	405.5	45	0.355	0.024

: Significant at P ≤ 0.05

Table 4: The mean, standard deviation (SD) values and results of two-way ANOVA test for comparison between biaxial flexural strength (MPa) of the four immersion mediums regardless of ceramic type.

Cola		Orange		Artificial saliva		P-value	Effect size (Partial eta squared)
Mean	SD	Mean	SD	Mean	SD		
381.5 C	33.9	412.1 B	25.8	438.1 A	40.4	0.001*	0.341

: Significant at P ≤ 0.05, Different superscripts are statistically significantly different

DISCUSSION

Basically, dental ceramics have been considered to be the most chemically inert restorative materials [11]. Ceramic materials used for aesthetic restorations are brittle, therefore they are subjected to the risk of fracture under cyclic forces such as occlusal forces [12]. Recently, several manufacturers have marketed novel lithium disilicate glass ceramic systems, thereby promoting their clinical application. Although many studies have reported on e.max, few reports on newly developed lithium disilicate glass ceramic materials are currently available. Therefore, we evaluated and compared the mechanical properties of two pressable lithium dislicate glass ceramics. The biaxial flexural strengths of LiSi and e.max did not differ significantly. This might be explained from the SEM observation of lithium disilicate crystals. Although the crystals of LiSi and e.max differ in size, both have a similar volume ratio of crystal to glassy matrix. Presumably, in the biaxial flexural strength test, lithium disilicate crystals can offer resistance against crack propagation, which might be facilitated in the glassy matrix. Thus, the densely distributed lithium disilicate crystals in LiSi and e.max can inhibit crack growth, which may, in turn, contribute to their higher flexural strengths [12]. This is in accordance with Munguia et al [13] where mean (SD) flexural strength values per group were e.max Press 486.96 (30.42) MPa and LiSi Press 378.16 (88.13) MPa, e.max Press had 28.8% higher biaxial flexural strength than LiSi Press. In the chemical solubility test with acid, LiSi showed lower solubility than e.max. Rather than the lithium disilicate crystals, the glassy matrix is considered to be responsible for chemical solubility. SEM observations of the lithium disilicate crystals revealed that LiSi exhibited densely distributed lithium disilicate crystals in a relatively small volume of the glassy matrix. Although the SEM images of lithium disilicate crystals in LiSi and e.max were similar, indicating comparable proportions of the glassy matrix. Still, the SEM images of e.max showed a number of pits and cavities on the surface more than that found in LiSi. Our findings regarding solubility were in accordance with ohashi et al [12] where the dissolution amount of LiSi in acid was significantly lower than that of e.max.

Conclusion

This study was conducted to evaluate and compare two pressable lithium disilicate glass ceramic materials provided by various manufacturers in terms of their flexural strength and acid resistance. The following results were obtained.

· The biaxial flexural strength of e.max was higher than that of LiSi but did not differ significantly.

· The dissolution amount of LiSi in acid was lower than that of e.max but did not differ significantly.

The results presented above confirm that the physical properties of the two lithium disilicate glass ceramic materials did not differ significantly. So, they indicate that both materials possesses superior physical properties and chemical stability as a dental material.

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