Original Article

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Dentistry Section

Translucency and Wear of Pressable Lithium Disilicate and Zirconia-reinforced Lithium Silicate Glass-ceramics: An In-vitro Study

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ABSTRACT

Introduction: New ceramic materials have been introduced with less research on their aesthetic outcome and durability for clinical implications. Lithium disilicate is one of the widely used materials for restoration. Recently, Zirconia-reinforced Lithium Silicate (ZLS) glass-ceramic enriched with 10% zirconia in highly dispersed glass phase of ceramic has been introduced.

Aim: To investigate the translucency of pressable Lithium Disilicate (LS_2) and ZLS and their effects on wear of opposing enamel.

Materials and Methods: This in-vitro study was carried out at MGM Dental College and Hospital, Mumbai, Maharashtra, India, between January 2017 and January 2020. Twenty disks of 15×3 mm; 10 each of LS_2 and ZLS were fabricated by hot pressing method. For translucency Commission Internationale de l'Eclairage (CIE) L*a*b values for each sample were measured against black and white background using a laboratory reflectance spectrophotometer. Translucency was calculated using Translucency Parameter $(TP)=\{(L^*B-L^*W)^2+(a^*B-a^*W)^2+(b^*B-b^*W)^2\}^{1/2}$. For wear testing same 20 disks were used as an antagonist. Enamel specimen of 20 maxillary premolar were abraded against each antagonist with two body wear testing machine in rotational motion under a constant load of 20 N at 350 rpm for 5000 cycles. The initial readings and final readings of enamel specimen in μm were measured using contact stylus profilometer. Non parametric Mann-Whitney U test was used to compare the significance of difference between two groups.

Results: The TP values obtained were 23.07 and 24.04 for LS_2 and ZLS, respectively (p-value=0.004). The mean wear values obtained were 0.71860 μm and 1.09500 μm for LS_2 and ZLS, respectively (p-value=0.049). The difference for both the parameters was statistically significant.

Conclusion: Within the limitation of this study, ZLS showed higher translucency values than LS_2. Wear rate of opposing enamel was more with ZLS than LS_2. Thus ZLS may provide excellent aesthetics which can be used as an option for rehabilitation in aesthetic zone.

Keywords: Aesthetics, Optical, Rehabilitation, Spectrophotometer

INTRODUCTION

To enhance aesthetic and functional demands of prosthetic restoration various materials have been developed. Metal-free restorations are emerging treatment option in fixed prosthodontics due to superior aesthetic properties and adequate mechanical properties over metal ceramic restorations [1]. Lithium disilicate is one of the widely used materials for restoration [2]. Before thermal conversion, Lithium disilicate is an amorphous glass matrix that converts into a crystalline material with about 70% of lithium disilicate orthorhombic crystal phase after heat treatment. Lithium disilicate provides good aesthetics but has limited mechanical properties [2].

Recently, Zirconia reinforced Lithium Silicate (ZLS) glass-ceramic enriched with 10% zirconia in highly dispersed glass phase of ceramic has been introduced [3]. Removal of silicate molecule and addition of zirconia may enhance the strength of the material but may affect the optical properties and could be detrimental to the opposing to enamel leading to wear [3]. ZLS glass-ceramic is a new glass-ceramic which shows combined mechanical characteristics of the zirconia and aesthetic property of glass-ceramic [3].

Translucency is one of the parameter for aesthetics, giving life like appearance to the restoration which is commonly measured by using the contrast ratio and Translucency Parameter (TP) [4]. The Commission Internationale de l'Eclairage (CIE) L*a*b* is a nonlinear transformation of the tri stimulus space to agree with Munsell spacing and has been largely used to compare translucency among materials [5].

Wear is a complex phenomenon that occurs when two surfaces are brought into direct contact or indirect contact [6]. Restorative dentistry strives to find a suitable and biocompatible alternative for hydroxyapatite so that the property of the material is similar to enamel, which will prevent damage to the opposing tooth structure. No sufficient literature was present on comparison of mechanical and optical properties of pressable lithium disilicate and zirconia-reinforced lithium silicate glass-ceramic. So this present in-vitro study was carried out. The purpose of this study was to evaluate and compare the translucency of pressable lithium disilicate and ZLS and their effect on wear of opposing to enamel giving the clinicians a better choice of material for the restorations which will be more aesthetic and less harmful to the opposing enamel. The null hypotheses were that no difference would be found in the translucency of pressable lithium disilicate and ZLS and their effects on wear of opposing enamel.

MATERIALS AND METHODS

This in-vitro study was carried out at MGM Dental College and Hospital, Mumbai, Maharashtra, India, between January 2017 and January 2020. Approval was obtained from Institutional Ethical Review Committee held on October 2017 (IERC-MGMDCH reference no.4l/2017 on 9/10/2017).

Inclusion criteria: Pressable lithium disilicate low translucency shade A2; pressable ZLS low translucency shade A2; twenty freshly extracted non carious, non restored, healthy premolars were included in the study.

Exclusion criteria: Ceramic material other than pressable ceramic; high translucency, medium translucency, medium opacity, high opacity of lithium disilicate and high translucency, medium translucency ZLS;

other than shade A2 of lithium disilicate and ZLS; Incisors, canines and molars; any decayed, attrited, restored, fractured and desiccated teeth were excluded from the study.

Minimum sample size required for the study was twenty samples. Ten samples of Pressable lithium disilicate low translucency ingot shade A2 {IPS e.max Press (LT), Ivoclar, Vivadent} and ten samples of Pressable ZLS Low Translucency Ingot shade A2 {Celtra Press (LT), Dentsply, Sirona} with 95% confidence interval and 80% power. Sample size estimation was done using Epi software.

Study Procedure

Fabrication of silicone laboratory putty mould: Silicone laboratory putty (Zeta plus, Zhermack) mould was fabricated by making an impression of a 15 mm diameter and 3 mm thickness metal disk for fabrication of 20 wax patterns (Renfert, Bego)

Fabrication of lithium disilicate samples and Zirconia reinforced Lithium Silicate (ZLS) samples: The wax patterns were sprued and mounted on the ring base such that the distance between the wax pattern and the silicone ring is atleast 10 mm [7]. The phosphate bonded investment material (IPS Press VEST speed Investment material Ivoclar Vivadent) was used to invest the wax pattern. Burnout was done in preheating furnace at 850°C/1562°F temperature for 60 minutes [7]. For pressable lithium disilicate (Low Translucency Ingot, shade A2; IPS Emax Press; Ivoclar Vivadent) the pressing was done at 910°C for 45 minutes and for pressable ZLS (Low Translucency ingot, shade A2; Celtra Press; Dentsply Sirona) the pressing was done at 865°C for 30 minutes [7]. The pressed disk was then immersed in Invex liquid (IPS Press) containing 1% of hydrofluoric acid for five minutes to remove the reaction layer and then cleaned in an ultrasonic cleaner [8]. The above lost wax and hot pressing method were used for fabrication of ten samples of pressable lithium disilicate and ten samples of pressable ZLS which were finished, polished and glazed.

Evaluation of translucency: A dual beam reflectance laboratory spectrophotometer (Agera) with specification of 0°/45°c (circumferential) ASTM E1164 with D65 illumination, was used for measuring the translucency of each samples [Table/Fig-1] [9,10]. The spectrophotometer was standardised against black tile and white tile for eight hours as per the specification given for Agera spectrophotometer. Each sample was placed in the centre of the port plate of size 15 mm in diameter. The portable clamp was then closed, so that it is in close contact with the sample. The even contact of the clamp with the sample was evaluated by inbuilt camera in spectrophotometer. By pressing the start button on the screen, the CIE L*a*b* coordinates of the sample were recorded, displayed and stored by the software [11],

where,

L: represents for lightness (colour coordinate ranges from 0 to 100);

a: represents greenness (positive axis) and redness (negative axis) (colour coordinate ranges from -90 to 70);

b: represents yellowness (positive b*) and blueness (negative b*) (colour coordinate ranges from -80 to 100).

[Table/Fig-1]: Translucency measurement of ceramic sample using Agera reflectance spectrophotometer.

Three readings were taken for each sample on each background and the mean CIE L*a*b* values were recorded for all the twenty samples, ten each of lithium disilicate and ZLS. Translucency was calculated using the TP by using following formula [11]:

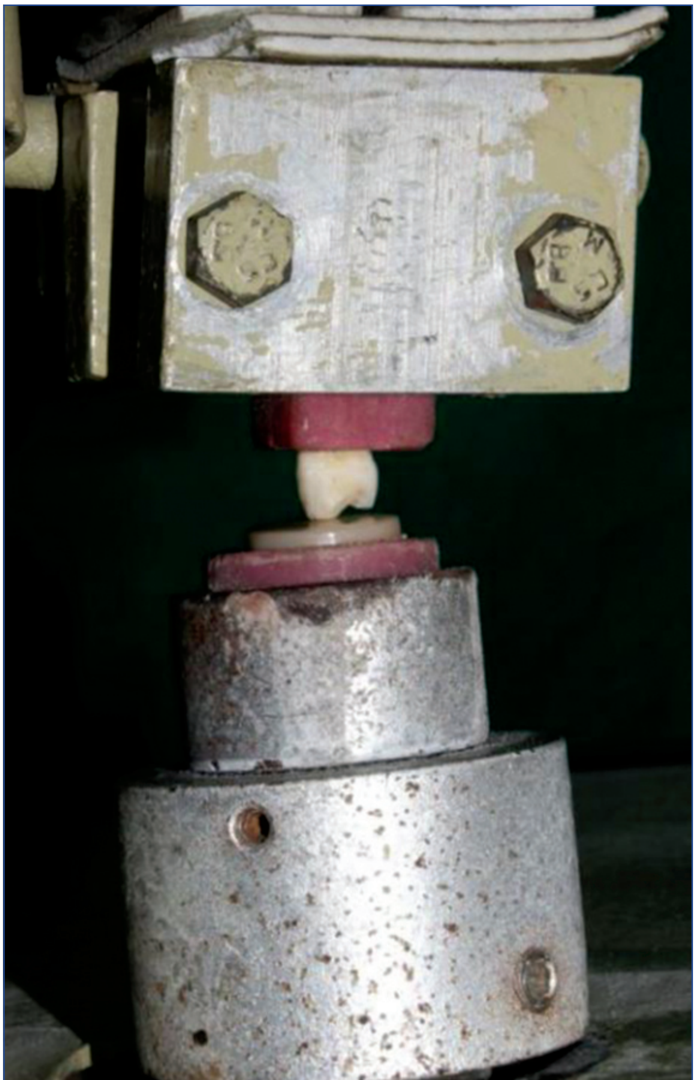
$$TP=\{(L^*B-L^*W)^2+(a^*B-a^*W)^2+(b^*B-b^*W)^2\}^{1/2}$$

Where,

'B' represents colour coordinates on the black background and

'W' represents colour coordinates on the white background.

Evaluation of wear of opposing enamel with lithium disilicate and Zirconia Reinforced Lithium Silicate (ZLS) samples: Twenty freshly extracted non carious, healthy, non restored maxillary premolars were selected as enamel specimens [12]. The extracted tooth was cleaned; scaling was done and disinfected with 0.05% thymol [13]. The entire premolar was then embedded on autopolymerising acrylic resin block of 10X10 mm and 30 mm thickness in the centre and leaving the entire crown structure uncovered with resin; with only buccal cusp undergoing wear testing [14]. Before wear testing all samples of 15 mm diameter and 3 mm thickness were stored in distilled water at 37ºC for 24 hours [12]. The cusp with resin block was held by holding device on the upper chamber of two body wear testing machine [Table/Fig-2]. Every premolar buccal cusp was scanned using a surface profilometer with 20 μm resolution before subjected to wear test to get the initial reading [15]. Each sample of 15X3 mm disk was placed in the lower chamber of two body wear testing machine. 5000 cycles of 20 N load was applied from the enamel cusp on to samples at 350 rpm in rotational motion by making a two body contact [16]. For every tooth sample a new disk of lithium disilicate and ZLS samples were placed.



[Table/Fig-2]: Tooth mounted on upper chamber held against ceramic sample on lower chamber of two body wear tester.

Measurement of wear depth by using profilometer: After wear testing the loss of enamel cusp was measured with the surface profilometer (Mitutoyo, Japan; Model: SJ 210). The profilometer consist of stylus profile tip with radius of 2 μm; Tip angle 60° with stylus speed of 0.5 mm/s, cut-off length of 1.25 mm and measuring force of 0.75 mN [17]. The sample was fixed in the profilometer and the stylus on vertical arm was positioned on the non abraded portion of the buccal cusp of the premolar [14]. The vertical deflection of the stylus was recorded (contact scanning) when premolar was moved horizontally over it. The profilometer connected to an x-y recorder, gives surface profiles of 20×29 magnification. At a parallel line with a distance of 0.1 mm in the mesiodistal direction from midline, the entire process was repeated for three times. The vertical substance loss was measured from the deepest point of the profile. Using the software Leica IM 50, the radius of wear area was directly measured at a 25X magnification [14]. The volumetric wear depth was determined by the profilometric software and the difference between the final and initial wear depth determined the wear loss of enamel by the subsequent materials. Wear was calculated using profilometer as difference between final reading and initial reading [18].

STATISTICAL ANALYSIS

Microsoft Excel Spreadsheet was used for data compilation and statistical analysis was done using Statistical Package for the Social Sciences (SPSS) software version 20.0 (IBM, India). The normality of data was determined using Kolmogorov-Smirnov and Shapiro-Wilk test. Data was not meeting the condition of test of normality, so non parametric test was done. Mann-Whitney U test was done to compare the significance of difference between the average translucency and wear value of lithium disilicate group and ZLS group. The value obtained for Mann-Whitney U test for translucency was 12.000 and p-value obtained for Mann-Whitney U test was <0.05 indicates statistically significant difference between two groups.

RESULTS

The TP and wear was evaluated for ten samples of lithium disilicate and ten samples of ZLS and a mean was generated for both parameters [Table/Fig-3].

Group	N	Mean	Standard deviation	Median	Mann-Whitney U value	Z-value	p-value (Mann-Whitney u test)
Intergroup comparison and descriptive statistics for translucency parameter (ΔE)							
IPS Emax	10	23.07	0.53	23. 2125	-	-	-
Celtra Press	10	24.05	0.65	24.33	12.000	-2.873	0.004*
Intergroup comparison and descriptive statistics of wear depth reading using profilometer (μm)							
IPS Emax	10	0.718	0.375	0.827	-	-	-
Celtra Press	10	1.095	0.444	1.212	24.000	-1.973	0.049*

[Table/Fig-3]: Values of translucency parameter and wear parameter.
*p-value <0.05 was considered statistically significant

The TP values obtained were 23.07 and 24.04 for lithium disilicate and ZLS, respectively. The mean wear values obtained were 0.71860 μm and 1.09500 μm for lithium disilicate and ZLS, respectively. The difference in the TP and wear for lithium disilicate and ZLS was statistically significant (p-value=0.004 and p-value=0.049, respectively).

DISCUSSION

Glass-ceramics have been used in aesthetic dentistry due to better mechanical properties and improved aesthetics [1,18]. Approximately, 70% of lithium disilicate crystals of 3-6 μm, embedded in a glassy matrix forms the microstructure of IPS Emax Press. They have improved mechanical properties and optical features, higher than the older glass-ceramics. ZLS is a new glass-ceramics contains lithium silicate (mean size of 0.5-1 μm) which are six times smaller than lithium disilicate crystals as the main crystalline phase in a vitreous matrix reinforced with 10% of zirconium dioxide crystals [19]. The mechanical properties of the material are enhanced by presence of 10% zirconium dioxide crystals in the microstructure. Zirconia particles hinder the crystal growth formation and helps in formation of a smaller and finer crystalline phase [19]. These new zirconium-reinforced lithium silicate materials provide good optical properties as compared to the traditional glass-ceramic due to presence of high amount of glass matrix [19].

It was proven that IPS Emax Press has better mechanical properties and optical properties compared to IPS Empress II and pressable lithium disilicate exhibits better mechanical properties compared to the Emax Computer-aided Design (CAD) [20,21].

Translucency is one of the important parameter for aesthetic purpose indicates the amount of light transmission or diffuse reflection from a substrate through a turbid medium [22]. A study carried out by Barizon KT et al., suggested that either constrast ratio or TP can be used to evaluate the relative translucency of ceramic [5]. Hence, in the present study, TP was used to measure the translucency. To determine the influence of ceramic thickness on the definitive shade of ceramic restorations, black and white backgrounds have been used. The colour difference of specimens on a black and white background gives TP [23]. Hence, in this study white and black backgrounds were used to measure the translucency.

Karamouzos A et al., carried out an in-vivo study to evaluate the precision of a reflectance spectrophotometer during longitudinal assessment of tooth colour and suggested that the repeatability and reproducibility of intraoral spectrophotometric measurements was affected [24]. Hence, in this study the Agera® reflectance spectrophotometer which is a contact, full spectrum, balanced Light-emitting Diode (LED) 360-700 nm illumination with Ultraviolet (UV) control, having black and white standardisation tool for error free measurements laboratory spectrophotometer was used [12,16].

The edge loss phenomenon, occurs when light is scattered to the edges without being reflected, is one of the factor resulting in loss of accuracy in colour measurement. The edge loss was decreased by increasing the window size of the spectrophotometer. The dimension of 15X3 mm was used in accordance to the requirement by the equipments. Translucency is influenced by the thickness of the material so each specimen was measured three times and means were compared [10].

The present study compared the translucency of pressable lithium disilicate and pressable ZLS and observed that the translucency of pressable ZLS was significantly more than that of pressable lithium disilicate which was in accordance to the study done by Sen N and Us YO [25]. The difference in translucency between the materials was due to the difference in grain size and crystalline structure. After crystallisation, the crystals of Zirconia-reinforced glass-ceramic had a mean grain size of 500 to 700 nm which were 4-8 times smaller than lithium disilicate crystallites in lithium disilicate ceramic [26,27]. Thus, the better TP values for ZLS were thought to be due to smaller silicate crystals in the lithium silicate glassy matrix with high glass content.

A study carried out by Lawson NC et al., suggested that wear rate was more for glazed porcelain than polished porcelain [28]. Hence, in this present study polished and glazed samples were used for wear testing. Sripetchdanond J and Leevailoj C conducted a study using pin-on-disk two body wear tester and the results were statistically significant [29]. Hence, this study was carried out using two body wear testing machine which works in rotational motion with 20 N load, 350 rpm and 5000 cycles [30]. The wear testing was calculated using a contact stylus profilometer as it has greater acceptance, surface independence, resolution, direct technique, not sensitive to surface reflectance and colour [31]. A study carried out by Zandparsa R et al., compared the wear of ceramic systems against human enamel and concluded that all ceramic systems showed higher durability and better wear resistance and no differences were found in the linear and volumetric reduction of enamel cusps abraded against enamel disks and other ceramic specimens [11].

The present study compared the effect of wear on opposing enamel by pressable lithium disilicate and ZLS and observed that there was a significant difference in the wear depth of enamel after wear testing. The present study concluded that the wear of opposing enamel against ZLS was significantly more than that with lithium disilicate.

Limitation(s)

The limitations of this study were that it was a laboratory study, certain errors can occur while fabrication of the samples by hot pressing method such as the temperature difference, amount of polishing and glazing of the samples. Some of the clinical factors like type of the luting cement which could influence the translucency perception of the restoration were not taken into consideration.

CONCLUSION(S)

Pressable ZLS showed higher translucency values than lithium disilicate thus may provide excellent aesthetic which can be used as an option for rehabilitation in aesthetic zone. Wear was more with pressable ZLS than lithium disilicate which can be used as an option for rehabilitation in the posterior region where the masticatory loads are minimal as in the area of non functional cusp and minimum contact with the functional cusp. However, further in-vivo studies need to be carried out to evaluate the translucency and wear resistance measuring patient satisfaction and longevity of both materials.

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