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EFFECT OF DIFFERENT LITHIUM DI-SILICATE CERAMICS WITH VARIABLE SHADES, THICKNESS AND CURING MODES ON THE DEGREE OF CONVERSION OF RESIN CEMENT

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ABSTRACT

Purpose: The bond strength between ceramics and tooth structure is affected by the degree of polymerization of resin cement. This study evaluated the effect of two light curing modes on polymerization of light cured resin cement through three lithium silicate-based ceramics (Lithium disilicate-reinforced glass ceramic (E.max CAD), Zirconia reinforced Lithium Silicate (Celtra Duo). And Zirconia reinforced Lithium Silicate (Vita Suprinity) with two shades (A2 and B1) and two ceramic thickness (0.5 and 1mm).

Materials and methods: Two hundred forty ceramic samples (n=240) were divided into three main groups (n=80) according to the material. Each group was subdivided into 2 subgroups (n=40) according to ceramic shade (A2 and B1). Each subgroup was subdivided into 2 divisions (n=20) according to thickness (0.5mm and 1mm). Then each division was subdivided into two subdivisions (n=10) according to light curing method (Continuous and pulsating light curing). Samples cemented and scanned using OMNIC 5.1c software connected to the FTIR unit.

Results: The results illustrated that there was no statistical significance difference in degree of conversion between the three ceramic materials. A higher degree of conversion was recorded with B1 ceramic shade than A2 shade. Also, there was a significant effect on the degree of conversion (DC%) with different thicknesses of the ceramic materials and there was a higher degree of conversion in the continuous light curing mode than the pulsating mode.

Conclusions: Within the limitations of this study, the results indicated that with respect to the ceramic thickness used, the ceramic type did not affect the degree of conversion of light cured resin cement. On the other hand, thicknesses up to 1.0 mm have a significant effect on the polymerization of resin cements. Higher degrees of conversion were shown with lighter ceramic shades. Also, mode of light curing had a pronounced effect on the degree of conversion of resin cements

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Clinical significance:

Given the success of all-ceramic restorations depends largely on the reliable bonding between ceramic and dental hard tissues by dental cement. The strength of this bond is largely affected by the degree of polymerization of the resin cement, we felt compelled to study the factors that affect the degree of conversion. These factors include the type of ceramic, its thickness, shade as well as the curing mode which can greatly assist the operator in achieving higher success of the restoration.

Null Hypothesis:

Neither the type of material, nor the shade or the thickness of the ceramic, and also the light curing mode would affect the degree of conversion of the light cured resin cement.

Key words: lithium silicate ceramics, thickness, shade, resin cement, curing mode.

INTRODUCTION

Continuous enhancement of ceramic materials due to an increase in social demand for natural looking restorations mimicking appearance, biocompatibility, high strength, as well as coefficient of thermal expansion to tooth structure. [1] However, the success of all-ceramic restorations depends largely on the reliable bonding between ceramic and dental hard tissues by luting materials. Strong bond between the ceramic and tooth structure supports restoration and actively transmit forces through the bonded interface. [2] Resin cements have been fostered because of their high bond strength, lower micro leakage with subsequent low solubility, and more accurate fit than those of non-adhesive luting cements. And finally due to their optimal mechanical properties that help reinforce the ceramic restorations. [3] In order to ensure maximum bond strength, optimal cure needs to be achieved; which will consequently guarantee greatest cement polymerization. Adequate cement polymerization is a decisive factor in obtaining the best physical properties and acceptable clinical performance of cement as well as enhanced long-term fracture and fatigue resistance. [4] On the contrary, suboptimal polymerization is known to be associated not only with altered mechanical properties and dimensional changes; but also, with decrease in bond strength and subsequent micro leakage and discoloration.[5] Factors that affect the degree of conversion include: type of ceramic, its thickness, translucency and shade, the resin cement composition, activation method, in addition to the curing light output power, mode, adjusted setting time, and distance from the cement and restoration.[6] The quality of light and the curing mode are important factors that affect polymerization and thus the clinical performance of the restoration.[7] Appropriate energy density is important for obtaining a high degree of conversion (DC%). Different curing modes can influence the hardness of the resin cement. Energy density is determined by the curing light intensity and exposure time. [8] Assessing the way in which the type of ceramic system, shade, thickness and mode of light curing can affect the degree of conversion of light cured resin cements can greatly assist the operator in achieving higher success of the restoration.

MATERIALS AND METHODS

This study was made using three lithium silicate based ceramic materials. The first material was lithium disilicate (IPS E-MAX CAD, Ivoclar vivadent., Schaan, Liechtenstein) ,The second material was (CELTRA DUO CAD, DeguDent, Hanau. Germany) which is a fully crystallized zirconia reinforced lithium silicate glass-ceramic. And third material was (VITA SUPRINITY PC. Vita Zahnfabrick, Bad Säckingen, Germany) which is zirconia-reinforced lithium silicate glass ceramic. Two shades were used of each material (A2 and B1). ("LT A2" and "LT B1") 32 mm length blocks of Emax CAD, ("LT/A2" and "LT/B1") 14 mm length blocks of Celtra Duo CAD and ("T A2/PC-14" and "T B1/PC-14") 14 mm length blocks of Vita Suprinity. Samples were sliced into two different thicknesses (0.5 and 1mm). One shade of light cured resin cement (Bisco Choice 2 Veneer Cement) (Translucent) and two light curing modes (continuous and pulsating) was used. The degree of conversion was measured using the FTIR device after complete curing of resin cements.

Sample size estimation

To Evaluate the effect of two light curing modes on polymerization of light cured resin cement through three lithium silicate-based ceramics (Lithium disilicate-reinforced glass ceramic (E.max CAD), Zirconia reinforced Lithium Silicate (Celtra Duo). And Zirconia reinforced Lithium Silicate (Vita Suprinity) with two shades (A2 and B1) and two ceramic thickness (0.5 and 1mm), ANOVA test will be used for comparison between groups. Based on Rashi Bansal (2016) [9] and Sheila P Passos (2013) [10] and Using G power statistical power analysis program (version 3.1.9.4) for sample size determination, a total sample size of N=120 ; will be sufficient to detect a large effect size with an actual power (1-β error) of 0.8 (80 %) and a significance level (α error) 0.05 (5 %) .

Sample grouping

For accurate and reliable results two hundred and forty ceramic samples (n=240) were divided into 3 main groups (n=80) according to the type of ceramic: (Group 1 E.max CAD), (Group 2 Celtra Duo) and (Group 3 Vita Suprinity). Each group was subdivided into 2 subgroups (n=40) according to ceramic shade: (Subgroup A shade A2) and (Subgroup B shade B1). Each subgroup was further subdivided into 2 divisions (n=20) according sample thicknesses: (Division I 0.5mm) and (Division II 1mm) Then each division was subdivided into two subdivisions (n=10) according to the light curing method: (Subdivision a Continuous light curing) and (Subdivision b Pulsating light curing).

Sample preparation

The ceramic samples were sliced through machine slicing of the prospective ceramic blocks using a low-speed diamond saw (Buehler Isomet diamond saw 4000, Buehler, USA) to uniform standard thicknesses of (0.5 and 1.0 mm). A digital calliper (Holex digital caliper, Hoffmann Group, Germany) was used to verify the thickness. Crystallization was done for both Lithium disilicate (E.max IPS CAD) and zirconia reinforced Lithium silicate slices (Vita Suprinity) according to the manufacturer recommendations in a special ceramic furnace (Programat EP 3010, Ivoclar vivadent, Schaan, Liechtenstein). Lithium disilicate (E.max CAD) was heat treated at 850°C for 24 minutes. Temperature cycles were first dry time/closing for 1 minute at base temperature of 400°C, then the temperature of 30°C rose per minute, then high temperature of 860°C at holding time for 10 minutes. The vacuum starts at 550°C and stops at 860°C. At the end, long-term cooling cycle 700°C for 6-7 minutes. Zirconia reinforced Lithium silicate (Vita Suprinity) was heat treated at 840°C for 8 minutes. The initial chamber temperature was 400°C for 8 minutes then temperature rate increased 55°C per minute, then crystallization temperature 840°C for 8 minutes, and finally the ending temp was 680°C. Two Teflon molds were fabricated to ensure a standard thickness of resin cement samples with an external diameter of 20mm×3mm thickness. An inner dimension 14×14 square shape was cut with two different thickness 0.6mm and 1.1mm to accommodate the designated thicknesses of ceramic slices 0.5 mm and 1.0 mm respectively and to ensure 0.1 mm uniform cement thickness. The ceramic slices were seated on the inner stopper of the mold. The lower opening which is a square of 14 X 14 mm used for the placement of the ceramic disc and the resin cement. Resin cement was then dispensed from the syringe into the ceramic slices to fill the 0.1 mm space between the surface of the mold and the surface of the ceramic slice seated in the square cut. To obtain a uniform thickness of the light cured resin cement, a celluloid strip was placed on top of the resin cement. Pressure was then applied using a glass slab to ensure complete seating and uniform thickness of cement of 0.1 mm created by the mold. The celluloid strip prevents the sticking of the cement to the glass slab. The mold along with the celluloid strip and glass slap were inverted together thus giving us the following order starting from the bottom up (glass slab – celluloid strip – resin cement – ceramic slice). LED curing light (Blue phase Light curing unit, Ascent PX, CAO group, USA) with intensity of 1500mW/cm^2 was used to cure the resin cement throughout the sample for 20 seconds. The desired curing mode (Continuous/Pulsating) was selected according to the subdivision. The light curing device was applied through the upper opening of the mold and is in direct contact with the centre of the ceramic slice. Finger pressure was applied to the side of the mold to ensure close contact of all parts and even thickness of all the specimens. After light curing was done, the celluloid strip was removed from the sample and the cement specimen was separated from the ceramic slice by a metal spatula. The thickness of specimens was then verified by a digital caliper to ensure that the thickness of all the specimens. The previous steps were repeated for all the samples.

FTIR spectroscopy analysis:

The specimens were kept for 24 hours in a dark container to prevent further polymerization and then subjected to analysis using the FTIR device. To obtain the degree of conversion from the given equation, separate values for cured samples as well as raw uncured samples should be calculated. These values are then substituted in the equation and the percentage degree of conversion calculated. The samples were prepared by grinding them separately into a fine powder. The powder was then mixed with potassium bromide powder (Potassium Bromide Powder, SRL Laboratories, India). The mixture was then compacted to form a disc shaped specimen for the FTIR spectroscopy. The Cured and uncured cement samples - after preparation - were scanned at a resolution of 4cm-1 and given a blot of wave number from 4000-400cm-1 against absorbance peak intensities, using OMNIC 5.1c software connected to the FTIR unit (FTIR, Nicolet 6700 Instrument Company, USA). In the MIR region, the DC% is determined by measuring the intensity (or area) decrease of the methacrylate (C=C) stretch absorption band at the absorption peaks of the aromatic double bonds were recorded at 1608 cm-1 (Abs 1608) and the peak of the aliphatic double bonds (C=C) were registered at 1637 cm-1 (Abs 1637 as the methacrylate monomer is converted to polymer. An infra-red spectrum is basically a graphical representation. On the vertical axis the light absorbance or transmittance and on the horizontal axis the frequency or wavelength. The percentage of unreacted aliphatic C=C bonds remaining throughout the polymerization reaction is obtained by the equation:

$$(\%C{=}C) = \frac{(\text{Abs(aliphatic)} / \text{Abs(aromatic)}]_{po/ymer}}{(\text{Abs(aliphatic)} / \text{Abs(aromatic}\}\}_{monomer}} \times 100$$

DC is determined by subtracting the residual percentage of aliphatic C=C from 100% (DC%=100-(%C=C)

RESULTS

One-Way ANOVA revealed no significant differences between the different types of ceramic materials on the degree of conversion of resin cement (P>0.05). Figure 1.

But there was a significant difference in the degree of convergence between different thicknesses of the ceramic material (P≤0.05). 0.5 mm thickness specimens showed a higher degree of conversion of resin cement than 1mm thickness specimens. Figure 2.

Also, there was a significant difference in the degree of convergence between different shades of the ceramics (P≤0.05). B1 ceramic shade showed a higher degree of conversion than the A2 ceramic shade. Figure 3.

Regardless of the ceramic type, thickness and shade, Continuous light curing specimens showed a higher degree of conversion of resin cement than the pulsating light curing specimens (P≤0.05). Figure 4.

Shade of ceramic, thickness and mode of curing had a significant effect on cement degree of conversion, while the type of material as well as different interaction combinations had no significant effect as shown in figure 5.

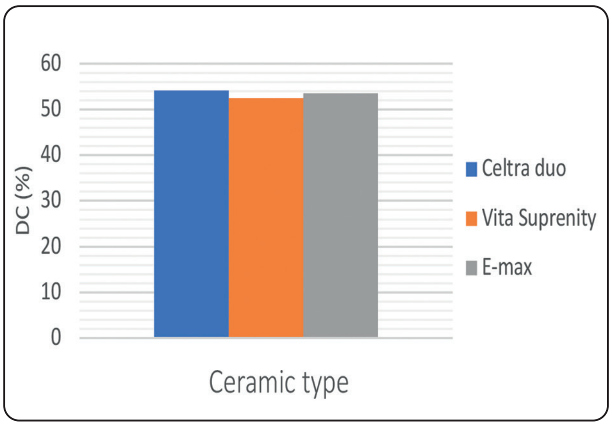

Fig. (1): Bar chart showing average degree of conversion for different types of ceramic

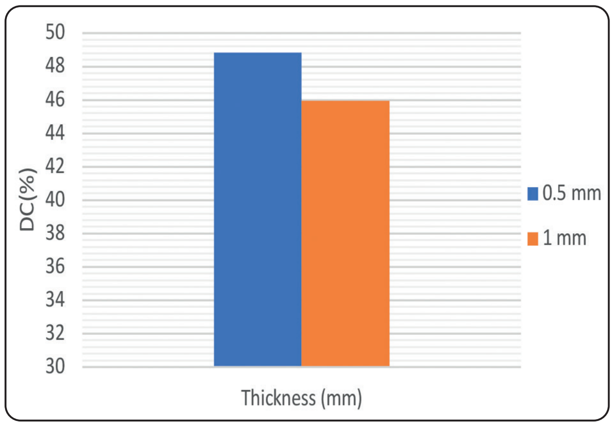

Fig. (2): Bar chart representing means of degree of conversion with respect to different ceramic thicknesses

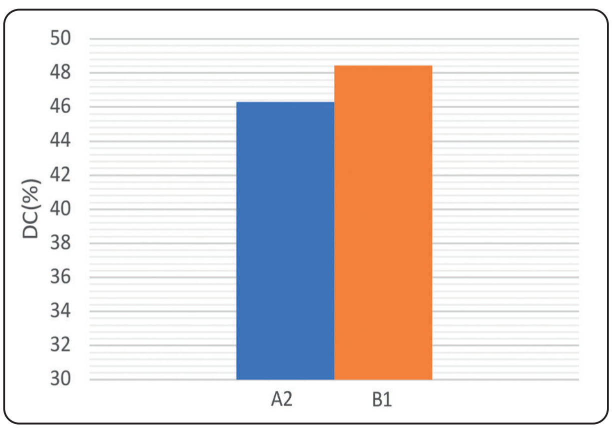

Fig. (3): Bar chart representing means of degree of conversion with respect to different shades of ceramic

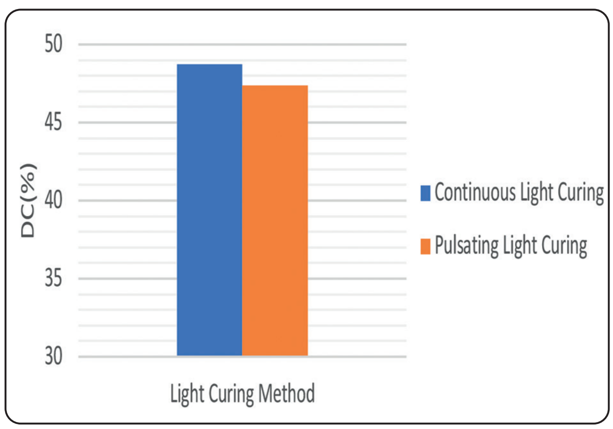

Fig. (4): Bar chart representing means of degree of conversion with respect to different light curing methods

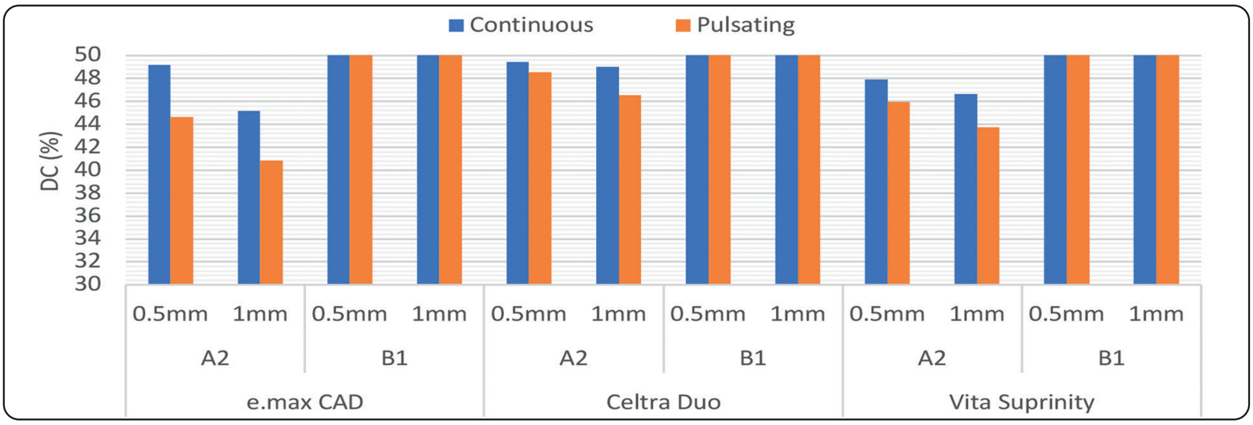

Fig. (5): Bar chart representing means of degree of conversion of resin cement with different variables and their interaction

DISCUSSION:

Degree of conversion of resin cement is important as it governs the physical and mechanical properties of luting cements. (11) Increasing the curing of resin cements leads to decrease the amount of uncured monomer which act as plasticizers. Inadequate curing with reduced degree of conversion alters bond strength and may compromise the clinical performance of the luting cement. (11) Degree of conversion was tested using Fourier Transform Infrared (FTIR) spectroscopy due to its ability of rapid scanning, high wavelength, better resolution, stability and accuracy. (11) In this study, the thickness of cement was controlled at 0.1 mm to be similar to the maximum accepted cement thickness under laminate veneers and other restorations clinically. Teflon mold were made-up according to the two thicknesses of ceramics used to regulate the thicknesses of cement used throughout the samples. As proven by other studies, thickness of 0.1mm for cement is suitable for fitting the veneer for better stress distribution between the ceramic and cement interface. (12) Potassium Bromide (KBr) pellet method was used to prepare the specimens for the FTIR spectrometer as all the solid samples were grinded with a mortar and pestle and then mixed with KBr ground particles. Separating the resin specimen from the mold might cause it to break into pieces but that had no effect on influence on the final result since all the specimens were grinded. The mixture is then compacted between two stainless steel disks under hydraulic pressure. (13) Ascent PX LED curing light with the intensity of 1500mW/cm^2 was used. As for adequate curing of resin cement, curing unit of high intensity 1200 mW/cm^2 for 20 seconds was recommended to be used to ensure complete curing of light cured resin cement.

Two different light curing methods were used as researchers speculated that different curing modes affect the total energy reaching the resin cement, and thus directly affects the degree of conversion of resin cement, along with other factors such as polymerization shrinkage and marginal integrity. (14) A celluloid strip was placed over each resin cement specimen during the curing of the cement to avoid the oxygen inhibiting layer during the polymerization of cement and also to prevent sticking of the cement to the glass slap. The light cure tip was positioned in direct contact to ceramic discs to confirm maximum light penetration through it and to ensure a standardized distance between the ceramic and the light curing tip throughout all specimens. (14) To ensure standard thicknesses between different groups of ceramic samples a low speed Isomet diamond saw was used, and then the thicknesses verified using the digital calliper.

Light cured resin cement was used since it provides better esthetics compared to the dual or chemical cured cements because of the absence of aromatic amines in its composition. Dual cure resin cements were excluded from use in this study since they have different polymerization kinetics and that the extent of polymerization changes between different cements. (15) Using light cured resin cement was advocated since they could be used underneath ceramic veneers with thicknesses of less than 1mm yielding high values of degree of conversion. (15)

The results of the current study revealed that regarding the ceramic type, there was no statistically significant difference between the 3 ceramic types used in the study (Celtra Duo CAD, Vita Suprinity, and IPS E-max CAD). This may be attributed to the high translucency of the three ceramics. This finding was confirmed by Runnacles et al in 2014 (12) who assessed the degree of conversion of resin cement with respect to ceramic type and thickness and revealed that DC of the light-cured cement through ceramics with 0.5 to 1.0 mm thickness was similar to the control ($p>0.05$), regardless of the type of ceramic. This is possibly due to the low thickness which resulted in less attenuation of light intensity. Regarding the ceramic shade, a statistically significant difference was found between different shades of the ceramic material on the degree of conversion of resin cement at $P\leq0.001$. B1 shade specimens showed higher degree of conversion of resin cement than A2 shade specimens.

This could be attributed to the fact that change in shade lead to change in colour parameters including chroma as well as translucency. According to Vita Zahnfabrick Company, it was confirmed that shade B1 has inherent higher lightness (value) as well as lower chroma than shade A2. (16) Also, it was reported that less energy reaches the composite when a ceramic restoration with a high chroma is used. Lower micro hardness values were reported underneath darker ceramics with higher opacity than for lighter ceramics. The restoration pigments are able to absorb light, negatively influencing the DC. (17)

Moreover, The L* value is directly proportional with the TP value. The more the lightness (value) of the material increases, the more translucent the material will be. In our study, due to the inherent higher lightness value of shade B1 specimens, the more translucent the specimens are more than those of shade A2 with consequently higher degree of conversion values underneath. (18) This was in agreement with Oh et al in 2018 (19) who found that there is a nearly perfect positive linear correlation between the light transmittance and translucency parameter (TP) in spite of different measuring methods. Higher DC values of resin cement were found under ceramic plates that transmitted more light due to their inherent higher TP values and subsequent higher translucency. Also, an additional study done by Duran et al in 2019 reported that darker ceramic shades with decreased value transmitted less light than lighter ceramic shades. (20) Specimens with 0.5 mm thickness showed higher degree of conversion of resin cement than 1mm thickness specimens. This may be attributed to the fact that increasing ceramic thickness result in light attenuation by the material thus resin cement receives lower light intensity and incomplete polymerization occurs.

The results of this study in agreement with the previous studies investigating effect of ceramic thickness on DC of resin cements. Bayındır et al in 2016 (21) showed a significant difference in DC of resin cement when using ceramics thicknesses 1mm,1.5mm and 2mm. Also, Faria-e-Silva in 2017 (22) showed that increasing the ceramic thickness resulted in a reduction of irradiance and total energy reaching the resin cement and this resulted in decreasing of DC of resin cement. Specimens cured by continuous mode showed significant higher degree of conversion of resin cement than in pulsating mode. This may be attributed to the fact that pulsating light method alternates periods of light on and light off. The light-off periods result in reduction of the polymerization rate; however, it also results in lower stress formation, higher probability of bonding preservation, and favour the formation of extended polymer chains. [23] The current results were in agreement with those of Bektas et al in 2011[24] who investigated the effect of light curing method on the polymerization shrinkage of composite resins. It was concluded that the higher total energy in standard mode is thought to be the cause of the higher polymerization shrinkage than those obtained in pulse mode.

For the results of this study, the null hypothesis was rejected in regard to the effect of the shade of ceramic and the thickness of the ceramic and the curing mode as they had significant effect on the degree of conversion of resin cement. The null hypothesis was however accepted regarding the effect of the type of ceramic on the DC as it did not display any statistically significant changes.

CONCLUSIONS

Within the limitations of this study, with respect to the ceramic thickness used, the ceramic type did not affect the degree of conversion of light cured resin cements but thicknesses up to 1.0 mm has a significant effect on the polymerization of resin cements. Also, ceramic shade had a noticeable effect on the polymerization of resin cements with lighter shades, providing higher DC values compared to darker shades. And finally, the mode of light curing had pronounced effect on the degree of conversion of resin cements.

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