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EFFECT OF DIFFERENT THICKNESSES AND TWO SHADES OF TWO CERAMIC MATERIALS ON THE DEGREE OF CONVERSION OF A LIGHT CURED RESIN CEMENT

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ABSTRACT

Statement of the problem: The success of a ceramic restoration depends primarily on the durability of the bond between ceramic and luting agent, and respectively between luting agent and enamel and dentin. When using composite resin as a luting material, the bond strength will be determined by achieving adequate resin polymerization which is affected by ceramic shade and thickness that interferes with light transmittance resulting in a decrease in the total energy reaching the luting cement.

Objective: This research was designed to evaluate the degree of monomer conversion of light cured resin cement under two ceramic materials (Lithium Disilicate, ultra translucent zirconia) using Different thicknesses (0.4 mm, 0.7mm, 1.0 mm). The degree of conversion is measured by FTIR (Fourier transform infrared spectroscopy).

Materials and methods: light cure resin cement (rely X veneer, 3M) was used as manufacturer's instructions with film thickness of 0.1mm, and cured for 20 seconds using Bluephase (Ivoclar Vivadent) 1200 mW/cm^2 curing done through 14×14 specimens of two types of materials (ulta-translucent zirconia katana UT, lithium disilicate e-max) with two shades (A1, A3) and different thicknesses (0.4 mm ,0.7mm, 1 mm). Then the degree of conversion of each sample evaluated using Fourier transform infrared spectroscope, (Nicolet 6700)

Results: One-Way ANOVA revealed no significant difference between different thicknesses of the ceramic material on the degree of conversion of resin cement ($P>0.05$). While there was a significant difference between different shades of the ceramics on its degree of conversion ($P\leq0.05$). ceramics with the shade A3 showed lower degree of conversion than ceramics with the shade A1, and there was a significant differences between the two types of ceramic materials on the degree of conversion of resin cement with the lithium disilicate material showing a higher degree of conversion than the ultra-translucent zirconia ($P\leq0.05$).

Conclusion: Thicknesses up to 1.0 mm has no significant effect on the polymerization of resin cements, Lighter shades transmit more light to the underlying cement than darker ones, Lithium disilicate has higher translucency and allow more conversion of monomer to polymer in the underlying cement.

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INTRODUCTION

Due to the high esthetic demand nowadays, ceramics have become the materials of choice due to their natural appearance, fluorescence, chemical stability, biocompatibility, durability and high compressive strength, in addition to their thermal expansion being close to that of the tooth structure[1].

Porcelain laminate veneers, are used to replace the conventional, less conservative full coverage restorations mainly used to optimize tooth form and position, close diastemata, replace discolored or un-esthetic composite restorations, correct teeth with incisal abrasions or tooth erosion, and mask or reduce tooth discoloration[2]. This preparation served to avoid aggressive dental preparation, thus maintaining tooth structure[3].

The high strength of the bond formed between the ceramic, resin cement and the dental hard tissues, is the key to success of a ceramic restoration[4].

This high bond strength is obtained through the optimal curing of resin cement luting the restoration. The cross-linking of monomer units to form long chains (polymers), is the base to degree of conversion of resin-based materials. This mechanism is responsible for the unique physical and mechanical properties of the resin-based composites and cements[5-8]. However, several factors affect this polymerization reaction starting by the unique composition of the different products as type of resin monomer and content of inorganic fillers, and also by extrinsic factors as temperature, curing units, amount of light energy received in addition to shade and thickness of the indirect restoration[9, 10].

The total light energy reaching the luting agent is greatly affected by the absorbing qualities of the indirect restorative materials and the distance from the light source leading to reduction on the amount of light reaching the luting cement[11]. This attenuation is strongly dependent on the inner composition of the indirect ceramic restoration as crystal structure, thickness and shape[12]. Dual cured resin cements were developed to overcome the inability of the light to completely reach the luting agent underneath thick indirect restorations, however the reduction of transmitted irradiance when the light passes through a ceramic restoration, can influence degree of conversion and bond strength of these dual-cure adhesive systems [11,13].

All ceramic restorations have become popular due to esthetic appearance and metal free structure. Zirconia (ZrO2)-based ceramics demonstrates superior mechanical properties such as high fracture strength and fracture toughness, enabling its use with posterior fixed partial dentures (FPDs). Due to optical opacity of these materials, zirconia is used as substructure material that is veneered with feldspathic ceramics. In clinical application, limited number of studies reported seldom zirconia substructure fractures but chipping of the veneer is described to be the most frequent occurrence that reduces the success rate of zirconia FPDs [14]. In order to overcome this problem, translucent tooth-colored zirconia (monolithic zirconia) which enables the fabrication of restorations without using veneering ceramic has been developed.

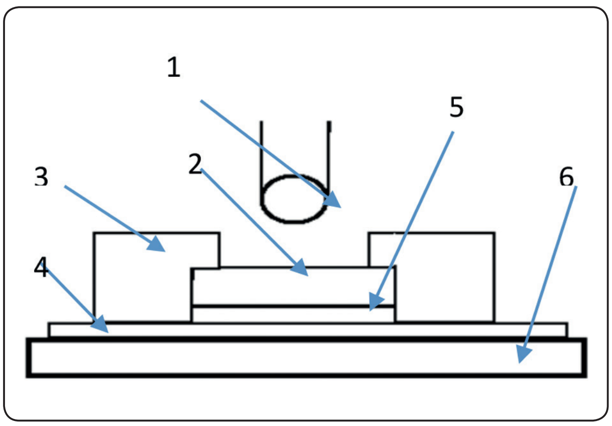
MATERIALS AND METHODS

In this study where three different thicknesses were made out of two different ceramic materials of two different shades. Degree of conversion of the resin cement of each specimen was measured after complete curing.

A light-cured, methacrylate resin-based luting material. RelyX Veneer cement is a single component, light-cure material packaged in a single syringe. The resin is composed of bisphenol-A-diglycidylether dimethacrylate (BisGMA) and triethylene glycol dimethacrylate (TEGDMA) polymer. Zirconia/silica and fumed silica fillers are used to impart radiopacity, wear resistance and physical strength. The filler loading is approximately 66% by weight. The average particle size for the filler is approximately 0.6 mm. Translucent shade was used.

Eighty-four samples were divided into two groups according to the type of ceramic used(n=42). The samples were further divided according to the shade into two subgroups (n=21). A subdivision of three groups according to the ceramic thickness was created (n=7).

Three Teflon moulds were fabricated to ensure a standard thickness of resin cement samples, with an external diameter of 20 mm × 3 mm thickness. An inner dimension 14×14 square shape was cut with three different thicknesses 0.5mm, 0.8mm and 1.1mm respectively to ensure an 0.1 mm uniform cement thickness and proper disc positioning.



1. Tip of the light curing device
2. Ceramic discs of different thicknesses
3. Custom made Teflon mold
4. Celluloid strip
5. Resin cement standardized to 0.1 mm thickness
6. Glass slab

The ceramic discs were seated on the inner stopper of the mold. Resin cement was dispensed from the syringe on the disc, a celluloid strip placed and then the glass slab was applied with pressure to ensure complete seating and uniform 0.1 mm thickness of cement created by the mold.

Blue phase Ivoclar Vivadent 1200 mW/cm^2 was used to cure the resin cement throughout all the disc samples. A high intensity LED light was applied for 20 seconds through the ceramic disc.

The celluloid strip was removed from the sample and thickness of cement verified by digital caliper, then separated from the disc.

Five uncured cement specimens were dispensed from the syringe, mixed with potassium bromide powder and compacted to form a disc shaped specimen for FTIR spectroscopy. Each one of cured samples was ground into fine powder and mixed with potassium bromide powder. The mixture was compacted to form a disc shaped specimen for the FTIR spectroscopy.

Cured and uncured cement samples were collected after preparation and scanned at a resolution of 4cm^{-1} submitted to FTIR (Fourier transform infrared spectroscopy) NICOLET 6700 (Nicolet Instrument Company, USA).

Degree of conversion for each specimen was evaluated using Fourier Transform Infra-Red spectroscopy. In the MIR region, 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. The percentage of unreacted aliphatic C=C bonds remaining throughout the polymerization reaction is obtained by the equation:

$$(\%C{=}C) = \frac{[Abs(aliphatic)/Abs(aromatic)]_{polymer}}{[Abs(aliphatic)/Abs(aromatic)]_{monomer}} \times 100$$

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

RESULTS

The collected data was revised, coded, tabulated and introduced to a PC using Statistical package for Social Science (SPSS 20.0 for windows; SPSS Inc, Chicago, IL, 2011). Data was checked for normal distribution, presented and suitable analysis was done according to the type of data obtained for each parameter.

One-Way ANOVA revealed no significant difference between different thicknesses of the ceramic material on the degree of conversion of resin cement (P>0.05).

TABLE (1) Means of degree of conversion with respect to the difference thicknesses

Thickness	Mean(SD)
1 mm	47.0 (5.9)[a]
0.7 mm	46.6 (3.8)[a]
0.4 mm	47.7 (4.3)[a]

Means with different superscript letters are statistically significant

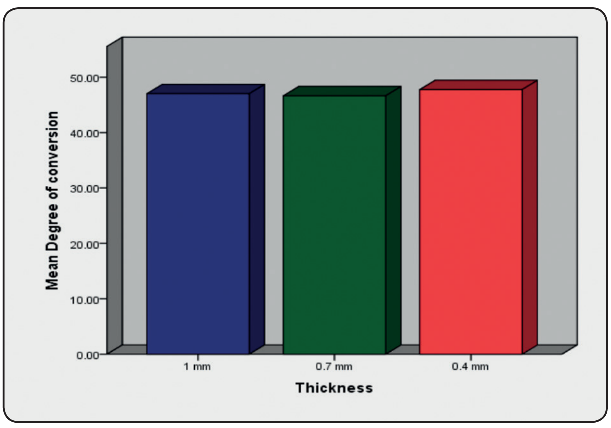


Fig. (1): Bar chart representing means of degree of conversion with respect to different ceramic thicknesses

Significant difference between different shades of the ceramics on its degree of conversion (P≤0.05). ceramics with the shade A3 showed lower degree of conversion than ceramics with the shade A1.

TABLE (2) Means of degree of conversion with respect to the different shades

Shade	Mean(SD)
A3	45.2 (3.4)[a]
A1	48.9 (5.1)[b]

Means with different superscript letters are statistically significant

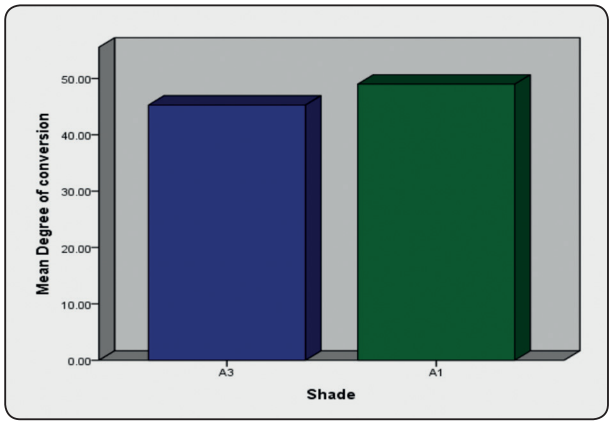


Fig. (2): Bar chart representing means of degree of conversion with respect to different shades

Significant differences between the two types of ceramic materials on the degree of conversion of resin cement with the lithium disilicate material showing a higher degree of conversion than the translucent zirconia (P≤0.05).

TABLE (3) Means of degree of conversion with respect to different ceramic materials

Material	Mean (SD)
Translucent zirconia	45.2 (3.8)[a]
Lithium dislocate	49.0 (4.7)[b]

Means with different superscript letters are statistically significant

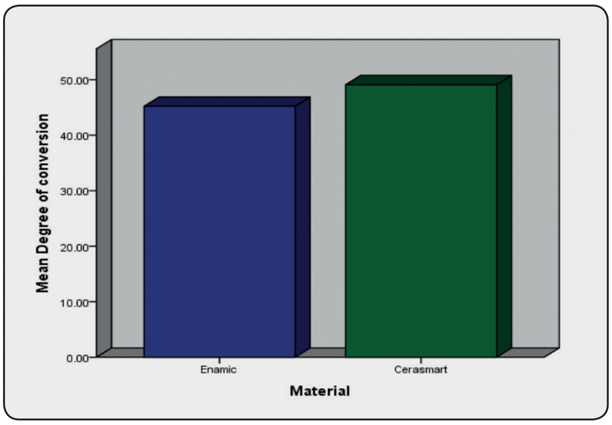


Fig. (3): Bar chart representing means of degree of conversion with respect to different ceramic materials

DISCUSSION

The degree of conversion has a direct influence on the physical, biological and mechanical properties of composite resins. Studies showed that these properties improve by the increase in degree of conversion attained during photo-polymerization[15].

Several factors affect the degree of polymerization of resin cement as shade, thickness and translucency of the ceramic used, resin cement composition and mode of polymerization. The type of light cure, curing output power, duration and distance also affect the cement polymerization[16]. Therefore, ceramic shade, thickness and type were included as variables in this study.

The aim of any dental biomaterials is to restore the missing tooth structure by emulating the complexity of enamel and dentin with their mechanical and biological characteristics. Dental tissues have a very unique and complex ultra-structure, making this task very hard. As dental ceramics show some physical properties close to that of human enamel and composites better reproduce characteristics of dentin, the research towards creating new materials with this combination has been conducted [17].

Ceramics of high esthetic qualities and superior mechanical properties are essential when it comes to restoring anterior teeth with porcelain laminate veneers. These mechanical properties are crucial to obtain minimal thicknesses ensuring maximum conservation of tooth structure and highest translucency.

Three different thicknesses of ceramic samples were used 0.4mm, 0.7mm, 1.0mm. Since porcelain veneer thickness is approximately 0.3 mm to 0.9 mm[18], the result of this study has high clinical significance in veneer cementation procedures, compared with other studies investigating large thicknesses of ceramics.

Bonding of ceramics to enamel ensure a more superior bond that that of dentin, therefore maximum conservation of the enamel is essential to decrease micro-leakage[19]. For this reason, studies on the thickness of remaining enamel at different parts of the labial surface have been conducted[20]. Thin thickness of porcelain laminate veneers is important for translucency and esthetics as well as conservation. Translucency increases as thickness of ceramic veneers decreases[21].

The thickness has a greater effect on translucency than the shade of the ceramic[22]. Recently, the concept of non-prep veneers has become a more acceptable conservative solution for some esthetic situations. The minimum thickness used can be 0.3 mm is order to avoid over-contouring[23]. To ensure standard thicknesses between different groups pf ceramic samples a low speed diamond saw, Isomet was used and then the thicknesses checked using the digital caliper.

In this study, a light-cured cement was investigated. The use of light cured resin cement has always been an advantage when it comes to cementing laminate veneers. Their color stability; due to the absence of amines, single paste formulation and longer working time, have made it a better choice over dual-cured cements[24]. The properties of light-cured cements are influenced by the thickness and composition of the ceramic used. This thickness affects the transmission of light[25] and its quality reaching the underlying cement layer[26].

The shade of the underlying cement affects the final shade and opacity of the restoration[27], Recent investigations have shown that this is true especially in the cases of thin porcelain laminate veneers where the resin cement shade can influence the overall color of a restoration[28]. A translucent shade was selected and standardized throughout the study.

In this study, the thickness of cements was controlled at 0.1 mm to resemble the maximum accepted cement thickness under porcelain laminate veneers clinically. Teflon mold were fabricated according to the three thicknesses of ceramics used to standardize the thicknesses if cement used throughout the samples. The thickness used a recommended by some studies, is suitable for internal fit of the veneer for proper stress distribution of interface between ceramic and resin cement, also thicker cement film may have an influence on the final esthetic outcome of the restoration [29,30]. **Patrício Runnacles et al in 2014**[31], used a cement thickness of 0.1 mm in his study to evaluate the degree of conversion of a light cured cement through ceramic veneers.

As for the shades used, A1 and A3 HT were considered. The need of high esthetics made lighter ceramic shades highly demanded by the patients on restoring anterior teeth with porcelain laminate veneers. Light transmission is affected by shade of restorative material used, lighter shades have better transmission than darker ones [26].

No significant effect was shown on the resin cement polymerization under different thicknesses of the ceramic materials used. This finding might have resulted from the high translucency of these new ceramics specially in very thin thicknesses proposed for laminate veneers, having a little effect on light attenuation This agrees with the literature where **Cho et al in 2015**[32,18] showed no significant difference in the conversion of light cured resin cement under thicknesses of ceramic used up to 1.2 mm meaning the light activation was enough to polymerize the LC resin cements up to 1.2 mm[18]. Also **CS Yuh et al in 2009[32]**, studied the effect of thickness of ceramic, light devices and curing time on the degree on conversion of light cured cement and found no significant effect between the thicknesses upto 1.5 mm[32]. This was also confirmed by **Patrício Runnacles et al in 2014[31** who stated that effect of light attenuation by ceramic veneers is not significant in thicknesses of 1.0 mm or less.

The darker A3 shade used showed lower values for degree of conversion of the resin cement when compared to the lighter A1 shade. This finding was confirmed by **Sheila P. Passos et al in 2013[33** the %DC of the resin cement was much lower under the darkest ceramic than under the lightest ceramic. Also **CJ Soares et al in 2006[34]** showed the same results. This factor may be attributed to the low rate of polymerization as darker shades may attenuate the light transmission. Therefore, high ceramic translucency improves polymerization of luting composite.

The use of different ceramics showed a significant effect on the degree of conversion of resin cement. There was a significant difference between the two types of ceramic materials on the degree of conversion of resin cement with the lithium disilicate material showing a higher degree of conversion than the ultra-translucent zirconia, the opacious nature of monolithic zirconia restorations can limit the amount of light transmitted through the material. The brand and thickness of zirconia can significantly influence light irradiance and radiant exposure.[35,36]

In order to enhance the translucency of zirconia, residual pores and impurities must be reduced because they create volumes of differing refractive index and lead to optical scattering on the surface zirconia and a reduction in its translucency.[15-19] Residual pores are formed as gaps between the zirconia grains at the time of molding. Some studies have reported that improving the properties of the zirconia powder and modifying its pressing methods at the time of molding can heighten the translucency of zirconia.[17-19] In addition, grain size and sintering temperatures may also influence the translucency of zirconia.[20,21,43] When light proceeds into the zirconia, it may scatter from the grain boundaries, with smaller grain sizes because of the larger number of grain boundaries. Thus, larger grains of zirconia show higher translucency than smaller ones. The grain size depends on sintering conditions. If the sintering temperature is increased, grain sizes become larger. The sintering of all the zirconias used in this study was performed at a temperature range of 1450 to 1550˚C.

Generally, the sintering temperature for conventional zirconia is set at 1200 to 1350˚C. Therefore, high translucency zirconias may require higher sintering temperature compared with conventional zirconia to achieve larger grains.

Generally, conventional zirconia contains 0.5 to 1.0wt % of Al_2O_3 and 3 to 6wt% of Y_2O_3, such as compositions from Zirkonzahn (Zirkonzahn GmbH), which contains 4 to 6wt% of Y_2O_3 and less than 1 wt% of Al_2O_3 and

High translucency zirconias are achieved with much lower alumina content compared with conventional zirconia. The zirconias used in this study contain 0.11 to 0.26 wt% of Al_2O_3. However, previous studies have reported that the small amount of alumina contained in zirconia is effective for the prevention of LTD.[24-27]

According to these studies on accelerated aging resistance, the radial propagation of phase transformations from the metastable tetragonal phase to the monoclinic phase of Y-TZP is blocked by the addition of alumina and the phase transformation occurs in a scattered manner. In addition, lager grains are more susceptible to phase transformation and decrease the resistance to LTD.,[21] Even conventional zirconia has been suspected of LTD, which is associated with the spontaneous transformation of metastable tetragonal phase to monoclinic phase in the oral environment.[28,29] Therefore, the high translucency zirconias used in this study may be more susceptible to LTD because of the reduced alumina content and the larger grain sizes. To counter LTD, the amount of Y_2O_3 was increased to 3.90 to 9.32wt% in the high translucency zirconias used in this study, especially in Prettau Anterior, Katana ST, and Katana UT which showed high values of Tt%. A previous study reported the effects of the mechanical properties of zirconia with differing amounts of Y_2O_3 after accelerated aging.[30] The study showed the reduction of the transformation from the tetragonal to monoclinic phase after accelerated aging with the higher amount of Y_2O_3. Based on the above, translucent zirconia may be produced by reducing the Al_2O_3 content to improve light transmittance and an increase in Y_2O_3 content to minimize LTD.

Additionally, previous studies have reported that Al_2O_3 in zirconia is also enhance the mechanical properties of zirconia.[24,26] Takaki[30,31] reported that mechanical properties, such as the flexural strength and the fracture toughness, were markedly decreased from 2.5 to 5.0 mol% by Y_2O_3 increasing. Therefore, the mechanical properties of high translucency zirconia may be of concern, since high translucency zirconias may be produced with such compositions.

Clinicians may consider the use of high translucency zirconia for monolithic restorations in the posterior segments, with a hybrid design in the premolar areas and less occlusal tooth reduction translating into less occlusal thickness and with conventional cementation rather than bonding. This study demonstrated that e-max CAD LT was significantly more translucent than all zirconias, with an approximately 20% difference in translucency compared with Katana UT at 0.5 mm thickness and approximately 15 to 20% at 1.0 mm thickness for Katana UT, Prettau Anterior, and

Katana ST. However, as stated by the manufacturer, the recommended thickness for monolithic lithium disilicate crowns is 1.5 mm because of its inferior mechanical properties to high strength zirconia ceramics. Moreover, such differences may not be as clinically significant for ceramic crowns with the monolithic or hybrid design, since other parameters such as value, shade, contour and surface texture may all collectively and individually significantly affect restoration match. Therefore, further clinical studies are required to assess the esthetics and translucency of such restorations with different zirconias and various ceramic materials.

CONCLUSION

1. Thicknesses up to 1.0 mm has no significant effect on the polymerization of resin cements.
2. Lighter shades transmit more light to the underlying cement than darker ones.
3. Lithium disilicate has higher translucency and allow more conversion of monomer to polymer in the underlying cement.

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