EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 1827:1835, April, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 27-02-2024 • Accept Date : 16-03-2024 • Available online: 10-04-2024 • DOI : 10.21608/EDJ.2024.273175.2960

INFLUENCE OF HYBRID CERAMIC THICKNESS AND TRANSLUCENCY ON RESIN CEMENT DEGREE OF CONVERSION (IN VITRO STUDY)

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ABSTRACT

Objective: Various factors influence the degree of conversion of dual-cure resin cement, including the restoration thickness, and the translucency of the ceramic material. This study aims to explore the impact of endocrown thickness and ceramic material translucency on the degree of conversion of dual-cure resin cement.

Material and Methods: Forty ceramic samples of vita Enamic were used. They were categorized into four groups based on the translucency T (n=10) and HT (n=10) and thickness 3mm (n=10) and 5mm (n=10). Two specially designed Teflon molds were fabricated for each thickness. The ceramic samples were placed inside the mold followed by dual cure Self-Adhesive Resin. The dual cured resin cement had a 0.1mm thickness. The cement film was detached from the ceramic samples. Then the Fourier Transform Infrared Spectroscopy was used to measure the degree of conversion.

Results: Two-way ANOVA showed significant differences between the different thicknesses of ceramic and different translucencies on the degree of conversion of the dual resin cement ($p < 0.05$).

Conclusion: Ceramic thicknesses have a significant influence on the degree of conversion of the underlying dual cure resin cement. Higher translucencies of ceramic material show higher cement conversion than lower translucencies.

KEYWORDS: Ceramic Thickness, Hybrid Ceramic, Translucency, Degree of conversion

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INTRODUCTION

In contemporary times, dental treatments face heightened aesthetic expectations, with a growing need for satisfaction and enhanced comfort during routine dental procedures for both dentists and patients. Consequently, the prevalence of ceramic materials has risen, attributed to the natural look of the material, biocompatibility, chemical stability , fluorescence ,and high strength in compression , durability , additionally their thermal expansion closely resembles the natural tooth [1].

The endocrown, also known as a one-piece restoration, represents a conservative, straightforward, and aesthetically pleasing solution that addresses various clinical challenges. It is especially beneficial in certain situations such as limited interarch space, short roots, and cases with curved or calcified canals. Moreover, it contributes to minimizing the risks of perforation, root fractures, and periodontal breakdown. The rationale behind employing this technique lies in utilizing the pulp chamber's surface area to achieve retention and stability through the adhesive bond between dental ceramics, resin cement, and dental tissue [2].

The ceramic restoration efficacy predominantly depends on achieving a robust bond strength within the formed adhesion complex among the ceramic material, resin cement, and the tooth [3].

To achieve a strong bond, sufficient curing of the cement is essential. The degree of conversion in materials based on resin relies on the cross-linking of monomer units, leading to the formation of elongated chains known as polymers. This process imparts distinctive mechanical as well as physical properties to composite resins and resin based cements[4,5]. Nevertheless, the specific composition of each product may influence the polymerization reaction, including factors such as monomer type and the inorganic particles content. Additionally, other variables like the thickness and shade of the restoration, temperature, curing lights, and the quantity of received light energy can also impact the process [6-8]. The light energy amount reaching the cement is significantly influenced by the light-absorbing property of the material as well as the distance between the curing unit and cement. This interaction can reduce the light reaching the resin cement [9].

In addressing the challenge of light penetration beneath thick restorations, dual cure resin cements were introduced. Nevertheless, as the light traverses through the ceramic restoration the decrease in transmitted irradiance may impact the adhesive systems bond strength as well as the degree of conversion [10,11].

Hybrid ceramic, a restorative dental material type, offers numerous benefits, including excellent, chemical stability, machinability, easy processing, elevated precision in molding and biocompatibility [12]. The advent of Vita Enamic ceramics, characterized by a dual network structure that seamlessly merges the strengths of both ceramics and composite materials, has recently spurred their use as machinable materials in conjunction with Computer Aided Design-Computer Aided Manufacture (CAD-CAM) techniques [13].

The null hypothesis of this study is that the endocrown ceramic material thickness and its translucency would not affect the degree of conversion of the resin cement.

MATERIALS AND METHODS

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there would be no difference between different tested groups regarding the degree of conversion. By adopting alpha (α) and beta (β) levels of (0.05) (i.e., power = 95%) and effect size (f) of (0.914) calculated based on the results of a previous study conducted by Patrício, et al., 2014 14, the total required sample size (n) was found to be (28) samples. The sample size was calculated using R statistical analysis software version 4.3.2 for Windows (R Core Team,

2024) (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.). This is a minimal estimation of sample size, so it was increased to (n=10) per group.

Forty ceramic slices with a shade of 1M1 were machined from their respective blocks and categorized into four groups based on thickness and translucency, 20 slices were fabricated to uniform standard thicknesses of 3 mm and another 20 slices of 5 mm using an isomet (Buehler Company, isomet 4000, llinois, USA). A digital caliper (Hoffmann Group, Holex, Knoxville, USA) was utilized to check the thicknesses. The groups comprised of two thickness variations, 3mm (n=10) and 5mm (n=10), each crafted from two distinct Vita Enamic (Vita Zahnfabrik, Bad Säckingen, Germany) translucencies: T (n=10) and HT (n=10). After complete curing of each dual-cure resin cement (Pentron, Breeze self-adhesive resin cement, California, USA) sample the degree of conversion was assessed.

Two Teflon molds, as depicted in figure (1), were created to maintain a consistent thickness for the dual-cure resin cement samples. These molds had an outer diameter measuring 20mm×3mm thickness. Within these molds, a square shape measuring 14x14mm was created with two different thicknesses: 3.1mm and 5.1mm. This design facilitated the accommodation of ceramic samples with designated thicknesses of 3mm and 5mm, respectively, ensuring a uniform 0.1 mm cement thickness.

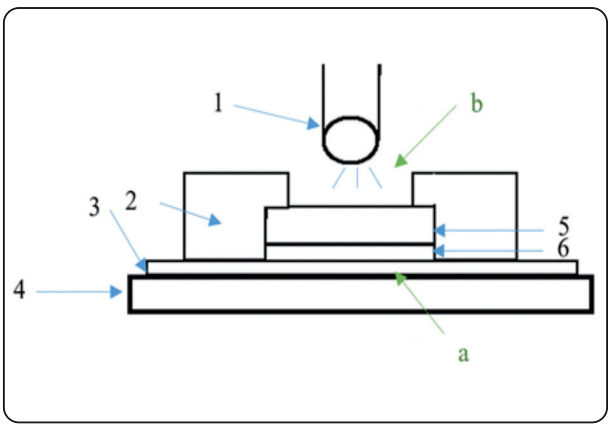
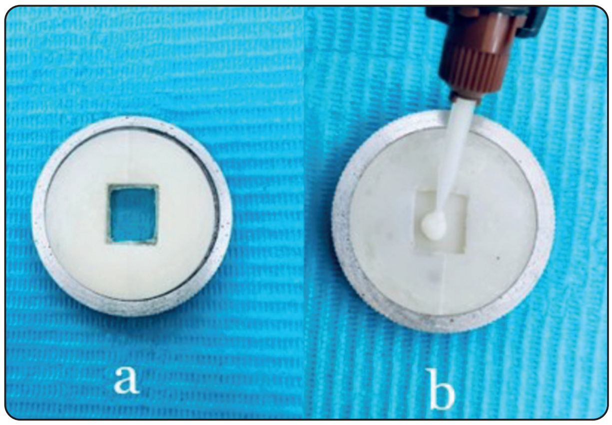


Fig. (1) Diagram of the resin/ceramic sample preparation 1) light cure tip 2) Teflon mould 3) Celluloid strip 4) Glass slab 5) Ceramic samples with different thicknesses 6) Dual cure resin cement with 0.1 mm thickness

The ceramic samples were positioned within the mold, followed by the application of the dual cure resin cement onto the ceramic samples. Then the celluloid strip (Generic, Celluloid Strip, Egypt) was applied, subsequently, a glass slab was applied with pressure to ensure the creation of a uniform 0.1 mm cement thickness, as determined by the mold [15] figure (2a & 2b).



Fig, (2) a) Teflon mold showing 0.1 mm internal stop b) Resin cement application on ceramic sample

Light cure unit (3M Company, Elipar™ DeepCure-L, Minnesota, USA) was used for 20 seconds with an intensity of 1470 mW/cm^2 to cure the dual cure resin cement through all of the ceramic samples, with the light cure tip in intimate contact with the ceramic samples.

Subsequently, the strip of celluloid was taken off from the sample, and the specimen of resin cement was separated from the ceramic sample. The resin cement specimens' thickness was confirmed using a digital caliper. These specimens were then placed in a dark container for twenty-four hours before undergoing analysis. Additionally, five specimens of unpolymerized cement were applied from the syringe specifically for FTIR spectroscopy.

Uncured and cured samples of cement were obtained after preparation and subjected to scanning at 4cm-1 resolution. A spectral plot of wave numbers ranging from 4000-400 cm^{-1} against the intensities of the absorbance peak was given, using OPUS 7.8c software which was connected to the FTIR unit (Bruker Corporation, Bruker ALPHA II, Billerica, Massachusetts, USA).

Fourier Transform Infrared (FTIR) spectroscopy was used to assess the degree of conversion for each cement specimen. In the Mid-Infrared (MIR) region, the degree of conversion (DC) is assessed by measuring the decrease in area or intensity of the absorption band of methacrylate (C =C). At 1608 cm^{-1} (Abs1608) recording of the aromatic double bonds' absorption peaks were done, and at 1638 cm^{-1} (Abs 1638) the peaks of the aliphatic double bonds (C =C) were noted, during the conversion of methacrylate monomer into polymer. The following equation is used to obtain the remaining unreacted aliphatic (C =C) bonds percentage:

$$\%DC = (1 - \frac{aliphatic\ C=C\ /\ aromatic\ C=C\ )\ polymer}{(aliphatic\ C=C\ /\ aromatic\ C=C\ )\ monomer} \times 100)$$

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

Statistical analysis:

The data were presented Numerically as mean with confidence intervals (CI) of 95%, standard deviation (SD), maximum (max) and minimum (min) values. The normality of the data was assessed through Shapiro-Wilk's test and data distribution, confirming normal distribution. Analysis was conducted using two-way ANOVA followed by comparison of simple effects with Bonferroni correction and utilizing the pooled error term from the main ANOVA model. The level of significance was set at ($p < 0.05$) for all tests. Statistical analysis was carried out using R statistical analysis software version (4.3.2) for Windows (R Core Team ,2024) (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The results indicated a significant influence between different variables on degree of conversion. (table 1). Regarding translucency, for the 3mm thickness, high translucency samples (50.91±1.71) (%) had a significantly higher degree of conversion than low translucency samples (48.33±1.47) (%) (p=0.002). For the 5 mm thickness, high translucency samples (46.02±1.23) (%) had a higher degree of conversion value than low translucency samples (45.31±1.36) (%) yet the difference was not statistically significant (p =0.237).

Regarding the thickness, with the high translucency samples, the 3mm thickness 50.91±1.71) (%) had a significantly higher degree of conversion value than 5 mm thick samples (46.02±1.23) (%) (p<0.001). While with the low translucency samples, the 3mm thickness (48.33±1.47) (%) had a significantly higher degree of conversion value than 5 mm thick samples (45.31±1.36) (%) (p<0.001) figure (3).

TABLE (1) Descriptive statistics for degree of conversion (%)

Translucency	Thickness	Mean	95% CI		SD	Min.	Max.
			Lower	Upper			
High translucency	**3 mm**	50.91	49.85	51.97	1.71	47.10	53.20
	5 mm	46.02	45.26	46.78	1.23	44.20	48.40
Low translucency	**3 mm**	48.33	47.42	49.24	1.47	46.10	50.40
	5 mm	45.31	44.47	46.15	1.36	43.40	48.00

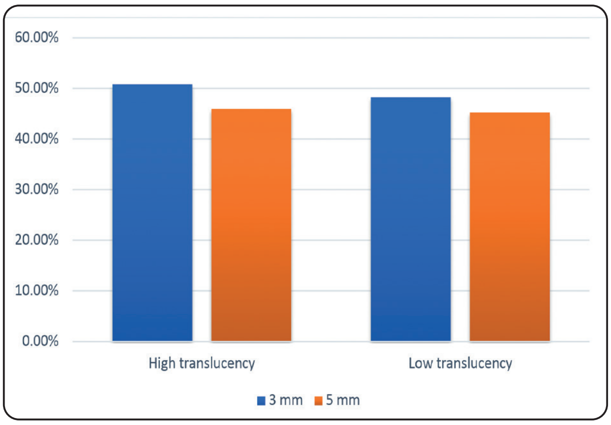


Fig. (3) Bar chart showing average degree of conversion (%) for different translucencies and thicknesses (B)

DISCUSSION

The ongoing evolution of materials for computer-aided design/computer-aided manufacturing (CAD/CAM) systems has expanded the range of options available to clinicians for patient rehabilitation. Among the suitable materials for machined restorations, composites and ceramics stand out as noteworthy alternatives [16,17].

The optical and mechanical properties of ceramics are excellent, as well as the biocompatibility, however, they exhibit rigidity, fragility, and are challenging to repair. Conversely, composites are easier to repair and manipulate, less abrasive to the antagonist natural tooth, and more flexible, however their drawback lies in poor resistance to wear and difficulty in obtaining a good polish, placing them at a disadvantage compared to ceramics. As a part of these new hybrid materials, Vita Enamic, a polymer-infiltrated ceramic-network can be identified[17,18]. Vita Enamic ceramics, a hybrid dental ceramic featuring a dual network structure that amalgamates the strengths of both ceramic and composite materials, has recently emerged as a machinable material for utilization[13].

Hybrid ceramic, serving as a dental restorative material, boasts numerous advantages, including excellent biocompatibility, chemical stability, ease of machinability, straightforward processing, and high precision in molding [12]. The properties of resin composites are positively affected as their degree of conversion increases [19]. Certainly, the degree of conversion plays an important role in influencing mechanical properties as strength, modulus of elasticity and hardness in materials like resin composites [20]. Degree of conversion also affects the physical properties of the resin composite as the water sorption and solubility behavior [21].

In this study we used two thicknesses of ceramic samples 3 mm and 5 mm simulating the occlusal thickness of endocrown. Endocrowns exhibit a higher resistance to occlusal loading compared conventional crowns. Added, the resistance to fracture of this system is higher with greater occlusal thickness [22]. To ensure uniform thicknesses among the different ceramic sample groups a low-speed diamond saw, Isomet, was utilized, and subsequently verified by using a digital caliper.

In this research, a dual-cure resin cement was employed, as it has been shown that dual-cure resin cement offers superior bond strength compared to light-cure resin cement, particularly in the context of endocrown restoration [23]. The dual-cure resin cement mechanical properties are affected by the ceramic composition and thickness used [24]. The cement shade may affect the final shade of the restoration [25]. For standardization throughout the study, a translucent cement shade was used. The cement thickness was carefully regulated at 0.1mm to align with the maximum cement thickness accepted clinically under restorations[26,27,28,29]. To ensure consistency, a Teflon mold was crafted based on the two ceramics thicknesses employed.

To prevent the formation of an oxygen inhibited layer during the cement polymerization, a celluloid strip was positioned over every specimen of resin cement before the curing procedure [30]. The tip of the light cure was placed directly on the ceramic sample to ensure optimal transmission and penetration of light through the specimens [31].

The degree of conversion measurement was employed using FTIR (Fourier Transform Infrared Spectroscopy). FTIR is widely recognized as the most commonly used method for assessing the degree of conversion in resin composite materials [32,33].

As for the thickness factor the null hypothesis was rejected. A significant difference was observed between the thicknesses of the ceramic material regarding the degree of conversion of dual resin cement at ($P \leq 0.05$). Specimens with a thickness of 3mm exhibited higher degree of conversion of resin cement compared to specimens with a thickness of 5mm. This may be ascribed to the ceramic thickness increase, leading to attenuation of light by the material. Consequently, lower light intensity reaches the resin cement, potentially leading to incomplete polymerization. This observation aligns with previous findings [4,15,34], which reported that the ceramic material translucency influences the degree of conversion, hardness, and modulus of elasticity of the evaluated luting materials.

The findings of this research align with the early researches investigating the impact of the thickness of ceramics on degree of conversion of resin cements. **Oh et al., 2018**, investigated the impact of thickness on the transmission of light and degree of conversion, revealing that the rate of light transmission was below 30% even at a thickness of 0.5 mm, and it exhibited an exponential decrease as the ceramic thickness increased[35]. Additionally, **Magalhaes et al., 2021**, demonstrated that ceramic shade, translucency, and thickness significantly affect the degree of conversion[36]. Specifically, a significant difference was observed in the degree of conversion of resin cement when the thickness of ceramic exceeded 2mm. It is indicated that an increase in ceramic thickness will lead to a decrease in the total energy and irradiance reaching the resin cement, causing a decrease in the degree of conversion of the resin cement[37].

Regarding the translucency factor, the null hypothesis was rejected. Statistically there was significant difference between the different translucencies on the degree of conversion at ($P \leq 0.05$). Higher degree of conversion was shown at the high translucency samples than lower translucency samples. This observation can be attributed to the decrease in translucency, which results in a reduction in the penetration of light energy needed for the monomer to polymer conversion. Consequently, this decrease in translucency may contribute to a reduction in the degree of conversion of the dual resin cement [38].

Mendonca et al., 2019 concluded that a positive correlation exists between the degree of conversion and ceramic translucency. Their study delved into the impact of the shade of ceramic on light transmission and the dual-cure resin cement degree of conversion[39]. Added, it was observed that translucency tends to increase with higher wavelengths and decreasing ceramic thickness [40].

On the other side, these findings contradict the research conducted by Cho et al., 2015 [41], which examined the impact of ceramic thickness on the degree of conversion of resin cement. The study demonstrated that varying ceramic thicknesses did not result in a significant difference in the degree of conversion of resin cement. This is consistent with the findings of Mazão et al., 2023 [42], who proved that there is no significant decrease in the degree of conversion observed when the thickness of ceramic increases.

The ceramic material optical properties are influenced by the material composition[43,44]. The overall energy of light get to the cement is significantly influenced by the characteristics of light-absorption of the restorative materials. This can lead to a decrease in the light amount that reaches the resin cement [9]. The ceramic restoration's internal composition, including factors such as thickness, structure of crystals, and shape, highly influences the extend of this effect [45 46].

In light of this study, it is advisable to pursue further research that takes into account additional variables such as light cure intensity and duration, various shades of the resin cement, as well as different shades of ceramic discs. These factors could significantly influence on the degree of conversion and merit exploration for a more comprehensive understanding.

CONCLUSION

1. A significant effect was shown on the polymerization of resin cements with decreasing the thickness of the ceramic samples.
2. Degree of conversion showed to be higher with lighter ceramic translucencies than with darker ones.
3. Ceramic samples with a thickness of 3mm and higher translucency showed better degree of conversion than 5mm thickness samples with lower translucency.

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