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Original Article

Effect of computer-aided design/computer-aided manufacturing bleach shade ceramic thickness on its light transmittance and microhardness of light-cured resin cement

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ABSTRACT

Background: This study aimed to measure light transmittance (LT) through various thicknesses of computer-aided design/computer-aided manufacturing bleach shade ceramics and to assess the Vickers microhardness (VMH) of underlying light-cured resin cement.

Materials and Methods: In this *in vitro* study, a total of 90 ceramic discs (VITA Mark II [VM], VITA Suprinity, and CELTRA Duo) were prepared in 0.5, 1, and 1.5 mm thicknesses. To measure LT, the Valo light-curing unit was placed in direct contact with the ceramics on the radiometer. The average LT was recorded after three measurements. In addition, 90 specimens of light-cured resin cement (Allcem Veneer) were cured in Teflon molds (0.5 mm in depth) beneath ceramic pieces. Ten specimens of resin cement were also cured without the presence of ceramic as a control group. VMH of the cement specimens was reported. The data were analyzed by one-way analysis of variance and multiple comparison tests (α =0.05) in SPSS version 17.

Results: In each ceramic group, LT was negatively related to ceramic thickness (P < 0.05). At a thickness of 1.5 mm among all ceramic types, the VMH of resin cement was significantly decreased (P < 0.05). In all thicknesses, the VMH of resin cement was lower significantly than the control group, except for the thickness of 0.5 mm of VM.

Conclusion: According to the results of this study, light-cured cement is not a suitable option for cementing the studied bleach shade ceramics. Furthermore, the thickness of the ceramic has a significant effect on LT (P < 0.05), unlike VMH.

Key Words: Ceramics, dental curing light, hardness, resin cements

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INTRODUCTION

Esthetic dentistry has become more popular due to the importance of dental and facial beauty in the quality of life.[1,2] Given the long-term and satisfying esthetic results of ceramics, the demand for full-ceramic and metal-free restorations is rising.[2-4] In addition, ceramics have a natural tooth-like color, translucency, and biocompatibility with the patient's periodontal tissues.[5]

Computer-aided design/computer-aided manufacturing (CAD/CAM) technology has enabled dentists to

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restore teeth using ceramic materials in a single session.[6,7] There are over 30 various types of ceramics available for CAD/CAM devices.[8] A number of these ceramics are used in the form of chairside economical restoration of esthetic ceramics (CEREC), such as CELTRA Duo (CD), VITA Mark II (VM), and VITA Suprinity (VS).[8,9] For use in the CEREC technology, zirconia-reinforced lithium silicate (ZLS) has been manufactured since 2014 under two different products, including VS and CD.[8] This structure consists of spherical zirconia particles added to the lithium silicate matrix.[8,10] As claimed by the manufacturer, this new ceramic glass enriched with zirconia incorporates the strength of zirconia with the esthetic properties of glass ceramic.[11]

Resin cements are generally used in the cementation of ceramic restorations and play a critical role in their durability and color.[12,13] Light-cured resin cements are widely suggested to cement ceramic restorations.[12,14] Dual-cured cements are recommended for restorations thicker than 1.5–2 mm, or restoration opacity inhibits the light transmittance (LT). In these cements, both chemical and light polymerizations are integrated.[15,16] Various parameters including translucency, thickness and color of the ceramic, resin cement composition, type of polymerization, distance from the light-curing unit, output power of the light-curing unit, and curing time, affect the polymerization of resin cement.[11,15] Any reduction in the energy density of light irradiation influences the mechanical properties, degree of conversion, color stability, surface hardness, and leakage of residual monomers of cement.[5,17] Surface hardness is an indicator of evaluating polymerization efficiency and is associated with the light intensity applied during polymerization.[13,18]

A previous study showed that the composition and thickness of ceramic influence ceramic LT.[19] Another article reported that the thickness and color of CAD/CAM ceramics affect the intensity of transmitted light and microhardness of the light-cured resin cement.[5] Various studies have indicated the influence of increasing the thickness of ceramics with common shades (A1, A2, and A3) on the polymerization of the underlying cement.[16,19,20] However, limited information is available on the LT of bleach shade ceramics and its effects on the hardness of the underlying resin cement. Bleach shade ceramics may distort the LT and polymerization of resin cement due to their higher opacity.

Considering the popularity of bleach shade ceramics and since little is known about the LT of these types of ceramics in the literature, this study aimed to investigate the LT of bleach shade of CD, VM, and VS ceramics in different thicknesses and hardness of resin cement. The null hypothesis was that the LT and Vickers microhardness (VMH) of the underlying resin cement are not influenced by the thickness and composition of different ceramics.

MATERIALS AND METHODS

The *in vitro* study protocol was approved by the Ethics Committee of Babol University of Medical Sciences (Ethics ID: IR.MUBABOL.REC.1399.077).

In this research, the following bleach shades of chairside CAD/CAM ceramics were used [Table 1]:

- CD (ZLS; Dentsply Sirona, DeguDent, GmbH, Hanau-Wolfgang, Germany) BL2_LT
- VS (ZLS; VITA Zahnfabrik, Bad Säckingen Germany) 0M1_T
- VM (Feldspathic Ceramic; VITA Zahnfabrik, Bad Säckingen, Germany) 0M1.

Specimens preparation

From each ceramic block (size 14: 12 mm × 14 mm × 18 mm in dimensions), discs with a diameter of 7 mm and thicknesses of 0.5, 1, and 1.5 mm were fabricated with a slow-speed saw (Delta Precision Sectioning Machine, Mashhad, Iran) using copious water spray. According to the parameters of thickness and ceramic type, 90 ceramic specimens were prepared (n = 10).[19,20] Ceramic discs were polished with 400, 800, 1000, and 1200 grit silicon carbide papers under wet conditions. The final thickness of each disc was confirmed by a digital caliper (Shinwa Digital Caliper, Niigata, Japan) (0.5 ± 0.05, 1 ± 0.05, 1.5 ± 0.05). Then, the specimens were placed in distilled water for 10 min in an ultrasonic device (BioSonic UC50D, Coltene, Whaledent, USA). Specimens were glazed on one side after applying a thin layer of VITA AKZENT Plus glaze LT Powder (VITA Zahnfabrik, Bad Sackingen, Germany) on VS, VITA AKZENT Plus glaze Powder (VITA Zahnfabrik, Bad Sackingen, Germany) on VM, and CELTRA Universal Glaze (Dentsply Sirona Restorative, Germany) on CD. Conditions for glazing ceramics were 840°C for 12 min, 950°C for 10 min, and 820°C for 8 min in a porcelain oven (VITA Vacumat 6000 MP, Vita Zahnfabrik, Bad Sackingen, Germany), respectively. VS ceramics were

Table 1: List and compositions of the materials used in this study

Material	Color	Type of material	Compounds	Lot number	Manufacturer
VS	0M1-T	Partially crystallized zirconia reinforced lithium silicate glass ceramic	SiO_2, Li_2O, KO_2, P_2O_5, Al_2O_3, CeO_2	43260	VITA Zahnfabrik, Bad Säckingen, Germany
VITABLOCKS Mark II	0M1	Feldspar-reinforced aluminosilicate glass	SiO_2, Al_2O_3, Na_2O, K_2O, Li_2O, CaO, TiO_2	66961	VITA Zahnfabrik, Bad Säckingen, Germany
CD	BL2-LT	Fully crystallized lithium silicate/phosphate glass ceramic	SiO_2, LiO_2, ZrO_2, P_2O_5, CeO_2, Al_2O_3, ZnO	5365411175	DeguDent, Hanau, Germany
Allcem Veneer	Trans	Light-cured resin cement	Methacrylate monomers, camphorquinone, co-initiators, stabilizers, pigments, silanized barium, Al, and silicate glass particles, and SiO_2 63% of filler content	120219	FGM, Joinville, SC, Brazil

VS: VITA Suprinity; CD: CELTRA Duo; LT: Light transmittance

additionally crystallized during the glazing phase, according to the manufacturer's instructions.

Etching process

Specimens were etched with 5% hydrofluoric acid (Pulpdent, Massachusetts, USA), based on the recommended time for each ceramic (60 s for VM, 20 for VS, and 30 for CD)[21,22] and rinsed with an air–water syringe for 30 s. To remove any contaminations and grease, specimens were ultrasonically cleaned with 98% alcohol and were dried with air spray. To simulate the clinical condition, silane (Bis-silane, Bisco, Schaumburg, IL, USA) was applied to the etched part of the ceramic using a microbrush and was dried by air spray after 1 min.

Measurement of light transmittance

A blue-violet LED-curing unit (VALO, Ultradent, South Jordan, UT, USA) was used with an irradiance of 1000 mW/cm^2. Ceramic specimens were placed on a radiometer diaphragm (Optilux, Kerr, Orange, CA, USA). The tip of the light-curing unit with 1000 mW/cm^2 intensity was in direct contact with the ceramic, and the average LT was recorded after three measurements. LT% was calculated using the following equation:[14]

$$\text{LT\%} = \frac{\text{The average of recorded numbers on the radiometer} \times 100}{\text{Light intensity of light-curing unit}}$$

Upon measuring the LT of every specimen, the intensity of the light-curing unit was checked by a radiometer to guarantee the precision of the intensity.

Microhardness test

Translucent Allcem Veneer light-cured resin cement (FGM, Joinville, SC, Brazil) was applied in Teflon molds with a 5 mm diameter and 0.5 mm depth. Then, 90 ceramic discs with different thicknesses and types were placed on the molds. A Mylar strip was placed between cement and ceramic to create a smooth surface of resin cement and prevent cement-ceramic adhesion during polymerization. Then, they were cured according to the following classification (the light intensity was monitored with a radiometer after using the light-curing unit every five times).

In the control group, 10 resin cement specimens were cured for 40 s under the Mylar strips without the presence of ceramics and in direct contact with the tip of the light-curing unit.

Then, 90 resin cement specimens ($n = 10$) were cured for 40 s in direct contact with ceramics (thickness of 0.5, 1, and 1.5 mm of VS, VM, and CD ceramic discs, respectively).

Following polymerization, resin cement specimens were polished with 1000 and 1200 silicon carbide paper to remove the resin-rich surface layer in contact with the Mylar strip. After labeling, all specimens were stored in an incubator (LTE SCIENTIFIC LTD., Greenfield, Oldham, UK) at 37°C under humid conditions for 24 h to complete polymerization.

The microhardness for each piece of resin cement was measured by Vickers hardness tester (Koopa Pazhoohesh, Sari, Iran) at three different points on the top surface of the cement with a distance of at least one mm, under 50 g loading for 10 s. The average number of these three points was reported as the microhardness of the specimen. Measurements were taken under ×10 magnifications.

Statistical analysis

The data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) through one-way analysis of variance (ANOVA) for comparing specimens in different groups and two-way ANOVA for assessing the effect of multiple variables at the same time. Factors included in two-way ANOVA were ceramic type and thickness for LT and ceramic thickness for microhardness assessment. Independent paired samples *t*-tests were used to compare each group with control and microhardness and LT in each ceramic type and thickness, respectively. If one-way ANOVA was significant, Tukey's *post hoc* analysis was used. $P < 0.05$ was considered statistically significant.

RESULTS

Light transmittance

LT values of ceramics with different thicknesses are presented in Table 2. By increasing the thickness of the ceramics from 0.5 to 1.5 mm, LT decreased (value $P < 0.05$).

VM and VS ceramics had the highest and lowest LT, respectively. Ceramic thickness ($P < 0.001$) had a greater effect on LT than the ceramic type ($P < 0.001$) [Table 2].

Microhardness

Table 3 shows the surface microhardness of resin cement for different ceramic groups. VMH decreased, while the thickness of ceramics increased from 0.5 mm to 1.5 mm in all groups ($P = 0.000$). This decrease was only statistically significant comparing 0.5 mm and 1.5 mm thicknesses ($P < 0.05$) [Table 3].

Table 2: Light transmittance (%) for various types and thicknesses of computer-aided design/computer-aided manufacturing ceramics

Ceramic	LT (thickness)			*P*
	0.5	1	1.5	
VS	52.4±0.7^{A,a}	36.8±1.3^{B,a}	24.4±1.8^{C,a}	<0.001
VM	55.2±1.1^{A,b}	43.3±0.3^{B,b}	32.8±1.0^{C,b}	<0.001
CD	53.7±0.7^{A,c}	41.1±1.4^{B,c}	31.1±1.3^{C,c}	<0.001
P	<0.001	<0.001	<0.001	

Different uppercase letters indicate a significant difference between various thicknesses of a ceramic (*P*<0.05) and different lowercase letters indicate a significant difference in same thickness of different ceramics (*P*<0.05). VS: VITA Suprinity; VM: VITA Mark II; CD: CELTRA Duo; LT: Light transmittance

DISCUSSION

The hardness of light-cured resin cement under ceramic restoration depends on the LT of ceramic.[13,14] This research showed that thickness and type of ceramic affect the LT and the hardness of resin cement; hence, the null hypothesis was rejected.

The results showed that LT decreases while increasing the thickness of ceramics from 0.5 mm to 1.5 mm in all groups. Various studies have confirmed this finding.[13,14,19,23] Ceramic thickness had a remarkable effect on LT due to higher absorption, reflection, refraction, and light scattering at thicker specimens.[14,19,24-26]

In accordance with previous studies,[5,27] our findings showed that VS ceramics had the lowest and VM ceramics had the highest LT. Jafari *et al*. demonstrated higher LT in VM compared to VS ceramics.[5] Higher LT in VM compared to CD and VS can be due to the fact that VM is a sanidine-reinforced feldspar ceramic (KAlSi3O8) with a crystalline content of about 30% by volume, showing less density than ZLS ceramics (~50% Vol.).[19] Various studies have shown that the translucency of ceramics, consequently LT, depends on the crystal structure, particle size, pigments, as well as the number, size, and distribution of porosity.[14,19,28]

In studies examining the translucency of different ceramics, the translucency of VM ceramics has been reported more than VS and CD ceramics. Similarly, the translucency of CD ceramics has been reported higher than VS, which is aligned with the results of this study.[29-32] VS and CD ceramics are high-strength ceramics due to the presence of ZrO_2 in their

Table 3: Vickers microhardness values (kgf/mm²) of Allcem resin cement under various types and thicknesses of computer-aided design/computer-aided manufacturing ceramics

Ceramic	Microhardness (thickness)			Control	*P*
	0.5	1	1.5		
VS	30.72±2.02^{A,a,c}	28.59±1.38^{A,a,c}	26.72±0.59^{B,a}	34.09±2.67^{C}	0.000
VM	32.02±2.22^{C,a,b}	29.79±0.64^{B,b}	27.74±0.76^{B,b}		0.000
CD	29.45±1.5^{A,c}	28.11±0.96^{A,B,a,c}	27.05±0.49^{B,a,b}		0.000
P	0.024	0.004	0.003		

Different uppercase letters indicate a meaningful difference in each row (*P*<0.05), different lowercase letters indicate a meaningful difference in each column (*P*<0.05). VS: VITA Suprinity; VM: VITA Mark II; CD: CELTRA Duo composition.[33] High-strength ceramics show less translucency and LT due to their higher crystalline content.[19,31,34] In addition, the presence of Al_2O_3 reduces translucency due to light scattering.[28,35,36] However, in Caprak *et al*. and Sen and Us's studies, the translucency of VS has been reported more than VM, which is presumably due to using a high translucent (HT) shade of VS ceramics.[35,37] Low translucent VS ceramics contain a large number of small crystals of lithium metasilicate, while HT ceramics contain fewer crystals in the precrystallized form.[19,38] A large number of these crystals reduces translucency due to light scattering.[19,31]

Based on the results, the effect of ceramic thickness on the VMH was significant. The microhardness of the resin cement decreased in a ceramic thickness of 1.5 mm aligning with our LT findings and other research.[13,16] On the other hand, some difference was found regarding microhardness between the same thicknesses of bleach shade ceramics; so that, in VM, hardness of resin cement was higher than the VS and CD. Our results are similar to other researches;[5,25] they found that the ceramic type and shade are influential factors in the microhardness of the underlying resin cement. In another study on different ceramics (IPS e.max Press and Cercon), the effect of the ceramic type on the microhardness of the underlying resin cement was confirmed.[13] The reason for the lower microhardness of the underlying cement of the ZLS ceramics compared to VM was the presence of zirconia crystals.

A direct correlation has been noticed between the degree of polymerization of cement and ceramic LT.[23] At higher ceramic thicknesses, lower energy is reached by the resin cement, resulting in a more linear polymer chain with greater mobility and lower hardness.[16,39] This result agrees with various studies.[16,40-42] In a study by Passos, however, a contrary result has been reported. Passos *et al*. studied six different shades and two different thicknesses of VM ceramics. They found that the shade and thickness of the ceramic did not affect the hardness of the Variolink dual-cured cement. The reason was the effect of additional chemical curing on the dual-cured cement.[43]

In this study, in all thicknesses, the VMH of resin cement was lower significantly than the control group, except for the thickness of 0.5 mm of VM. The reason can be the opacity and brightness of bleach shade ceramics, which acts like a double-edged sword. On the one hand, it improves beauty, and on the other hand, it disrupts the light transmission and polymerization of cement. This item should be noticed because low VMH means weak polymerization and a weak network of resin has many disadvantages such as water uptake, discoloration, and wear. Maybe, increasing light exposure time or intensity improves resin cement VMH. Dual-cured resin cement can also be a choice. This problem needs more research.

As a limitation, only bleach shade ceramics and one type of light-cured cement were used in this study. The effect of other factors such as other types and shades of CAD/CAM ceramics in different cementation conditions is recommended to be investigated in future studies. It is also suggested to work with digital radiometers to improve the accuracy of experiments.

CONCLUSION

Within the limitations of our study, the following conclusions could be edited:

1. LT was decreased with increasing ceramic thickness
2. Ceramics of the ZLS group showed less LT compared to glass ceramics
3. The ceramic type was effective on the VMH of the resin cement.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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