ORIGINAL RESEARCH

The Effect of Ceramic Thickness on the Surface Microhardness of Dual-cured and Light-cured Resin Cements

Leila Pishevar[1], Zohre Ashtijoo[2], Mahsa Khavvaji[3]

Abstract

Aim: This study was conducted to evaluate the effect of ceramic thickness on the surface hardness of light-cured and dual-cured resin cements.

Materials and methods: Forty disk-like specimens of the dual-cured resin cement and twenty-four specimens of the light-cured resin cement were prepared (with 6 mm diameter and 1mm thickness). The samples were light-cure d for 40 seconds through three different ceramic disks (2 mm, 3 mm and 4 mm). Control specimens from each group were directly polymerized under a Mylar strip. In the control group of the dual-cured resin cement, the cement setting was realized by chemical reaction alone. After storing dry in darkness (24 hours, 37°C), the surface hardness of the specimens was measured using the Vickers microhardness test. Data were statistically analyzed using a two-way analysis of variance (ANOVA) followed by the LSD's test ($p < 0.05$).

Results: BisCem resin cement which had been dual-cured under the 4 mm thickness ceramic with the 4.3 Vickers hardness, showed minimum surface microhardness, while the light-cured resin cement which had been directly activated in the control group with the 51.8 Vickers hardness value exhibited the maximum surface microhardness. So, BisCem dual polymerized control specimens had significantly higher hardness values in comparison to the chemically polymerized and indirectly activated ones ($p < 0.001$).

Conclusion: An increase in the thickness of ceramic could decrease the hardness of the resin cement. An overlying ceramic thickness of 3 mm and above was found to adversely affect the polymerization of the LC and DC resin cement and it was considered as the clinical threshold. In addition, using only the self-cured mode in the dual-cured resin cement was not sufficient for achieving the optimum surface microhardness.

clinical significant: Adequate polymerization of resin cement is essential for the optimal mechanical properties and clinical performance. It affects by increasing the thickness of ceramic restorations.

Keywords: Ceramic, Resin cement, Surface microhardness.

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Introduction

Due to the improvements in recent years, ceramic system technology has become a valid option in the restoration of anterior and posterior teeth that require indirect prosthetic rehabilitation.[1,2] The clinical success of ceramics is mainly due to their reliable bonding to dental hard tissues by the luting material. Ceramics have good biocompatibility and durability, because of their bonding to the tooth structure, they can strengthen the residual dental tissues. The success of a ceramic restoration is mainly based on the high bond strength formed upon the adhesion complex between the ceramic, resin cement and dental hard tissues.[3] Bonding of ceramic restorations is done using the resin cement. Resin cement reduces the microleakage and increases the restoration strength, showing higher mechanical properties than other conventional dental cements.

Resin cements are available in two types: light-cured and dual-cured modes; according to the type of ceramic restoration, they can have different clinical applications. In ceramic restorations with less thickness, such as ceramic veneers, which are capable of light transmission, the light-cured cements are used. However, when the ceramic thickness is high, as in all-ceramic crowns, inlays and onlays with light transmitting limitations, the dual-cured cement are considered. Adequate polymerization of resin cement is essential for the optimal mechanical properties and clinical performance. In the light-cured resin cement, reducing energy density leads to decreasing the degree of conversion and the loss of mechanical properties of the cement. In the dual-cured resin cement, there is a combination of chemical and light polymerization. Therefore, polymerization is expected to occur at a greater depth or in the layers with a higher thickness to reach the restorations with more adequacy. However, some studies have shown that the hardness and the degree of conversion of the dual-cured resin cement are also affected by ceramic thickness, and these properties are reduced by increasing the thickness of ceramic restorations.[4] The degree of conversion and hardness affected by the ceramic thickness because the light transmission is decreased with increasing the ceramic restoration thickness. Some studies have shown a decrease in surface hardness and mechanical properties, such as flexural strength, as a result of the increased thickness.[5]

The main purpose of this study was, therefore, to investigate the effect of ceramic thickness on the hardness of two types of light-cured and dual-cured resin cements.

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Materials and methods

In this study, 64 ceramic disks with three different thicknesses (2, 3 and 4 mm) were prepared by (Kiss porcelain powder)

(DentsplaySirona, USA). The manually layering technique was carried out, and the specimens had a 20% larger dimension to offset the polymerization shrinkage. Ceramic disks were sintered in a furnace at 930°C (P300/G2, Ivoclar, Vivadent.) The polishing process was carried out with the medium diamond fissure instrument (Varenkor, Germany) and the green rubber polishing point until the surface was glazed.

Two types of resin cement were used (Table 1). Forty samples were BisCem (Bisco, USA) dual-cured resin cement and 24 belonged to Choice 2 (Bisco, USA), the light-cured resin cement (Table 1). A special Teflon mold (6 mm in diameter and 1 mm in height) was prepared to confine the cement dimension. Both types of resin cement were injected directly from their special syringe into the mold. The BisCem dual-cured resin cement had a self-blending head mixing two cement tubes with specific ratios. A glass slide and a Mylar strip were placed on the lower and upper of each sample to ensure an even and smooth surface. They also provided isolation from the ceramic disk. Then, the square metal plate which had three thicknesses, according to the size of the ceramic disks, were placed on the cement in such a way that the circular vent in the middle of the metal plate coincided with the mold circular vent.

Finally, the ceramic disk was inserted into the vent of the metal plate. Here cement was polymerized through ceramic disks for 40 seconds with an LED light-cured unit whose tip touched the ceramic disk (DENTAMERICA; LITEX695C; USA). Cured light output was monitored continuously and the maximum output of the LED unit was calculated as 21200 mW. These steps were repeated for each ceramic thickness and cement. Both groups of resin cement were divided into four sub-groups (three ceramic thicknesses + one non-ceramic polymerized control group), and a group of BisCem dual-cured resin cement was chemically polymerized.

Control samples from each cement group were directly polymerized under a Mylar strip without the presence of any ceramic. In one group of BisCem dual-cured resin cement, without light curing and ceramic placement, two glass slides were glued together and the specimen was placed in an anti-radiation box in the incubator for 24 hours. After following the polymerization steps, all resin cement samples were removed from the generator. Then, they were labeled and stored in a dark container in an incubator at 37°C to complete the delayed polymerization before testing. The light transmission through ceramic disks with a thickness of 4 mm was not sufficient for the curing of the choice 2 light-cured resin cement; Therefore, the cement was not cured. As a result, the samples of this group were excluded from the test.

The surface microhardness was measured using the Vickers microhardness tester (BUHLER-Micromat-1501, Japan) at Isfahan University of Technology. Three indentation points were created on the upper surface of resin cement discs, which was the surface closest to the light source under a 25 g load and a 10 second indentation time. The pyramid located at the tip of the device was in the form of a diamond with equal sides, leaving a diamond shape impact on each of the three points. Finally, the hardness value for each point was obtained by calculating the mean diameters of the resulting diamond and using formula; eventually, the mean hardness of the three points was obtained for each sample. The obtained values were recorded in the relevant checklists; then the information was entered into the statistical package for social services (SPSS) software. Two-way ANOVA and LSD post hoc tests were used for analyzing the data and $p < 0.05$ was considered as a statistically significant difference.

Results

The mean surface microhardness of the eight test groups is shown in Tables 2 and 3. Two-way ANOVA showed that the type of cement used (BisCem, choice 2) and ceramic thickness (2, 3 and 4 mm) were effective on the surface microhardness value and the difference between them was statistically significant ($p < 0.001$). According to Table 2 and Graph 1, the minimum surface microhardness with the 4.33 Vickers hardness was in the BisCem dual-cured resin cement under the cured ceramic with a thickness of 4 mm as the dual-cured one. The maximum surface microhardness with the 51.85 mm Vickers hardness was in choice 2, the light-cured resin cement, without the ceramic on it, as shown in Table 3.

Two-way ANOVA analysis showed that both cement types ($p < 0.001$) and ceramic thicknesses ($p < 0.001$) were effective on the microhardness, as shown in Tables 2 and 3 and Graph 2. The mean microhardness in choice 2 cement was significantly higher than that of BisCem cement and with the increase in the ceramic thickness, the microhardness was reduced.

Discussion

With the growing demand for the conservative and aesthetic dentistry approach, then there is a demand for all-ceramic adhesive restorations (inlay, onlay, crowns, and FPD).[6] Resin cements are often used for the cementation of all-ceramic restorations because of their aesthetics, low solubility, high strength, and outstanding mechanical properties, which can improve ceramic restorations.[7-9]

Table 1: Resin cements used in this study

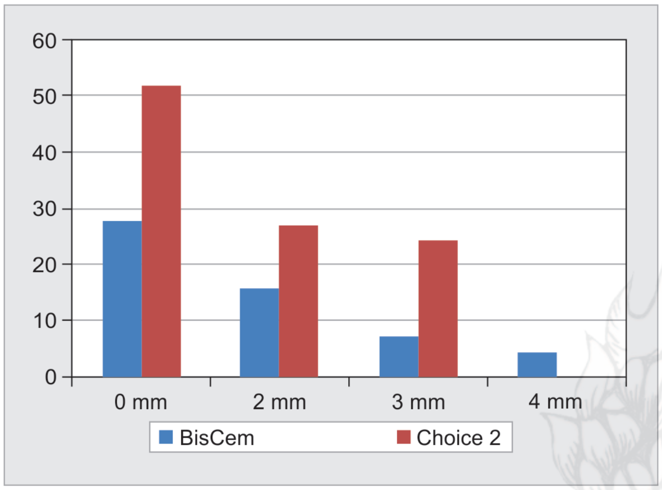
Resin cement	*Manufacturer*	*Monomer*	*Shade*	*Batch number*
Bis cem	Bisco, Inc, USA	Bis-GMA and urethane dimethacrylate	A2	1200013498
Choice 2	Bisco, Inc, USA	Bis-GMA and strontium glass and amorphous silica	A2	1200013044

Table 2: Dual-cured resin cemten microhardness values (standard deviation)

Test group (unite gr/mm²)	*Mean ± SD*
BisCem auto-cured resin cement without ceramic placement	21.85 ± 4.95
BisCem dual-cured resin cement without ceramic placement	27.77 ± 1.19
BisCem dual-cured resin cement with the 2 mm ceramic	15.67 ± 3.05
BisCem dual-cured resin cement with the 3 mm ceramic	7.25 ± 2.55
BisCem dual-cured resin cement with the 4 mm ceramic	4.33 ± 0.84
Total	15.37 ± 9.26

Table 3: Light-cured resin cemten microhardness values (standard deviation)

Test group (unite gr/mm²)	*Mean ± SD*
Choice 2 light-cured resin cement without ceramic placement	51.85 ± 4.14
Choice 2 light-cured resin cement with the 2 mm ceramic	27.38 ± 4.40
Choice 2 light-cured resin cement with the 3 mm ceramic	24.50 ± 6.42
Total	34.59 ± 6.83



Graph 1: Microhardness values of light-cured and dual-cured resin cements under various thickness of ceramic

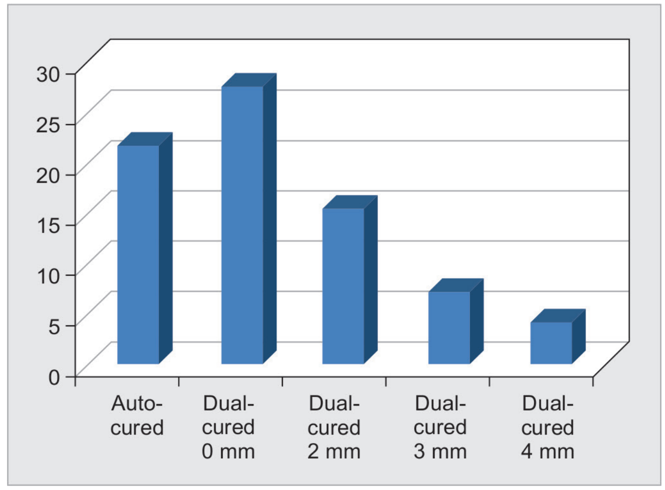
Light-cured resin cements are often preferred due to their controlled polymerization characteristics.[6] Since there is no chemical cure for cementing the light-cured resin, they need adequate light to initiate and establish the polymerization. Thus, they are used along with thin and translucent restorations for which there is the adequate light transmission.

When the restoration thickness is greater than 1.5–2 mm or its opacity prevents light transfer due to the incomplete polymerization of light-cured resin cements, dual-cured resin cements are preferred.[7,10,11]

Kesrak and Leevailoj indicated that there was a clear difference between the Knoop hardness of the two types of light-cured cement polymerized under different ceramic types and thicknesses. With the increase in thickn ess, this hardness was declined since the light intensity was decreased as a function of the ceramic type and thickness.[12]

In this study, with the increase in the ceramic thickness and the decline in the light transfer, the hardness of the light-cured resin cement, choice 2, was diminished (p <0.001). In both types of polymerization, a desirable cure was vital as resin cements with inadequate polymerization were prone to the altered mechanical properties, altered dimensional stability, diminished attachment to the teeth structures, development of microleakage, decreased biocompatibility, color change, and postoperative sensitivity.[7,13-16]

It should be added that complete polymerization of resin cement is essential for the strength, fixation, and longevity of the restoration.[17] In addition, various factors affect the depth of the curing of adhesive cements, including the type of ceramic, thickness, composition, color and its translucency, light source,



Graph 2: Microhardness values of dual-cured resin cement under different made of polymerization and various ceramic thickness

wavelength and intensity of the light applied, type of the adhesive resin cement (type of activation, color, composition), and the substrate dental nature.[6]

Ceramic thickness also interferes with the degree of polymerization of the light-cured and dual-cured cement. It has been well proved that a ceramic thickness with more than 2 mm jeopardizes the hardness of both light and dual-cured cements.[6] Bansal et al. carried out a study on light and dual-cured cements and various ceramic thicknesses, up to 4 mm, demonstrating the gradual reduction in KHNs due to the increase in ceramic thicknesses.[18]

The thickness of an anterior restoration may often be within the range of 1 mm or lower than the facial and lingual levels. However, the ceramic thickness may increase up to 1.5–2 mm on the incisal edge. An onlay or inlay restoration should have a thickness of at least 1.5–2 mm, but the ceramic thickness may increase up to 3–4 mm in the proximal box.[7,8,13] This could be the reason for choosing 2, 3, and 4 mm thicknesses for the ceramic in the present study.

The ceramic samples with lower thicknesses were simulated for the anterior restorations while the ceramic samples with the higher thicknesses were used for the posterior inlay and onlay restorations.

In the study done by Meng et al., the intensity of the light passed was decreased with the increase in the ceramic thickness, especially when the ceramic thickness reached 4 mm. Thus, the degree of polymerization and in turn, the hardness of the lower dual-cured resin cement were decreased. The light intensity was decreased from 800 to less than 100 mW/cm^2 with the light transmission through ceramic with a thickness of over 3 mm.

In this study, it was found that the cured rate during light exposure was 5–20 times higher than that of the chemical cured alone.In addition, it was only in ceramic with 4 mm thickness that the resin cements indicated only a weak chemical reaction during the light curing.[19,20] This result was in line with those of the present study, as by using the 4 mm ceramic, the hardness of dual-cured cement was diminished dramatically due to the sharp decrease in light for the activation of the chemical phase of the cement.

It has been claimed that the ceramic thickness can have a greater impact than translucency.[6,21] The final color and translucency of the ceramic system are important for a desirable aesthetic. The ceramic color and translucency can be affected by many properties including the thickness and crystalline structure.[6]

Thicker ceramics can cause inadequate polymerization of the light-activated resin cements. Dual-cured cement has been developed to overcome this problem. The ratio of light *vs.* chemical phase of the cement can have an important effect on the extent of polimerization.[6] Dual-cured cements are significantly different from each other by considering the amount of chemically or light-activated catalysts.[19] This can explain why some of these cements have a greater degree of hardness in comparison with others.[6]

Piva et al. have stated that the maximum bond strength of the dual-cured cement is only achieved when light activation is done properly.[22] The final hardness of the dual-cured resin cement is dependent on the extent of exposure to the curing light. In addition, there are clear differences between the materials in terms of the ratio of the content of photoinitiator and the self-cured components.[23]

In the present study, the dual-cured resin cement, similar to the light-cured resin one, showed a clear reduction in hardness with an increase in the thickness of the ceramic and light transmission was diminished accordingly. This suggests that dual-cured cements are dependent on the extent of exposure to the cured light.

It can be concluded that the higher the extent of photoinitiator in dual-cured cement, the more dependent the cement on light exposure; thus it can be further affected by the reduced light passed.

Wats et al. have stated that some products are over-dependent on the light activation, which may result in inadequate clinical curing and function.[24] When dual-cured cements are used, it may be assumed that the chemical component of the cements is compensated by the diminished translucency. However, it has been proven that the chemical component of dual-cured resin cements cannot be adequate alone for reaching the maximum monomer conversion.[7,8,11]

In the present study, the control group of BisCem dual-cured cement with chemical polymerization showed a lower degree of polymerization, as compared to the control group with dual polymerization. Adequate polymerization of the resin cement could cause the high strength of the bond between the teeth and restoration. Light intensity is a significantly important factor affecting the polymerization of light-cured resin cements. Recent studies have indicated a correlation between the intensity of light and degree of conversion of restoration materials.[12]

Pazin et al. stated that polymerized cements, such as those dual-cured with the thicker ceramic, had the minimum hardness among all groups except for the control group with the chemical cured. This finding is possibly associated with the attenuation of light-induced due to the presence of an intermediate material.[25] llie et al. have explained that ceramic can cause the curing light to be absorbed, scattered or transmitted. In their study, they have found that dental ceramics can absorb 40–50% of light intensity.[26] To compensate for this reduction, light exposure time should be increased.[27] So the less the energy dose reaching the adhesive material, the lower the degree of conversion and hardness. Similar hardness results were observed for the control groups with light and dual-cured and both of them were significantly harder than the control group with the chemical curing. This suggests that dual-cured materials are dependent on light exposure in order to reach higher properties. Indeed, it has been reported that self-cured components alone are not adequate for ensuring high hardness.

The results of this study were similar to those of the present study in that the light control group and the dual group were harder than the control group with the chemical curing. However, the fact that the light and dual control groups had similar hardness was incongruent, as the light-cured group had a significantly higher hardness in comparison to the dual-cured control one. Zhang and Wang also compared different types of polymerization of the dual-cured cement under different ceramic thicknesses. They stated that due to the dramatic decrease in the intensity of the light passed with the increase in the ceramic thickness, the use of thicker ceramic diminished the Vickers hardness number across the resin cement. Further, self-cured mechanism alone could have less effect on achieving the complete polymerization of the dual-cured resin cement, as compared to dual polymerization and the self-cured resin cement alone, showing a lower hardness.[28]

The results obtained from this study were similar to those of the present study in that with the increase in the ceramic thickness, the hardness of resin cement was declined. Also, the self-cured polymerization that occurred alone and without light radiation had a lower hardness in comparison to dual polymerization in a dual-cured resin cement.

Kilinc et al. concluded that the thickness of 3 mm and above for the ceramic reduced the microhardness in both groups of light-cured and dual-cured resin cements. The results obtained from this study indicated that the ceramic thickness had a significant effect on the resin microhardness and light transmission. Thus, it was in line with other studies, suggesting a logarithmic reduction. The microhardness of the light-cured group was significantly lower than that of the dual-cured group, and the control groups had higher hardness across all cement groups.[7] Every resin and its different types of polymerization were evaluated individually and the numerical values were compared in only that group.[6]

The results of this study were incongruent with our results based on the lower thickness of light-cured resin cement. This is because the hardness should not be used for comparing the degree of conversion of resin cements. This is because variety in the monomer composition, filler amount, type and its size can influence hardness. This can be due to the fact that the hardness should not be used for comparing the degree of conversion between the resin cements. This is because the effect developed due to the diversity in the monomer composition, the extent of filler, its type and size can affect the extent of microhardness.[7,20]

A higher numerical value on a specific resin group does not suggest that the resin has reached a higher degree of polymerization. Hence, the great differences in the numerical value of microhardness resulting from the different resin cements have absolutely no clinical relationship. The only comparison was made between the variables which affected each resin, including the ceramic color, thickness, and light transmission.[7]

When the hardness test was used for the indirect evaluation of the cured degree, the comparison between different composites could be meaningless, as the mechanical properties of a polymer are dependent on the density of cross-linking and the quality of the network formed during the polymerization (Farakan). In addition, the content of the composite filler could be responsible for its hardness (Chang and Greener). Accordingly, there was no hardness value capable of predicting the degree of conversion for all composite resins. However, these hardness tests made it possible to assess the effect of self and light-cured components existing in the activation system of dual-cured cements.[16]

The degree of conversion can be evaluated using direct and indirect methods. The direct methods including FT-IR or Raman laser spectroscopy are the most sensitive methods; however, they are considerably time-consuming and expensive. The economical alternatives are indirect methods including cured depth and microhardness test. The hardness test under different conditions is the most common method used for calculating the degree of conversion of the resin cement.[29]

In the present study, due to economic issues, the indirect method of microhardness test was used to investigate the degree of conversion of resin cements.

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