European Journal of Prosthodontics and Restorative Dentistry (2017) **25**, 15-19

The Effect of Lithium Disilicate Opacity on Polymerization of a Dual-Cured Resin Cement

ABSTRACT

The aim of this study was to evaluate the influence of different levels of opacity of the lithium disilicate framework upon polymerization of dual-cured resin cement. Four ceramic discs were used, one for each opacity framework covered by their respective ceramic veneering, and a cement group without a ceramic cover. The degree of conversion for each resin cement was estimated using the Knoop microhardness test. The group with the highest opacity showed the lowest hardness score at baseline. The study concluded that the opacity level of lithium disilicate framework could influence the degree of polymerization of a dual-cured resin cement.

Keywords

Ceramics
Hardness
Lithium Disilicate
Resin Cement

Authors

Dr Dylton da Costa Neto [§]
(DDS, MSc)

Dr Jefferson Pereira *
(DDS, MMedSci, PhD)

Prof. Saulo Pamato *
(DDS, MSc)

Dr Accácio do Valle [§]
(DDS, MSc, PhD)

Address for Correspondence

Dr Jefferson Pereira *

Email: jeffripe@rocketmail.com

* *University of Southern Santa Catarina*

[§] *University of São Paulo*

Received: 07.11.2016
Accepted: 17.01.2017

doi: 10.1922/EJPRD_01626daCostaNeto05

INTRODUCTION

The use of ceramics in the manufacture of dental crowns has undergone constant evolution. Due to the limitations of the first manufactured crowns, which showed low clinical performance because potential for fracture of the ceramic veneer,[1,2] besides being very difficult to manufacture, the casting techniques of metal alloys and the ceramic burning process have been enhanced, improving the mechanical behavior of these materials, and as of the 1950's, these processes were combined to produce metal-ceramic crowns.[3]

However, the presence of metal in the traditional metal-ceramic and metal-plastic crowns interferes with the coloration of the final prosthetic work by limiting, in some cases, a satisfactory aesthetic achievement. The elimination of this metal support structure would imply real aesthetic improvement.[4] Thus, all-ceramic systems were developed to obtain reinforced ceramic framework, such as glass-infiltrated alumina, lithium disilicate glass-ceramics, densely sintered aluminum oxide ceramics, and yttria-stabilized tetragonal zirconia ceramics, with their respective vitreous ceramic coating.[5]

The lithium disilicate reinforced ceramic (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) is reinforced by lithium disilicate glass-ceramics (Li_2O-SiO_2), which is obtained by using a combination of lost-wax and heat-pressing techniques. A glass-ceramic pellet of the desired color is injected into an investment mold under pressure and vacuum. This system is suitable for making pure ceramic crowns (anterior and posterior), inlays, onlays, and veneers. More recently, the lithium disilicate reinforced ceramic system has also been used for making fixed partial dentures of 3 anterior teeth or even second premolars.[6] The different shades provided can be used for fabrication of partial restorations (HT/high translucency), posterior teeth restorations (LT/low translucency), frameworks on vital or slightly discolored preparations (MO/medium opacity) and frameworks on a severely discolored preparation or molten metallic core (HO/high opacity).[7]

The indirect restorations must bond to the support substrate to enhance clinical survival and stability. The goal of dental cements is to promote bonding between the porcelain, enamel and dentin, forming a single body and allowing the tensile transfer of the restoration to the dental structure. Among the cements available in the market, the resin cements have low solubility, and layer thickness should be uniform, with up to 100 μm to be satisfactory.[8]

Resin cements are composed of methacrylic monomers, such as BisGMA, UDMA, plus a considerable amount of diluents, such as TEGDMA, HEMA, and silane-treated inorganic particles, such as alumina, silica.[9] The polymerization of dual-cured resin cements can be chemical, in which two pastes are mixed together to start the process. One of the two pastes contains benzoyl peroxide (initiator), and the other paste contains a tertiary amine (activator). The polymerization can also be physical in which the reaction occurs between a photoinitiator, generally camphorquinone, and an accelerator, commonly a tertiary amine.[10] The dual-cured resin cements were developed in order to combine the favorable characteristics of self-curing and light-curing, which translates into greater control of working time and ensures that not enough degree of cement conversion is achieved in low light. The dual-cured resin cements are indicated in situations such as opaque restorations, very deep cavities and intra-canal cores in which the resin cement is not light-cured appropriately. Although both forms of activation are present, they are not independent. If exposure to light is not enough, part of the resin cement will be affected, and the maximum polymerization rate will not be achieved.[11]

Factors such as the composition, thickness, opacity and color of the ceramic material can interfere with the passage of light rays, and thus, reduce the degree of cement conversion, which limits the scope of their mechanical properties and impairs clinical performance.[12,13] Thus, the aim of this study was to evaluate the influence of the different opacity levels of the lithium disilicate framework upon the polymerization of dual-cured resin cement. The null hypothesis stated that there would be no influence of different translucency levels of lithium disilicate framework upon the degree of polymerization of a dual-cured resin cement.

METHODS

For this study, four lithium disilicate ceramic discs were fabricated, one for each opacity level: HT, LT, MO and HO provided by lithium disilicate reinforced ceramic (IPS e.max Press, Ivoclar Vivadent, Amherst, NY, USA). These discs were 10 mm in diameter and 2 mm thick, of which 0.7 mm of framework and 1.3 mm of ceramic veneer (*Figure 1*).

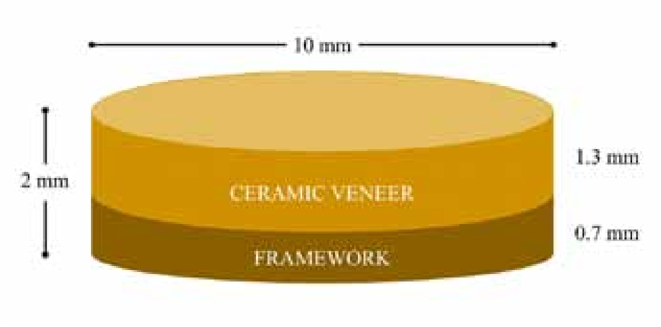

Figure 1: Dimensions of the ceramic disc.

A cylindrical aluminum matrix of 10 mm in diameter and 0.7 mm thick was used to standardize the measurements of framework in the desired size and it were coated with a thin layer of petroleum jelly to obtain a standard wax (Kota Ind. e Com. Ltda., São Paulo, SP, Brazil). The wax was liquefied and poured into the matrix, which was placed on the glass plate. After cooling, the solid wax discs were removed and stored in a container with water until the injection procedures (*Figure 2*).

Figure 2: Cylindrical aluminum matrix used to framework standardization. (A) Cylindrical aluminum matrix, (B) liquefied was into the matrix, (C) solid wax disc after matrix removal.

The wax discs were injected according to the manufacturer's recommendations. However, even with the use of the matrix, the discs did not have a uniform thickness. In order to achieve a thickness of 0.7 mm, the discs were secured on a glass slide and placed on a polisher (EXAKT Grinding System, Oklahoma City, OK, USA), a tool with micrometric precision calibrated to provide the desired thickness of the discs.

The porcelain coating (IPS e.max A3 color) was applied according to the manufacturer's recommendations for paste preparation, condensation, temperature, and cooking time. The ceramic coating was applied with the aid of another cylindrical matrix measuring 10 mm in diameter and 2 mm thick. The ceramic disc was positioned inside the cylinder, and the remaining space (1.3 mm) corresponded to the thickness of the veneering material. At the end, each disc received a glaze layer on the last burning.

The ceramic discs were made to serve as a light filter during the fabrication of Variolink II resin cement specimens (Ivoclar Vivadent, Amherst, NY, USA). Four groups used the discs during polymerization, and one group was polymerized without a ceramic disc between the curing light and the resin cement (control group). Fifteen cement specimens were obtained for each group, which totaled 75 specimens.

A halogen light-curing unit (Optilight Plus, Gnatus, São Paulo, SP, Brazil) was used for the polymerization of the cement specimens. A radiometer was used to measure if the light intensity was within the recommended limits (600mW/cm^2).

A cylindrical matrix made of polyethylene was used to standardize the positioning of the ceramic disc. One end had an internal relief of 10 mm in diameter corresponding to the diameter of the tip end of the curing light. At the other end, a relief for accurate seating of the ceramic disc was made. This matrix was opaque in order to prevent curing light rays to scatter and reach the cement, thereby ensuring that all light rays pass through the ceramic disc.

The standardization of the resin cement specimens was performed by using a steel matrix, inside of which the cement was placed. The product was composed of a base paste and a catalyst paste, and the manipulation was performed according to the manufacturer's guidelines, providing a mixture of equal parts by using a precision scale (Bel Engineering, Onda Científica LTDA, Campinas, SP, Brazil).

The paste was mixed with the help of a plastic spatula until a homogeneous mass was obtained, and placed inside the matrix previously positioned on a glass plate, with an interposed polyester strip to avoid luting to the plate. Another polyester strip was placed on the top of this matrix filled with cement, and on it, a glass slide that was pressed to remove the excess cement.

Therefore, the set had the following sequence: glass plate, polyester strip, matrix with cement, polyester strip, and glass plate. The light-curing unit was placed on the top of the set in the center of the glass plate, where there was a mark to standardize the position, and then cement polymerization was carried out according to the manufacturer's instructions (40 seconds).

After the polymerization was completed, the resin cement was submitted to polishing for 20 seconds under constant irrigation and subjected to grinding with sandpaper of 1200 granulation, thus facilitating microhardness readings.

For the evaluation of the degree of cement conversion, the Shimadzu Micro Hardness Tester HMV-2000 (Shimadzu Corporation, Kyoto, Japan) was used, coupled to CAMS-WIN software (Newage Testing Instruments, Southampton, PA, USA) with a Knoop type diamond penetrator to analyze the images. Immediately after polishing, the specimen was stored in a dark container, so that there was no interference from natural light, and a new reading (final reading) was performed seven days later.

Ten indentations were performed on each specimen, of which five in the initial reading and five in the final reading. The first indentation was made in the center of the specimen; the other four were performed sequentially as follows: 2 mm above, 2 mm below, 2 mm to the right, and 2 mm to the left, totaling 600 indentations. The means were calculated and expressed as Knoop hardness number units (KHN), used for statistical analysis.

The data were tabulated and the scores were described as means and standard deviations. Repeated measures analysis of variances (Anova) was used for comparison between the groups and the Tukey's test was used for multiple comparisons. Statistical analysis was performed using the statistical package Sigma Plot 12.0 (Jandel Scientific, San. Rafael, CA, USA), with a significance level of $\alpha = 5\%$.

RESULTS

The means and standard deviations of microhardness scores for the five groups at both the initial and final time are shown in table 1. Repeated measures analysis of variance (two-way Anova) showed difference between each group and time, and interaction between the two factors ($p<0.05$). The Tukey's test identified between which groups and time there were significant differences.

The group with the highest opacity discs (HO) showed the lowest microhardness score (9.4±0.3) at baseline. The highest microhardness score occurred in the final control group (38.5±1.0). The groups with LT and MO discs showed no difference between the initial and final time.

The highest microhardness scores occurred when a ceramic disc was used in the HT group at final time (29.5±1.8), which showed a score close to the control group at the initial time, but statistically different.

Table 1. Mean Knoop microhardness scores (KHN) and standard deviation for the five groups.

Group	Time reading	
	Initial	Final
C	27.8±0.4^{f}	38.5±1.0^{h}
HT	16.5±1.4^{c}	29.5±1.8^{g}
LT	12.7±0.9^{b}	26.2±0.4^{e}
MO	12.1±0.7^{b}	25.8±0.3^{e}
HO	9.4±0.3^{a}	22.8±0.5^{d}

Different letters have p <0.05 when compared with other letters.

DISCUSSION

The results from this study do not support the null hypothesis that there was no statistically significant difference between the groups.

This study evaluated the influence at different opacity levels of the lithium disilicate framework upon the polymerization of a dual-cured resin cement. The microhardness scores at baseline were lower at the initial time compared with the final time in all groups. Although the dual-cured cement presents a self-polymerization component, only its association with the photopolymerization component can ensure clinically acceptable hardness scores, especially in critical areas in which the photopolymerization component alone is not sufficient to guarantee a high hardness level.[14] Thus, the two forms of polymerization are dependent from each other, since chemical polymerization does not compensate for photoactive and non-photoactive polymerization and vice versa.[12] The lack of one of them compromises polymerization, and consequently, the mechanical properties of resin cements.[13] Borges *et al.*[15] evaluated the microhardness level of a dual-cured resin cement at initial time and after 24 hours, and the results showed that after 24 hours the mean hardness level of the cement was always higher than the initial time, which supports the results of the current study. Therefore, polymerization of resin cement depends on the light activation element as well as the quantity and effectiveness of the chemical component.

Additionally, the group that was polymerized under the HO ceramic discs showed the lowest mean hardness score (9.4±0.3). One reason that could justify this behavior might be the differences in the ceramic particles for achieve different degrees of opacity and shades. However, these data were not reported by the manufacturer, which only specified the basic components common to all ceramic discs. To our knowledge, no studies comparing the different opacity levels of lithium disilicate were perform so far, although other studies have compared ceramics of different opacities, and the results were consistent with this study. Ceramics with a higher degree of opacity, such as Procera, Cercon, In-Ceram alumina, among others, have a greater influence upon the degree of cement conversion than less opaque ceramics, such as Cergogold, IPS Empress, IPS Empress 2, IPS e.max Press, and others. The dual-cured cement is said to be more suitable for the most translucent ceramics, whereas self-curing cements would be more suitable for the most opaque ceramics.[16] Using a methodology similar to that in this study, Soares *et al.*[17] found that the more the chroma in the A matrix (brownish red) (A1, A2, A3, A3.5, and A4) was changed, the lower the microhardness scores were.

In addition to lower results in the HO group compared to the other groups, it was observed that the control group (final time) had the highest microhardness scores (38.5±1.0), which supports the findings from other studies[12,17-21] in which the photopolymerization through the ceramic disc, as compared to the direct irradiation, reduced the scores for most of the mechanical parameters of the resin cement.

It is important to notice that the attenuation of the curing light passing through the ceramic disc that can decrease the light intensity and thus reduce the polymerization degree of resin cements. The light transmission through an indirect restoration is critical. The influence of higher distance from the light point, the ceramic thickness, ceramic opacity, and ceramic shade will decrease the conversion degree of composite resin cement, influencing in your final properties. A suitable polymerization can theoretically be obtained through an ongoing chemical reaction within dual-cured cements where access to photopolymerization is limited.[13]

In the results from this study, the groups with LT and MO discs showed equal behavior in both the initial and final time, with no difference between them, which can possibly be explained by the similarity that these two opacity levels may have in the composition, equalizing the amount of light. Awareness of the composition and factors influencing the opacity level of the discs could collaborate with the understanding of this aspect.

Except for the control, the group that obtained the highest microhardness scores was the HT group at the final time (29.5±1.8), with scores close to the control group at the initial time, but statistically different. This fact confirms that even using a more translucent disc in this study, it promoted a light decrease, and consequently, a lower hardness of cement when compared to the control group.[12,17-21] Although causing a significant attenuation in curing, as compared to other discs, the HT group was the one that had the highest microhardness scores, which can be explained by its greater translucency, as observed in other studies.[16,18] The order of the microhardness scores at both the initial and final time dropped progressively as the opacity level was increased (C>HT>LT=MO>HO). Thus, this study demonstrates the importance of individual polymerization behavior of each resin cement for each type of restorative material. The dentist must fulfill certain criteria in adhesive cementation and choose the appropriate material for each type of prosthesis because no cement is universally applicable, as well as no ceramic system is suitable for all cases.

Finally, it seems necessary to find a way to compensate for the light attenuation influenced by the interposition of ceramics. Future studies should test different cement brands, forms of polymerization, ceramic types, activation time, types of photopolymerization, and thus help getting a better understanding of the degree of cement conversion given that this factor is not only important for mechanical strength but also for biological factors, such as post-cementation sensitivity due to the excess of residual monomer.

CONCLUSIONS

Within the limitations of this study, the different levels of opacity of the lithium disilicate framework have influence upon the polymerization of a dual-cured resin cement. However, the LT and MO groups showed equal behavior at both the initial and final time.

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