

Degree of Conversion of a Resin Cement Light-Cured Through Ceramic Veneers of Different Thicknesses and Types

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During the cementation of ceramic veneers the polymerization of resin cements may be jeopardized if the ceramics attenuate the irradiance of the light-curing device. The aim of this study was to evaluate the effect of different types and thicknesses of ceramic veneers on the degree of conversion of a light-cured resin-based cement (RelyX Veneer). The cement was light-cured after interposing ceramic veneers [IPS InLine, IPS Empress Esthetic, IPS e.max LT (low translucency) and IPS e.max HT (high translucency) - Ivoclar Vivadent] of four thicknesses (0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm). As control, the cement was light-cured without interposition of ceramics. The degree of conversion was evaluated by FTIR spectroscopy (n=5). Data were analyzed with one-way ANOVA and Tukey's test ($\alpha=0.05$). Significant differences were observed among groups ($p<0.001$). The degree of conversion was similar to the control for all light-cured groups with interposition of ceramics of 0.5 mm and 1.0 mm ($p>0.05$). Among 1.5-mm-thick veneers, IPS e.max LT was the only one that showed different results from the control ($p<0.05$). At the thickness of 2.0 mm, only the IPS e.max LT and HT veneers were able to produce cements with degrees of conversion similar to the control ($p>0.05$). The degree of conversion of the evaluated light-cured resin cement depends on the thickness and type of ceramics employed when veneers thicker than 1.5 mm are cemented.

Key Words: ceramics, degree of conversion, dental veneers, light-cured resin cements.

Introduction

The use of ceramic veneers has increased in Dentistry. For the success of this procedure, the esthetic quality of the material is not the only criterion to be considered. It is important that ceramic veneers are firmly attached to the tooth structure with resin-based cements (1). However, for best properties to be obtained, these cements should be well polymerized.

Traditionally, two kinds of resin-based cements have been used for luting indirect restorations: chemically cured cements and dual-cured cements (chemically and light-cured). The dual-cured cements have been shown to be dependent on the light exposure to improve their physical and mechanical properties, instead of being only chemically cured (2). The incorporation of air bubbles into the resin mass is inevitable, which may theoretically weaken some properties, such as hardness and roughness. Due to the lack of control of the positioning time of ceramic veneers, use of these cements without the catalyst paste has been proposed (3). This procedure, however, may cause a decrease in the mechanical properties of the resin cement (4). For these reasons, one-paste resin-based materials, in which the operator could control the curing time, were developed. The use of light-cured cements is based on the idea that the light could easily pass through the indirect restoration due their translucency and reduced thickness.

The translucency of ceramic materials may be influenced by several factors, such as different shades, color saturation, crystalline structure, thickness, number of firing cycles, size of crystalline particles and pigments of the ceramics (5). Thus, the properties of light-cured resin-based cements could change depending on the type and thickness of ceramics. The thickness of the ceramic may influence the light transmittance (6) and the quality of light that reaches the underlying cement layer (1,7,8). It has been proposed that the larger the veneer thickness, the greater the exposure time to the light to obtain improved mechanical properties (4).

When cementing laminate veneers with light- and dual-cured resin cements, it is important to understand that the different ceramic materials and veneer thicknesses may attenuate the light (1,9). These veneers are not all equal; they may differ not only in color, opacity and thickness but also in composition and manufacturing technique. Thus, understanding of how different types and thicknesses of ceramic veneers may influence the degree of conversion of light-cured resin-based cements could assist the clinician in choosing the best restorative and luting material in order to provide esthetic and functional results with a safe and durable effect. The aim of this study was to evaluate the degree of conversion of resin cement light-cured by interposing ceramic veneers of different

types and thicknesses. The hypothesis was that the degree of conversion of a light-cured resin cement, developed specifically for the cementation of thin veneers, would be affected by the interposition of ceramic veneers.

Material and Methods

A light-cured resin cement (RelyX Veneer; 3M ESPE, St. Paul, MN, USA), shade A1, was employed in the present study. This material has in its composition glycidil bisphenol methacrylate (BisGMA) and triethylene glycol dimethacrylate (TEGDMA), and zirconia and silica filler particles. The cement has 66% in weight of filler particles with an average size of 0.6 μm . Also, four different types of dental ceramics were used: IL - IPS InLine (feldspathic porcelain), EE - IPS Empress Esthetic ingot E TC (leucite-reinforced glass-ceramic), LT - IPS e.max Press LT (low translucency) ingot (lithium disilicate glass-ceramic), and HT - IPS e.max Press HT (high translucency) ingot (lithium disilicate glass-ceramic) (Ivoclar Vivadent, Liechtenstein). The shade A1 was used.

Ceramic veneers were fabricated in elliptical shape with thicknesses of 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm. Feldspathic porcelain veneers were prepared as monolayers using the conventional technique of manual stratification. The glass-ceramics (IPS Empress Esthetic and IPS e.max) were prepared with a CAD/CAM system (CeraMill Mind and CeraMill Motion, Koblach, Austria) to design veneers with the desired size and thickness and to obtain wax patterns.

The glass ceramics were heat-pressed according to each manufacturer's instructions with the corresponding A1 shade ingot. All ceramic veneers underwent hand finishing and polishing to reach the final dimensions. A digital caliper (Starret, Jiangsu, China) was used to verify the dimensions during all procedures.

For the determination of the degree of conversion, a portion of approximately 0.05 g of the uncured cement was dispensed onto a plastic film. Another plastic film was placed over the material and the set was pressed with a pneumatic press (Shimadzu, Kyoto, Japan) at 10 kN, in order to obtain thin films approximately 0.1 mm thick and 20.0 mm diameter. The uncured specimens were submitted to Fourier transform infrared spectroscopy (FTIR 8400; Shimadzu) at a resolution of 4 cm^{-1} and 32 scans ranging from 4,000 to 800 cm^{-1} . 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 1636 cm^{-1} (Abs 1636). The films were then light-cured for 40 s through the different ceramic veneers with an LED curing unit (Translux Power Blue; Heraeus Kulzer, Hanau, Germany), with an irradiance of 1,000 mW/cm^2 , which was determined by a radiometer without the interposition of the ceramic veneers. New FTIR

readings were obtained immediately after polymerization of the cement. A total of 85 samples were prepared, five samples *per* group.

The percent degree of conversion (DC) was determined using the following equation:

$\text{DC} = 100(1 - R_{\text{cured}}/R_{\text{uncured}})$, (1) where R is the ratio between Abs 1636 and Abs 1608 calculated for both cured and uncured resin cements.

DC data were subjected to one-way ANOVA and Tukey's test ($\alpha=0.05$).

Results

The mean values and standard deviations obtained for DC are shown in Table 1. Significant differences among the groups were observed ($p<0.001$). DC of the light-cured cement through ceramics with 0.5 and 1.0 mm thickness was similar to the control ($p>0.05$), regardless of the type of ceramic (Table 1 and Fig. 1). For 1.5-mm-thick veneers, only LT showed values different from the control ($p<0.05$). For 2.0-mm-thick veneers, only the LT and HT ceramics were able to produce specimens with DC similar to the control ($p>0.05$). DC for all ceramics evaluated was found to be a negative linear function of thickness, with slightly

Table 1. Mean values and standard deviations of degree of conversion (DC)

Material	Thickness (mm)	DC (%)
Control	0.0	69.48 \pm 2.4 ^{AB}
	0.5	72.31 \pm 4.4 ^A
	1.0	67.35 \pm 4.9 ^{ABC}
	1.5	60.53 \pm 2.8 ^{BC}
IPS InLine	2.0	56.25 \pm 2.4 ^C
	0.5	65.13 \pm 1.3 ^{ABC}
	1.0	58.67 \pm 3.8 ^{BC}
	1.5	61.46 \pm 6.1 ^{ABC}
IPS Empress Esthetic	2.0	56.59 \pm 3.8 ^C
	0.5	61.02 \pm 4.6 ^{ABC}
	1.0	63.45 \pm 4.5 ^{ABC}
IPS e.max Press LT	1.5	56.64 \pm 5.6 ^C
	2.0	59.40 \pm 5.4 ^{BC}
	0.5	68.48 \pm 5.9 ^{AB}
IPS e.max Press HT	1.0	63.97 \pm 7.0 ^{ABC}
	1.5	61.74 \pm 5.1 ^{ABC}
	2.0	58.44 \pm 10.1 ^{BC}

Different letters represent statistically significant difference ($p<0.05$).

higher correlation coefficients resulting from quadratic regression (Fig. 1).

Discussion

Although there are advantages in using light-cured resin-based cements for luting ceramic veneers, the possible attenuation of the light intensity provided by the thickness and type of ceramic may be relevant. This hypothesis, evaluated in the present study, was partially accepted. Despite the clear tendency to reduce the degree of conversion by increasing the thickness of the ceramic, there was no significant difference between the control group and the light-cured cement through IPS e.max Press HT. This is a highly translucent material and is indicated when there is no need to change the color of the dental substrate. In the case of restoring discolored teeth or metal core build-ups, less translucent ceramics such as e.max LT are indicated. The clinician should be aware that the polymerization could be jeopardized if light-cured resin cement is employed to cement a restoration thicker than 1.0 mm, as the data found in the present study suggest

that the effect of light attenuation by ceramic veneers is not significant in thicknesses of 1.0 mm or less.

The light-curing protocol employed in the present study should be discussed. To prepare the specimens, an LED light-curing unit was used. According to the manufacturer, the device has high irradiance (approximately 1,000 mW/cm²) and spectral emission in the range of 440–480 nm (peak emission near 470 nm). Additionally, it should be noted that a polymerization time of 40 s was used instead of 30 s, as recommended by the manufacturer. Thus, the high irradiance and exposure time could have reduced the light attenuation of the studied materials. After interposing different indirect restorative materials, Pick et al. (8) found similar results when evaluating the degree of conversion of a resin cement cured with a tungsten halogen lamp (750 mW/cm²) and an LED unit (1,060 mW/cm²) (9). Devices with lower irradiance could produce different results (10,11). It is important to stress that the use of high energy densities is not directly linked to higher degrees of conversion (12). Another aspect to be discussed is that in the present study, the degree of conversion was evaluated immediately after

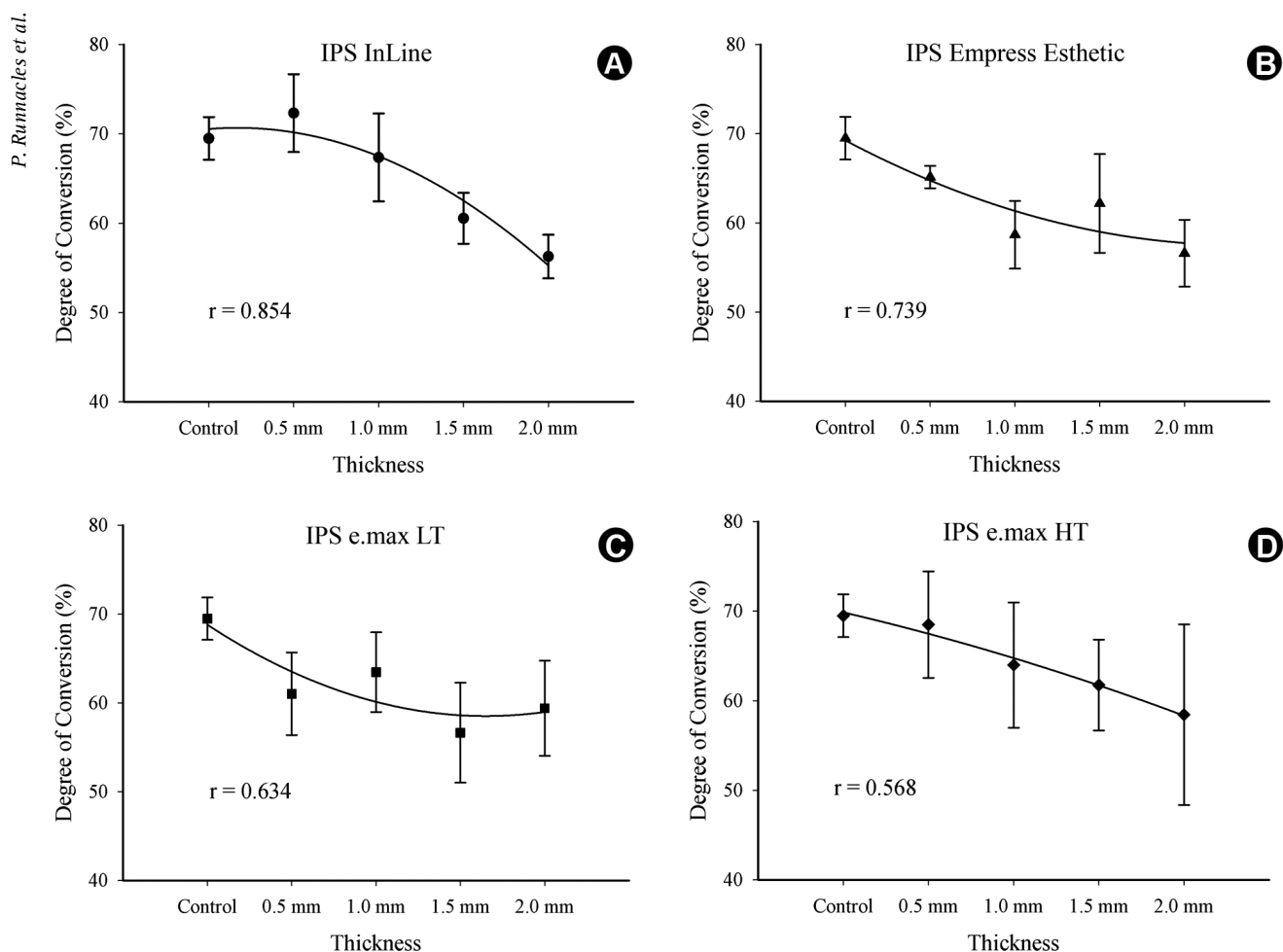


Figure 1. Degree of conversion for the different ceramics evaluated.

preparation of specimens at room temperature. It is known that the curing of resin-based materials increases over time (13), with higher values being achieved after 24 h (14). Moreover, curing the resin cement at higher temperatures could increase the degree of conversion (15). It has been observed that the type of curing unit has an influence on the bond strength of fiber-reinforced posts (16). In a similar way, the results of the present study could be different if another light source of different type or irradiance were employed.

The curing of a resin cement may be considered dependent on the light exposure time up to a certain extent in a way that a "maximum" polymerization could be achieved after a certain time of light-curing (4). This nonlinear relationship between curing and curing time may be explained by the typical auto-acceleration/auto-deceleration stages of a polymerization reaction (17), in which the chain flexibility and molecular mobility decrease while the complete polymerization of the material is avoided (18) due to the limitation of diffusion in the reaction medium (19). Ilie and Hickel (4) evaluated the correlation between ceramics translucency/thickness and the hardness of a resin cement, observing that 10 to 15 s of curing time resulted in values of Vickers hardness compared to the control when the resin cement was cured through ceramics with 0.5 mm and 1.0 mm thickness. These authors observed that increasing the exposure time to 20 and 30 s no longer influenced the hardness. On the other hand, Archegas et al. (20) observed that curing resin cements for 40 s through an opaque ceramic resulted in lower degree of conversion than curing through a translucent ceramic, while an exposure time of 120 s resulted in similar degree of conversion values for both opaque and translucent ceramics (20).

Previously reported data have shown that the thinner the ceramic material interposed between the resin cement and the light source, the higher is the degree of conversion (1,8). However, in the present study, the 2-mm-thick HT and LT ceramic veneers resulted in degrees of conversion statistically similar to the control group. This result should be considered cautiously as LT showed a lower mean value ($DC\% = 59.40 \pm 5.4$) when compared with the control ($DC\% = 69.48 \pm 2.4$).

The degree of conversion ranged from 56% to 72%, with relatively high standard deviations. These results could be related to the composition and microstructure of the involved ceramics. The microstructure of a ceramic material, specially its crystalline phase, may influence the polymerization process of the underlying resin cement due to their differences in transmittance and scattering of light. The higher mean value was obtained when the feldspathic porcelain IL 0.5 mm was employed ($DC\% =$

72.31), against 69.48% for the control group. This result suggests a better distribution and scattering of light than in the other evaluated ceramics. The IPS e.max Press is a lithium disilicate glass ceramic for use with heat-press technique. In this study, only the LT and HT ceramics were evaluated. More opaque ceramics such as the HO (high opacity) and MO (medium opacity) were not evaluated, because they are more indicated as infrastructure, according to the manufacturer.

The data from this study suggest that the light-cured cement should be used carefully when ceramic veneers thicker than 1.5 mm are employed, since 2-mm-thick ceramics showed degree of conversion values with great variability. This is related to the idea that depending on the composition and thickness of the ceramics, the light reaching the underlying cement may be less than required (1,21). On the other hand, it is important to note that a single cement was evaluated in the present study. Different results could be obtained considering that not all light-cured resin cements are equal and that different monomers and comonomers play a major role in the curing properties of these materials (22). Thus, within the limitations of this *in vitro* study, it may be concluded that the degree of conversion is affected by thickness and type of the ceramic veneers for veneers thicker than 1.5 mm.

Resumo

Durante a cimentação de facetas cerâmicas, a polimerização de cimentos resinosos pode ser comprometida se a cerâmica atenuar a irradiância do aparelho fotopolimerizador. O objetivo deste estudo foi avaliar o efeito de diferentes tipos e espessuras de facetas cerâmicas sobre o grau de conversão de um cimento resinoso fotopolimerizável (RelyX Veneer). O cimento foi fotoativado após a interposição de facetas cerâmicas [IPS InLine, IPS Empress Esthetic, IPS e.max LT (baixa translucidez) e IPS e.max HT (alta translucidez) - Ivoclar Vivadent] de quatro espessuras (0,5 mm; 1,0 mm; 1,5 mm e 2,0 mm). Como controle, o cimento foi polimerizado sem interposição de cerâmica. O grau de conversão foi avaliado por espectroscopia FTIR ($n=5$). Os dados foram analisados através de ANOVA a um critério e teste de Tukey ($\alpha=0,05$). Foram observadas diferenças significativas entre os grupos ($p<0,001$). O grau de conversão foi semelhante ao do controle para todos os grupos polimerizados com interposição de cerâmicas de 0,5 mm e 1,0 mm ($p>0,05$). Entre as facetas de 1,5 mm de espessura, IPS e.max LT foi a única que apresentou resultados diferentes do controle ($p<0,05$). Com a espessura de 2,0 mm, apenas IPS e.max LT e HT foram capazes de produzir cimentos com grau de conversão semelhantes aos do controle ($p>0,05$). O grau de conversão do cimento resinoso fotopolimerizável avaliado depende da espessura e do tipo de cerâmica utilizados quando facetas mais espessas do que 1,5 mm são cimentadas.

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