JOURNAL OF DENTISTRY 42 (2014) 684–690

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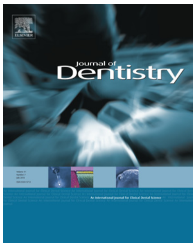

Quantification of the amount of light passing through zirconia: The effect of material shade, thickness, and curing conditions

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ARTICLE INFO

Article history:
Received 1 September 2013
Received in revised form
6 March 2014
Accepted 11 March 2014

Keywords:
Zirconia
Irradiance
Blue light
Translucency

ABSTRACT

Objective: This study aimed to evaluate the amount of light (360–540 nm) passing through shaded zirconia with respect to material thickness, exposure distance, and different curing modes.

Methods: The specimens were divided into groups according to thickness as follows: 0.5, 1, 1.5, 2, 2.5, and 3 mm. Thirty-five zirconia and seven glass-ceramic (control group) specimens were fabricated for each group ($N = 252$). Zirconia was divided into five subgroups ($n = 7$) and stained to the following shades: CL1, CL2, CL3, and CL4. One zirconia group remained unstained (CL0). Irradiance passing through the different specimens was measured using a violet-blue LED curing unit in three curing modes (Xtra-power, high-power, and standard-power mode) with a fibre-optic USB4000 spectrometer. Irradiance was measured at varying exposure distances, ranging from direct contact of the curing unit with the surface to a distance of 7 mm from the surface, increasing in 1 mm steps. Data were analyzed using a multivariate analysis and linear mixed models ($p < 0.05$).

Results: The control group, the glass-ceramics, transmitted the highest irradiance values, followed by CL0 (unshaded zirconia), CL1 (~A1/B1), CL2 (~A3/A3.5/A4/B3/B4), and CL3 (~A3.5/B3/B4/C3/D3), respectively. The highest transmitted irradiance was measured at a specimen thickness of 0.5 mm for all materials, decreasing exponentially with increased ceramic thickness. Within one type of ceramic, one thickness, and one polymerization mode, a decrease in transmitted irradiance with increased exposure distance could be observed only at a distance of 3 mm and above.

Conclusions: Unshaded zirconia was significantly less translucent compared with the glass-ceramic, but the translucency decreased slower with material thickness. The Beer–Lambert law describes well the decrease of transmitted irradiance with an increase of the specimens' thickness for all materials. Except for dark ceramics, this would allow for calculating the transmitted irradiance through any material thickness and any initial irradiance.

Clinical significance: The amount of light passing through ceramics is an important aspect for an adhesive cementation, since many dual-cured luting materials reveal a high sensitivity to additional occurrence of blue light. For restorations thicker than 1.5 mm in light-shaded zirconia and 0.5 mm in darker-shaded zirconia the use of less-light-sensitive dual-cured cements are recommended.

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http://dx.doi.org/10.1016/j.jdent.2014.03.007
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1. Introduction

The excellent mechanical properties of zirconia, such as flexural strength and fracture toughness, legitimate its efficiency as a framework material for fixed dental prostheses (FDPs).[1–3] While few fractures of zirconia frameworks have been reported, chipping of veneering ceramic is a frequent complication.[4] To overcome chipping, zirconia FDPs are now produced without veneering ceramics, as fully anatomic zirconia or monolithic zirconia restorations. The clinical advantage of monolithic zirconia FDPs is the significantly reduced thickness of material compared with that of conventionally veneered or other monolithic ceramics.[5] The FDPs can be shaded individually in their white state to sintering, allowing for good aesthetic results in the posterior region, even in cases with substantially reduced space.[5] Moreover, its simple and quick fabrication with computer-aided design/computer-aided manufacturing (CAD/CAM) technology increased the use of monolithic reconstructions, allowing the forgoing of expensive manual veneering and saving costs.[5]

Because of the specific chemical composition of zirconia, its adhesive cementation can only be accomplished with specific resin composite cements.[6–8] It should be noted that these resin composite cements or their corresponding coupling agents must contain at least one acidic group (phosphate or carboxylate) that can chemically bond with zirconia.[9–14] The advantage of resin composite cementation compared with traditional cementation, such as fixation with glass ionomer or phosphate cements, is a reduced marginal microleakage.[15] Marginal discrepancies of dental restorations can result in a higher risk of cement ditching, increasing the risk of endodontic or periodontal complications or the occurrence of secondary caries.[15] These biological complications may compromise the longevity of the tooth as well as the dental restoration itself.

Most of the used cements are dually cured resin composite cements, that is, they can be cured chemically (autocuring) and by blue-light activation. The impact of light on the polymerization process of dually cured resin composite cements was shown to be dependent on the material, whereas a large amount of luting materials reveal a high sensitivity to additional occurrence of blue light, reaching significantly higher mechanical properties when compared with autocuring alone (RelyX Unicem, Multilink Automix, G-Cem, Maxcem Elite, iCEM, Clearfil SA, G-Cem Automix, SmartCEM2).[16] The translucency of zirconia ceramic is thus an indispensable characteristic if an adhesive cementation with dually cured resin composite cements is intended, and it is affected by the thickness of the framework and by the crystalline content.[9–12] One investigation tested the contrast ratio of differently shaded zirconia materials and observed significant differences in translucency between the shade intensities.[17]

The translucency or the contrast ratio/translucency of various zirconia materials in terms of aesthetic properties has recently been examined in many studies.[17–29] However, to the authors' best knowledge, there is no information of the amount of irradiance that can reach a luting material underneath zirconia ceramics with regard to adequate cementation using dually cured resin cements. Therefore, the objective of the present study was to investigate how much light is passing through different shaded zirconia ceramics in view of adhesive cementation. Different material thicknesses, radiant exposures, as well as clinically relevant exposure distances are therefore considered.

The hypotheses tested were that (1) shades of zirconia, (2) material thickness, (3) exposure distance, and (4) initial irradiance level (curing modes) show no impact on irradiance passing through the zirconia ceramics; and (5) zirconia ceramics and glass-ceramics behave similarly with regard to irradiance passing through the materials.

2. Materials and methods

2.1. *Specimen preparation*

A total of 252 specimens were fabricated. Therefore, thirty-five zirconia (Ceramill ZI; Amann Girrbach, Koblach, Austria, Lot No.: FL08-04119) and seven glass-ceramic (A3C, VITABLOCS Mark II; VITA Zahnfabrik, Bad Säckingen, Germany, Lot No.: 18090) disks (10 mm width × 10 mm length) were cut using a low-speed diamond saw (Well 3241, Well Diamantdrahtsägen, Mannheim, Germany) according to the following thicknesses: 0.5, 1, 1.5, 2, 2.5, 3 mm, respectively. Glass-ceramics acted as the control group.

Thereafter, each thickness of zirconia specimens was randomly divided into five groups ($n = 7$) and stained using the immersion technique (Ceramill Liquid; Amann Girrbach). The chemical composition of the Ceramill Liquid was as follows (weight%): water, 10–80%; iron(III) chloride, 0–20%; erbium(III) chloride, 0–20%; and disodium dihydrogen ethylenediaminetetraacetate dihydrate, <0.05%. For this, using plastic tweezers, the specimens were immersed in the solution for 30 s. Subsequently, the specimens were drained and sintered (Ceramill Therm; Amann Girrbach) at a heating rate of 8 °C/min to 1450 °C with a holding time of 120 min. The following Ceramill Liquid shades were used: CL1 (~A1/B1, $n = 7$), CL2 (~A3/A3.5/A4/B3/B4, $n = 7$), CL3 (A3.5/B3/B4/C3/D3, $n = 7$), and CL4 (A4/C4/D3, $n = 7$). One zirconia group ($n = 7$) remains unstained (CL0).

The used zirconia contains (weight%) $ZrO_2 + HfO_2 + Y_2O_3$, >99.0%; Y_2O_3, 4.5–5.6%; HfO_2, <5%; Al_2O_3, <0.5%; other oxide, <0.5%. The mean grain size is 0.577 ± 0.09 μm.[30] Glass-ceramic contains the following (weight%): SiO_2, 56–64%; AI_2O_3, 20–23%; Na_2O, 6–9%; K_2O, 6–8%; CaO, 0.3–0.6%; and TiO_2, 0–0.1%. The feldspar particles have a mean size of 4 μm.[31]

Thereafter, zirconia disks were polished under standardized conditions with rotating silicon carbide paper (SiC) P1200 for 60 s, P2000 for 60 s, P5000 for 40 s, followed by 1 μm diamond suspension for 40 s under constant water rinsing in a polishing machine (Tegramin 2.0; Struers, Ballerup, Denmark) and then ultrasonically cleaned in isopropanol. The final dimensions of all specimens were 10 × 10 × 0.5 (1, 1.5, 2, 2.5, 3) ± 0.05 mm.

2.2. *Irradiance measurements*

The analysis of irradiance passing through the ceramics was performed on a laboratory-grade NIST-referenced USB4000 spectrometer (MARC [Managing Accurate Resin Curing]