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Influence of ceramic thickness on mechanical properties and polymer structure of dual-cured resin luting agents

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ABSTRACT

Objective. To investigate the influence of ceramic thickness on the mechanical properties and polymer structure (degree conversion and cross-linking density) of three dual-cured resin luting agents.

Methods. Three dual-cured resin luting agents [Linkmax HV (GC), Nexus 2 (Kerr), and Variolink IIHV (Ivoclar-Vivadent)] were polymerized with or without 800 mW/cm^2 irradiation through 0–3-mm-thick GN-I (GC) machinable ceramic. Bar-shape specimens were subjected to three-point bending to determine flexural strength (FS) and elastic modulus (EM) after dry storage at 37 °C for 24 h. Knoop hardness was measured on the irradiated surface of disk-shaped specimens before (KHN1) and after (KHN2) storage of 100% ethanol solution at 37 °C for 24 h. KHN1 and KHN2 were estimated as indirect indicators of degree of conversion (DC) and cross-linking density, respectively. Data were analyzed by one-way ANOVA and Student–Newman–Keuls test for each luting agent, and four mechanical properties were subjected to regression analysis.

Results. For three resin luting agents with dual-cured mode, FS, EM, KHN1, and KHN2 decreased with the increase of ceramic thickness. FS except for Nexus 2 and EM for three resin luting agents had a positive linear relationship with both KHN1 and KHN2.

Significance. The variables tested behaved differently. When the ceramic thickness increased, the chemical cured components of dual-cured resin luting agents did not produce significant compensation for all variables. Mechanical properties and polymer structure of dual-cured resin luting agents was dependent on the intensity of light irradiation.

1. Introduction

Adequate polymerization is a crucial factor for obtaining optimal mechanical properties and satisfactory clinical performance of dental resin material. For light-cured resin materials, the reduction of energy density of light irradiation can decrease the degree of conversion (DC) and mechanical properties [1–4], which limits the application of light-cured resin luting agents in the bonding of thicker esthetic restorative materials.

Dual-cured resin luting agents were developed in an attempt to combine the desirable properties of chemically polymerizing and light polymerizing materials, and were expected to provide further polymerization by chemical cat-

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alysts in deeper areas or under thicker restoratives. However, many studies have suggested that, even if under dual-curing mode, DC and final hardness of most dual-cured resin luting agents were reduced when the thickness of restorative materials is increased [5–8]. This may be attributed to the fact that fast light polymerization prevents any significant contribution from the chemical polymerization to DC of dual-cured resin luting agents [9].

Apart from thickness of restorations, the three curing modes (dual, light, and chemical) used for dual-cured resin luting agents may affect the mechanical properties [10–13]. It was believed that different brands of dual-cured resin luting agent had different ratios of light/chemical catalysts. However, Feng and Suh [14] found that dual-cured composites could produce a similar DC polymerized by dual-cured and chemical-cured mode, but chemical-cured specimens showed a lower elastic modulus than dual-cured specimens. This suggests that dual-cured resin luting agents with different cure modes produce different polymer structures. Other studies showed that flexural properties of composite resin were not completely dependent upon DC [15,16]. Therefore, DC, despite being an important factor, does not give a complete characterization of polymer structures. Polymerization of the methacrylate monomers in dental resin can form a highly cross-linking matrix, in which a large number of strong covalent linkages between different kinetic chains may transform the molecules into a rigid, very high-molecular-weight material. The cross-linking density could affect the mechanical properties of dental resin material. Hardness of resin composite was shown to be a good predictor of DC [17]. The cross-linking density could be estimated indirectly by measuring the hardness of the polymer after ethanol softening [18–20]. With this method, it is inevitable that a certain amount of the polymeric material (unreacted monomer, oligomers, and linear polymer) is extracted into the ethanol.

Establishing the mechanical properties of ceramics is a matter of utmost importance in cementation of esthetic restorations involving dual-cured resin luting agents. Therefore, the purpose of the present study was to verify the influence of increasing ceramic thickness on mechanical properties (flexural strength, elastic modulus, and Knoop hardness before and after ethanol softening) of three dual-cured resin luting agents.

2. Materials and methods

2.1. *Ceramic and dual-cured resin luting agents*

Three thick of ceramic plates (10 mm × 8 mm with 1.05, 2.05, and 3.05 mm thick) were prepared from machinable blocks (GN-I, shade A3, GC Corp., Tokyo, Japan) using a low-speed cutting saw (Isomet, Buehler Ltd., Lake Bluff, IL, USA). Prefabricated ceramic material is mainly composed of SiO_2, K_2O, and Al_2O_3 and the main precipitated crystal is leucite $K_2O{\cdot}Al_2O_3{\cdot}4SiO_2$. The ceramic plates were sanded to a flat surface by hand grinding on wet 320-, 400-, 600-, and 800-grit silicon carbide paper and cleaned ultrasonically in distilled water for 5 min. The final thickness of each ceramic plate was 1.0, 2.0, and 3.0 mm. Three dual-cured resin luting agents

Table 1 – Dual-cured resin luting agents tested in this study (information provided by manufacturers)

Dual-cured resin luting agent	Batch	Manufacturer	Monomer	Filler			Initiator	
				Content (wt%)	Size (μm)	Component	Base	Catalyst
Linkmax HV (LMHV)	B: 0601131, C: 0601131	GC Corp. (Tokyo, Japan)	UDMA, TEGDMA	70.0	0.8	F–Al–Si-glass	CQ, amine	BPO
Nexus 2 (NX2)	439766	Kerr Corp. (Orange, CA, USA)	Bis-GMA, UDMA, TEGDMA	68.0	0.6	Ba–Al–B–Si-glass, SiO_2	CQ, amine	BPO
Variolink IIHV (VLIIHV)	B: H23580, C: H22074	Ivoclar-Vivadent (Schaan, Liechtenstein)	Bis-GMA, UDMA, TEGDMA	75.3	0.7	Ba–Al–F–Si-glass	CQ, amine	BPO

UDMA: urethane dimethacrylate; TEGDMA: triethyleneglycol dimethacrylate; Bis-GMA: bis-phenol-A-diglycidylmethacrylate; Al: aluminium; B: boron; Ba: barium; F: fluorine; Si: silicon; BPO: benzoyl peroxide; CQ: camphorquinone.