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Correlation between polymerization stress and interfacial integrity of composites restorations assessed by different in vitro tests

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ABSTRACT

Objective. to correlate polymerization stress data obtained under two compliance conditions with those from different interfacial quality tests.
Methods. Six commercial composites were tested (Filtek Z250/3M ESPE, Heliomolar/Ivoclar Vivadent, Aelite LS Posterior/Bisco, Filtek Supreme/3M ESPE, ELS/Saremco and Venus Diamond/Heraeus Kulzer). Bond strength (BS) was evaluated by push-out test on slices of bovine dentin (2-mm thick) with tapered cavities. For microleakage (ML) and gap analysis, cylindrical cavities in bovine incisors (4-mm diameter and 1.5-mm height) were restored and epoxy replicas of the cavo-surface margins were prepared for analysis under scanning electron microscopy (200×). The same specimens were submitted to a microleakage protocol using $AgNO_3$ as tracer. After sectioned twice perpendicularly, ML was determined under a stereomicroscope (60×). Polymerization stress (PS, $n = 5$) was determined by the insertion of the composite ($h = 1.5$ mm) between poly(methyl methacrylate), PMMA, or glass rods (Ø = 4 mm) attached to a universal testing machine. Data were analyzed using Kruskal–Wallis (ML and gaps), and ANOVA/Tukey (BS and PS, $\alpha = 5\%$). Pearson's correlation test was used to verify correlations between stress and interfacial quality.
Results. BS varied from 4.7 to 7.9 MPa. Average ML data ranged from 0.34 to 0.89 mm. Maximum ML varied from 0.61 to 1.34 mm. Gap incidence varied from 13 to 47%. PS ranged from 2.5 to 4.4 MPa in PMMA, and between 2.1 and 8.2 in glass. Statistically significant correlations were observed between stress and interfacial quality, except between BS and PS in glass. These correlations were stronger when PMMA was used as bonding substrate.

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Conclusions. PS data obtained using a high compliance testing system showed a stronger correlation with "in vitro" interfacial integrity results, compared to data from a low compliance system.

1. Introduction

According to clinical studies, drawbacks such as postoperative sensitivity, marginal discoloration and possibly secondary caries are often associated with loss of marginal integrity in composite restorations [1–3]. One of the possible causes for interfacial debonding is polymerization stress. When composites polymerize confined in a cavity preparation, shrinkage associated with the development of modulus of elasticity generate stresses in the tooth/restoration interface, which may lead to debonding [4].

Several research groups have focused on developing mechanical tests to quantify polymerization stress [5–8]. In the most commonly used test, the composite is inserted and polymerized between two flat surfaces of glass, metal or poly(methyl methacrylate), PMMA, rods attached to an universal testing machine [9–16]. The load cell records the contraction force exerted by the composite on the substrate during polymerization and the nominal stress is calculated, in MPa, by dividing this value by the cross sectional area of the rod. This method has been widely used to compare commercial [17] and experimental composites [14,18], photoactivation methods [19] and to evaluate several factors associated with stress development [16]. Some studies have correlated the stress values from mechanical tests with interfacial integrity, noting that microleakage and cuspal deflection increase proportionally with increasing stress [4,20,21]. However, no relationship was found between stress and gap formation in porcelain inlays [22]. A study evaluating polymerization stress as a function of photoactivation methods observed that modulated photoactivation results in lower stress values, leading to higher bond strengths [19].

The studies mentioned above have in common the fact that stress was determined in low compliance systems, using glass as bonding substrate for the composite. However, the system's compliance has great influence on ranking materials regarding stress magnitude [23,24]. The lower the compliance of the testing system, the lower is its ability to elongate and relief the stress. Consequently, the recorded value is higher. In the past few years, bonding substrates with lower modulus of elasticity have been used polymerization stress testing [11,12,23,24].

Even assuming that data from mechanical tests cannot be extrapolated to the clinic, a question arises regarding which system would be more closely related to the interfacial quality of composite restorations. It is possible that the use of low compliance testing systems could overestimate the stress values, in comparison with those found in high compliance conditions, more akin to the behavior of a prepared tooth. Estimating the compliance of the tooth in a clinical situation is nearly impossible. The stiffness of the dental tissues varies among teeth and even in the same tooth there is a substantial difference in stiffness between enamel and dentin. But even being that complex, the tooth cannot be considered as a rigid system. In fact, several studies have shown that polymerization shrinkage could lead to tooth deformation [25,26]. In a previous study, several commercial composites ranked similarly for microleakage and stress values obtained in a high compliance system, but the same did not apply to stress data obtained in a low compliance system [23].

Considering the above, it is important to verify if data from polymerization stress tests can be correlated with results from interfacial quality tests, namely, bond strength, microleakage and gap formation. The null hypothesis was that the polymerization stress values shows no correlation to interfacial integrity, regardless of the system compliance. Additionally, a second null hypothesis was tested, stating the compliance of the testing system did not influence polymerization stress values.

2. Materials and methods

Six dimethacrylate-based commercial composites shade A3 were tested (Table 1). Three of them (Heliomolar, Filtek Supreme and Filtek Z250) were chosen based on their filler content (by volume). The other three (Venus Diamond, ELS and Aelite LS) are considered as "low shrinkage" or "low stress" materials by the respective manufacturers. Venus Diamond has TCD-urethane in its composition, in addition to conventional dimethacrylates, while ELS has no diluent monomer (TEGDMA) and Aelite LS has a very high filler content. Elastic moduli (determined by three point bending test) and post-gel shrinkage (determined by the strain-gage method) were obtained in a previous study, and correspond to the values recorded 10 min after phtoactivation using the same irradiance and radiant exposure adopted in the present study [27].

2.1. *Push-out bond strength*

Bovine incisors ($n = 15$) had their crowns removed at the cement-enamel junction with a diamond disc under refrigeration. The buccal surface was flattened with wet sandpaper until the enamel was completely removed. The lingual surface was sectioned using a diamond disc (Isomet 1000, Buehler Ltd., Lake Bluff, IL, USA) to obtain a slice with 2 mm thickness. Tapered cavities with 2.9-mm diameter on the buccal surface and 3.5 mm diameter on the lingual surface were prepared using cylindrical and truncated cone diamond burs.

The cavity walls were etched with 37% phosphoric acid for 15 s and then rinsed in running water for 15 s. Excess water was removed with short air blasts, leaving the surface visibly moist. Two layers of an one-bottle adhesive system