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Influence of the resin cement thickness on the fatigue failure loads of CAD/CAM feldspathic crowns

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ABSTRACT

Objectives. to evaluate the influence of the occlusal resin cement thickness on the cyclic loads-to-failure of feldspathic crowns and to compare the results to data from monotonic tests. A large range of cement thickness (50 μm and 500 μm) was tested, in order to better measure the influence of this variable.

Methods. Feldspathic ceramic crowns (Vita Mark II blocks, Vita Zahnfabrik) were bonded to dentin analog dies (G10 (NEMA grade G10, International Paper), with occlusal resin cement thicknesses of 50 μm and 500 μm (Multilink Automix, Ivoclar). The dies were prepared with microchannels for water transport to the cement layer. After 96-h water storage, the specimens ($n = 20$) were submitted to cyclic loads (500,000 cycles at 20 Hz; initial maximum load = 40% of monotonic load, from previous data) following a staircase sensitivity design (step size = 25 N). Failure loads at 500,000 cycles were compared to monotonic failure loads (from a previous study with specimens produced by the same author, using the same materials, specimen configuration and cementation protocol).

Results. Crowns with an occlusal cement layer of 50 μm were more resistant than those cemented with 500 μm (246.4 ± 22.9 N *vs.* 158.9 ± 22.9 N), under wet cyclic testing conditions ($p < 0.001$). The fatigue failure loads were reduced compared to monotonic loads: to 37% of monotonic for 50 μm; to 53% of monotonic for 500 μm.

Significance. An occlusal cement thickness of 50 μm was more favorable for the structural performance of feldspathic crowns than was 500 μm. Cyclic fatigue reduced failure loads well below those found under monotonic loading.

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1. Introduction

The effect of the resin cement thickness on the durability of ceramic restorations has not been widely investigated and until recently it has been considered a factor of minor influence [1,2]. However, Scherrer et al. [3] tested feldspathic ceramic tabs cemented to composite with resin cement thicknesses ranging from 26 ± 11 μm to 297 ± 48 μm and observed a gradual decrease of the fracture strength that became statistically significant at a cement thickness of 300 μm.

Many studies have reported that the occlusal thickness of cement under CAD/CAM ceramic crowns can vary widely. Colpani et al. [4] found a narrow space in the occlusal area of CAD/CAM zirconia copings (45.2 and 55.2 μm). An average occlusal space centered on 100–250 μm is quite common in the recent literature [5–12]. However, variable occlusal misfits, of 24 μm and 634 μm beneath cusp tips and central fossa [13] and as large as 1316 μm [14], have also been reported.

May et al. [15] showed a significant influence of the occlusal cement thickness on the failure loads of feldspathic ceramic crowns, either under bonded or non-bonded conditions. This study took into account the polymerization shrinkage of the cement layer, demonstrating that this phenomenon can be directly related to the gap formation and to the increase of tensile stresses on the crown, resulting in decreasing failure loads over occlusal cement thickness ranging from 50 to 500 μm.

However, according to Feilzer et al. [16] water sorption can relieve stresses generated by shrinkage polymerization in hydrophilic composite, such as those based on BisGMA/TEGDMA or UDMA. The dentin underneath the restoration is a source of water and its sorption can actually surpass the neutral condition and could be responsible for some expansion stresses in the adhesive interface. The sorption rate is dependent on the nature of the resin, the kind/amount of fillers, adhesion matrix/filler, the resin volume and its accessibility to water [17]. Alrahlah et al. [18] found from 0.58 to 2.26% of hygroscopic volumetric expansion in 2 mm disks of eight resin composites. Equilibrium was attained by 60 days. For the lowest filler loading, the volumetric expansion reached around 56% of the final value by 7 days.

Cyclic mechanical loads were applied under wet conditions to simulate the use of the ceramic restorations and the damage accumulation that occurs clinically. In a wet environment, the water sorption by the cement layer may work to reverse the negative influence of the polymerization shrinkage. Cyclic loads can also lead to softening in brittle polymers, such as the dental cements. Damage accumulation involving, for example microcracking ahead of propagating cracks, can lead to modes of crack initiation and growth not seen under monotonic loads, either in cements or ceramics [19].

Thus the presence of water during the cyclic loading may allow the cement to expand by sorption [16] and also can act chemically at crack tips, assisting the phenomenon known as slow crack growth [20,21], which decreases the strength of glasses and ceramics [22,23]. This phenomenon happens to all ceramics even with only a little bit of water as in atmospheric conditions.

The aims of this study were: (1) to evaluate the influence of the occlusal resin cement thickness (50 μm and 500 μm) on the failure loads of feldspathic crowns bonded to dentin analog dies using wet mechanical cyclic tests, and (2) to compare these results to monotonic data produced in a previous work, with specimens produced by the same operator, using the same materials, specimen configuration and cementation protocol. The range of thickness evaluated was chosen in order to have a better measurement of its effect. The null hypotheses were: (1) mean failure loads will not be influenced by the occlusal cement thickness; (2) wet mechanical cyclic testing will not reduce the failure loads in comparison to the monotonic testing, for both occlusal cement thickness, 50 μm and 500 μm.

2. Materials and methods

2.1. Specimen preparation

Forty dentin analog dies (preparation height = 5.32; internal angle radii = 0.5 mm; axial wall convergence = 16°; cervical preparation depth = 1.2 mm; round shoulder radii = 0.5 mm) were machined from 11 mm-diameter rods of an epoxy-glass cloth – G10 (NEMA grade G10, International Paper, Hampton, SC, USA). Five microchannels for water transport were made in the intaglio surface of each die (Fig. 1).

Crown patterns with occlusal cementation spaces of 50 μm ($n = 20$) and 500 μm ($n = 20$), occlusal thickness of 1.5 mm and nearly 100 μm of cementation space in the axial-walls were machined from aluminum. These patterns were scanned, imported to the CEREC in Lab CAD utility and duplicated by machining from Vita Mark II blocks (Vita Zahnfabrik, Germany). After machining, the crowns were tried onto their respective dies. When any binding was encountered in the axial walls, the dies were adjusted. This adjustment allowed every crown to reach the maximum seating at the margin so that the intended occlusal cement thickness was achieved. The occlusal spaces were checked in 2 crowns per group, using poly (vinyl siloxane) and the values were found to range between: 57 μm and 85 μm for the 50 μm group; 505 μm and 555 μm for the 500 μm group. Cement thicknesses were measured in all crowns following testing.

Crowns were finished on their occlusal surface (silicon carbide grit # 600), resulting in final occlusal thickness of 1.4 mm. The internal crown surface was acid etched with 9% HF (Porcelain Etch, Ultradent products Inc., South Jordan, Utah, USA, batch # B461M) for 60 s, washed for 15 s and ultra-sonic cleaned for 1 min, in order to remove the acid residues off the surface.

The dies were cleaned in an ultra-sonic bath (3 min). After drying they had their microchannels occluded with accessory gutta-percha points (# 35) (Fig. 1a and b) and their surface treated with a primer mixture (Primer A and Primer B, Ivoclar, Liechstenstein).

Resin cement (Multilink Automix, (Ivoclar Vivadent, Schaan, Liechtenstein, batch #41970) was applied through an automix tip to the occlusal surface of the dies and the crowns were seated under a load of 4.6 N. Excess cement was removed following 2 s of light curing from two opposite directions at the margin. Light curing was applied to two opposite axial walls for 20 s each. Following that, the weight was removed and