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Mechanical reliability of air-abraded and acid-etched bonded feldspar ceramic

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ABSTRACT

Objectives. This study investigated the effect of surface treatment (air-abrasion with alumina or hydrofluoric acid-etching) on feldspar ceramic mechanical strength and initial reliability (24 h) before/after adhesive luting.

Methods. Ceramic discs (VITA) were tested as monolithic specimens (Acid; Abrasion), luted bilayers (Acid + luting agent; Abrasion + luting agent), or untreated (Control). Luted groups were coated using resin-based agent (RelyX Veneer, 3 M ESPE). Biaxial flexural test with ball-on-ring setup was carried out ($n = 30$). Biaxial flexural strength (σ_{bf}, MPa), characteristic strength (σ_0, MPa), and Weibull modulus (m) were calculated for axial positions $z = 0$ (ceramic surface) and $z = -t_2$ (luting agent surface). For each condition, 95% confidence intervals were calculated. Scanning electron microscopy was used for topography and fractography analyses.

Results. At $z = 0$, σ_{bf} and σ_0 of luted specimens were higher than of monolithic specimens for both surface treatments. Groups Acid and Abrasion had lower σ_{bf} and σ_0 than Control. Group Abrasion had poorer mechanical strength. Similar structural reliability was observed for all conditions except for the group Abrasion + luting agent, which had lower m than all other groups. At $z = -t_2$, no significant differences between luted groups were observed for mechanical strength and reliability. A more irregular surface topography with more sharp angles was left by air-abrasion than etching. Monolithic specimens failed from surface pores at the tensile area, whereas failure in luted specimens originated from pores below the resin–ceramic interface.

Significance. Air-abrasion yielded lower mechanical strength and initial reliability than acid etching. Presence of a resin-based luting agent layer bonded to ceramic significantly increased its mechanical strength.

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1. Introduction

The continuous technological advancement of dental ceramics has brought to clinicians a wide variety of materials for preparing mechanically strong and esthetic indirect restorations. In the oral environment, ceramic restorations often involve the use of layered ceramic materials [1,2]. Although strong ceramics with varied crystalline phase content for mechanical reinforcement are available, feldspar ceramics are still the restoratives of choice for esthetic restorations due to their lower opacity and other optical qualities.

Sodium- or potassium-based feldspar ceramics can be used to produce laminate veneers or single crowns. These restorations may show clinical survival over 20 years [3,4]. Although inherently brittle, feldspar ceramics might obtain additional strength when bonded to tooth structures using resin-based luting agents [5,6]. A variety of mechanisms has been proposed to explain the strengthening provided by adhesive luting, including microcrack sealing at the intaglio ceramic surface interrupting crack propagation [7] and formation of a ceramic-luting agent-tooth abutment set that leads to a more homogeneous stress distribution to the tooth abutment [8,9], avoiding stress concentration at the ceramic structure or adhesive interface.

Bonding of resin-based materials to dental tissues might be based on chemical interaction and/or micromechanical retention [10–12]. Adhesion occurs when chemical bonds are formed in the interface, while mechanical retention occurs by interpenetration of resin-based agents and tooth tissues to form a bonded interphase [13]. For bonding feldspar ceramic restorations to dental structures, the restorative material must undergo a surface treatment for creating surface roughness in order to generate micromechanical retention [14,15]. This can be accomplished by either etching with hydrofluoric acid or by airborne-particle abrasion with alumina. Whereas airborne-particle abrasion promotes irregularity by mechanical shock of alumina particles, acid-etching promotes selective dissolution of the ceramic glass phase, theoretically being a more controlled procedure than airborne-particle abrasion. Air abrasion tends to create a rougher and more irregular ceramic topography as compared to acid etching [3,15]. In addition, some studies also associate airborne-particle abrasion with the creation of surface cracks and reduction in the mechanical strength dental ceramics [7,16].

The literature presents several studies comparing acid-etching and airborne-particle abrasion procedures as regards surface roughening and bonding of resin-based materials to ceramic [3,17]. However, the mechanical performance of the bonded feldspar ceramic subjected to those different treatments has received little attention. The aim of this study was to investigate the effect of ceramic surface treatment (alumina particle abrasion or hydrofluoric acid-etching) on the mechanical strength and reliability of feldspar ceramic before or after adhesive luting. The study hypothesis was that acid-etched ceramic would show higher mechanical strength and initial reliability (24 h) compared to air-abraded ceramic.

2. Material and methods

2.1. Study design and groups tested

This *in vitro* investigation involved an experimental study designed for testing the effect of two surface treatments (air abrasion with alumina particles or etching with 10% hydrofluoric acid) of a feldspar dental ceramic on its mechanical strength before (monolithic groups: Acid; Abrasion) and after adhesive luting (bilayer groups: Acid + luting agent; Abrasion + luting agent). In total, five groups were tested ($n = 30$), including the Control group (untreated ceramic). The response variables were biaxial flexural strength (σ_{bf}, MPa), characteristic strength (σ_0, MPa), and Weibull modulus (m). Scanning electron microscopy (SEM) and X-ray energy dispersive spectroscopy (EDS) were used to investigate surface topography and elemental composition of treated and untreated ceramic. Fractographic analysis of the fractured surfaces after mechanical testing was also carried out using SEM.

2.2. Preparation of ceramic discs

In total, 150 feldspar ceramic discs were obtained from presintered CAD-CAM blocks (I14 A1C Vitablocs Mark II; Vita Zahnfabrik, Bad Säckingen, Germany). The blocks were initially milled under water-cooling to obtain a cylindrical shape (diameter 12 mm). The cylinders were cut into 0.8 ± 0.1 mm thick discs using a diamond saw under water-cooling (Isomet 1000; Buehler, Lake Bluff, IL, USA). The top surfaces of the discs were sequentially wet-polished using 320, 400, 600, and 1200-grit SiC abrasive papers. The final dimensions of each specimen were measured using a digital caliper with 0.001 mm accuracy (Mitutoyo, Tokyo, Japan).

2.3. Ceramic surface treatments

The discs were randomly divided into the five groups previously described ($n = 30$). The surfaces of thirty discs received no treatment (control group). Sixty discs were etched with 10% hydrofluoric acid for 60 s (Dentsply Caulk, Milford, DE, USA). The gel was applied to the intaglio ceramic surface and evenly distributed using a microbrush. After application, the specimens were cleaned with air/water spray for 60 s and dried with compressed air for 30 s. The intaglio surfaces of the remaining sixty specimens were air-abraded with 50 μm alumina particles for 15 s at 2.8 bar pressure, 90° angle, and 10 mm distance from the surface [15], followed by cleaning and drying as previously described. From the total 60 specimens subjected to each surface treatment, half the number was tested without further treatment (monolithic groups: Acid; Abrasion), while the other half was luted using a resin-based luting agent (bilayer groups: Acid + luting agent; Abrasion + luting agent).

2.4. Adhesive luting

After surface treatments, the experimental groups Acid + luting agent and Abrasion + luting agent were coated with resin-based luting agent. Two layers of a two-bottle, ethanol-diluted proprietary silane coupling agent (Silano;

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