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Effect of surface modifications on the bond strength of zirconia ceramic with resin cement resin

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ABSTRACT

Objectives. Purpose of this in vitro study was to evaluate the effect of surface modifications on the tensile bond strength between zirconia ceramic and resin.

Methods. Zirconia ceramic surfaces were treated with 150-μm abrasive alumina particles, 150-μm abrasive zirconia particles, argon-ion bombardment, gas plasma, and piranha solution (H_2SO_4:H_2O_2 = 3:1). In addition, slip casting surfaces were examined. Untreated surfaces were used as the control group. Tensile bond strengths (TBS) were measured after water storage for 3 days or 150 days with additional 37,500 thermal cycling for artificial aging. Statistical analyses were performed with 1-way and 3-way ANOVA, followed by comparison of means with the Tukey HSD test.

Results. After storage in distilled water for three days at 37 °C, the highest mean tensile bond strengths (TBS) were observed for zirconia ceramic surfaces abraded with 150-μm abrasive alumina particles (TBS_{AAP} = 37.3 MPa, TBS_{CAAP} = 40.4 MPa), and 150-μm abrasive zirconia particles (TBS_{AZP} = 34.8 MPa, TBS_{CAZP} = 35.8 MPa). Also a high TBS was observed for specimens treated with argon-ion bombardment (TBS_{BAI} = 37.8 MPa). After 150 days of storage, specimens abraded with 150-μm abrasive alumina particles and 150-μm abrasive zirconia particles revealed high TBS (TBS_{AAP} = 37.6 MPa, TBS_{CAAP} = 33.0 MPa, TBS_{AZP} = 22.1 MPa and TBS_{CAZP} = 22.8 MPa). A high TBS was observed also for specimens prepared with slip casting (TBS_{SC} = 30.0 MPa). A decrease of TBS was observed for control specimens (TBS_{UNT} = 12.5 MPa, TBS_{CUNT} = 9.0 MPa), specimens treated with argon-ion bombardment (TBS_{BAI} = 10.3 MPa) and gas plasma (TBS_{GP} = 11.0 MPa). A decrease of TBS was observed also for specimens treated with piranha solution (TBS_{PS} = 3.9 MPa, TBS_{CPS} = 4.1 MPa).

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A significant difference in TBS after three days storage was observed for specimens treated with different methods ($p < 0.001$). Thermal cycling significantly reduced TBS for all groups ($p < 0.001$) excluding groups: AAP($p > 0.05$), CAAP($p > 0.05$) and SC($p > 0.05$). However, the failure patterns of debonded specimens prepared with 150-μm abrasive zirconia particles were 96.7% cohesive.

Conclusion. Treatment of zirconia ceramic surfaces with abrasive zirconia particles is a promising method to increase the tensile bond strength without significant damage of the ceramic surface itself. An alternative promising method is slip casting.

1. Introduction

The esthetic demand for all dental restorations has led to the development of ceramics with both, high mechanical strength and high translucency, such as alumina and zirconia ceramics [1–3]. Yttria stabilized tetragonal zirconia polycrystal (Y-TZP) is used for dental applications because its martensic transformation enhance flexural strength and toughness to level superior to all other potential ceramic materials [4–10].

Ceramic surfaces require appropriate surface treatment for a stable and reproducible bonding with resins [11]. The properties of these bonds depend on the interaction between resin and ceramic surface and the density of bonds. The purpose of surface treatments is to increase the density [12] of bonds that itself depend on a number of factors such as cleanliness, roughness and interaction of the resin with the ceramic surface. Durability of the resin-ceramic bond is additionally depending on the prototype of this bonding, purely mechanical, chemical, or a combination. Chemical bonding is stronger than the mechanical bonding but its durability is depended on its stability against hydroxylation [12]. Treatment of silica-based dental ceramic with hydrofluoric acid is well known to increase the anchorage density of the resin on the ceramic surface. This etching is not applicable for zirconia ceramics since it does not create an adequate surface roughness for resin bonding [13–17]. Zirconia ceramics require alternative techniques to achieve a durable resin-ceramic bonding. Moreover, it must fulfill the requirements set forth by technical application: in very short time they must remove any surface contamination, create adequate roughness to provide mechanical interlocking and increase the number of site for chemical bonding between resin and ceramic surface [12]. Till now, only treatment with abrasive alumina particles is known to fulfill these conditions. The surface of Y-TZP ceramics is damaged during the airborne- particle abrasion with alumina particles which could negatively affect mechanical properties [18–22]. For this reason exploring alternative methods to improve strength, and durability of resin-ceramic bonding without damage of the ceramic surface is a major challenge in current dentistry.

In order to avoid damage of Y-TZP ceramic surfaces, some authors recommended the use of softer, rounder abrasives, instead of sharp and hard alumina [18]. Substitution of airborne-particle abrasion with other more suitable surface-modifications may indeed extend the life time of zirconia ceramic restorations [19].

Other authors recommend the atmospheric pressure plasma to improve the adhesive properties of zirconia surface [23–25]. According to these authors the gas plasma treatment creates reactive sites at the surface which improve the bond strength between zirconia and resin.

Sa et al. have studied the effect of argon-ion bombardment of titanium surfaces on the cell behavior [26]. They concluded that the argon-ion bombardment promoted the modification of titanium surfaces properties like topography, roughness, and wettability [26]. Kowalski has studied the effect of ion bombardment on the surface morphology of solids [27]. According to this author ion bombardment induced changes of surface shape and surface roughness.

Based on the recommendations of various researchers [12,19,23–29] in this study zirconia ceramic surfaces were treated with abrasive zirconia particles, argon-ion bombardment, gas plasma, and piranha solution. Alternative methods used in this study were increasing of surface roughness by grinding prior to sintering and slip casting.

The working hypothesis was that not only airborne-particle abrasion with alumina particles improves the strength and the durability of the resin-ceramic bonding.

2. Materials and methods

2.1. *Specimens preparation*

The material investigated in this study was high translucent (HT) Y-TZP (>91 wt% zirconia, >5 wt% Y_2O_3, 2 wt% HfO_2, 0.1 wt% Al_2O_3, <0.03 wt% Fe_2O_3 and colored HT Y-TZP (>90 wt% zirconia, >5 wt% Y_2O_3, 2 wt% HfO_2, 0.1 wt% Al_2O_3, <1 wt% Fe_2O_3). Katana zirconia (HT and colored HT) were supplied from Kuraray Noritake dental company (Aichi, Japan, Table 1). Y-TZP blanks were cut (ISOMET 1000, Buehler, Düsseldorf, Germany) into discs under copious water. Specimens were divided into 13 groups, listed in Table 2. All specimens, except the specimens of group SC, were sintered in a programmable furnace (Nabertherm 310 P, Lilienthal, Germany).

According to the manufacturer's instructions (sintering was performed at a temperature of 1500 °C for 2 h, heating and cooling rates were 10 °C/min). Specimens of group SC were prepared by Fraunhofer Institute, Dresden, Germany, according to their slip casting procedure [29].