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Effects of sandblasting distance and angles on resin cement bonding to zirconia and titanium

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ABSTRACT

Objectives: The aim of this study was to evaluate effects of sandblasting distance and angles resin to zirconia and titanium bonding.

Methods: Densely sintered zirconia and cp2 titanium specimens were prepared and randomly divided into groups, and then sandblasted with various distance (5 mm, 10 mm and 15 mm) and angles (45°, 60°, 75° and 90°). After surface treatment, each specimen surface underwent a silane primer application (RelyX, 3M ESPE), followed by bonding of a resin cement (RelyX Unicem Aplicap, 3M ESPE). Then, each cylindrical resin stub (diameter 3.6 mm × 2 mm) underwent a shear adhesive (bond) strength test and surface roughness evaluation. SEM evaluation and EDX analysis were used to observe surface properties of both zirconia and titanium samples. Results were statistically analyzed using analysis of variance (ANOVA) and Turkey test ($\alpha = 0.05$).

Results: Surface roughness showed a significant difference amongst the different distances and angles for both the zirconia and titanium materials and these changes in surface roughness were evident in the SEM imaging photos. As for the adhesive strength, there was a significant difference in the adhesive strength for the titanium and zirconia with different angles. In general, 75° gives the best results although this is not significantly different from 90°. However, no significant difference was observed in changes of sandblasting distance for both materials. EDX analysis at the surface revealed elements carbon, oxygen, silicon, aluminum, and zirconia on the surface.

Conclusions: Sandblasting at various distance and angles contributes differences in surface roughness when it comes to both zirconia and titanium materials. Despite both 75° or 90° sandblasting angle could yield a sufficiently high adhesive strength for resin to titanium or zirconia bonding, sandblasting at 75° seems to be optimal to increase the adhesive strength.

1. Introduction

Titanium and also in a growingly extent zirconia are the two most commonly preferred materials for dental subgingival implants. These materials fulfill the safety and biomechanical standards that have been used and suggested by researchers and dentists to be the most ideal for dental implants and other indirect dental restorations [1,2]. Both these materials have superior strength that can endure the everyday occlusal forces that teeth may undergo and they also have excellent biocompatibility without any adverse side effects [3].

Zirconia is one of the most commonly studied current ceramic in dentistry. Its ability to take different forms at different temperatures makes the material very special and unique to other materials. The most desired characteristic of zirconia is its translucent color and esthetic appeal [4]. Furthermore, the high biocompatibility and osseointegration ability enrich the usage of zirconia [5]. In fact, researchers have found that zirconia possesses similar mechanical properties to stainless steel. Some other applications for zirconia in dentistry include implant screws, abutments, bridges and crowns [6].

Titanium, on the other hand, has been the material of choice used for dental implants within the past several decades. Although titanium and its alloys are known for their biocompatibility, low

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density, and strength, their greatest characteristic is ability to osseointegrate with living bone and other tissues. Thus, titanium in dentistry is ideal for some applications with high biocompatibility and strength [2].

One of the major applications for sandblasting in dentistry, in addition to cleanse surfaces, is to increase the surface roughness. Surface roughness focuses on the topography of a surface [7]. Even with a naked eye, a surface can appear to be smooth, however with a surface roughness tester at a microlevel, we can see that a smooth surface is in fact, not really smooth. It is not surprising that with a rougher surface area, sandblasting dramatically increases the surface area.

With this is mind, sandblasting a surface can help increase surface area and result in increased micromechanical adhesion by interlocking [8]. For titanium implants, researchers have suggested that an increased surface area can result in an increase of osseointegration [9]. As for sandblasting on zirconia surfaces, researchers have argued that by sandblasting at a close distance, the mechanical properties of zirconia in fact, decrease, as it can initiate micro cracks throughout its process [3]. Under examination of a scanning electron microscope (SEM), the roughness of a surface is evident and in fact, alters the material's mechanical properties [10]. Indeed, besides sandblasting, many attempts has been done on altering the zirconia surface to improve the resin–zirconia bonding, such as laser [1], hydrofluoric acid etching [11,12], selective infiltration etching (SIE) [13,14], glazing [11], as well as chemical modification using *e.g.* silanes [15], phosphates [16] and zirconate [17]. All of these surface treatment methods seemed to give quite good results, but controversial arguments exist [18] due to non-standardized test method and the environmental difference between laboratories. Therefore, even for the most common sandblasting method, despite the theories of the optimal sandblasting distances and angles exist, there is no clear standard to ensure that the optimum bond strength is applied in particular to zirconia and titanium materials.

The adhesive strength of an interface between two materials is one of the most important characteristics it can hold. Without it, the material bonding will have no future, especially in the challenging oral conditions. In dentistry, the strength of adhesion could be evaluated in laboratory under shear or tensile modes [19]. In particular, shear mode focuses on the stress of layers of atoms or molecules displacing from one layer to the next, and tensile mode differs from shear in a way that tensile stress varies depending on the given load [20]. The shear adhesive strength (previously so-called as 'shear bond strength') measured between the resin cement and either zirconia or titanium material has been well studied and reported [19]. Therefore, studying the shear adhesive strength on zirconia and titanium with resins could be regarded as a generalized method, whereas the effects of different geometric factors of sandblasting can be evaluated.

The purpose of this laboratory study was to evaluate the effects of geometric factors, *i.e.* the distance and angles of sandblasting to find out the optimal adhesion between zirconia and titanium materials with resin cement using as an adhesion promoter, a silane coupling agent [7]. The objectives included testing whether or not there was a significant difference on the surface roughness of sandblasted titanium and sandblasted zirconia, whether or not there is a significant difference on the shear adhesive strength at different angled sandblasting, and lastly, whether or not there is a significant difference on the shear adhesive strength at different distances of sandblasting. The hypotheses were: (1) there is a significant difference in the surface roughness on either zirconia or titanium, when comparing before and after sandblasting, (2) the optimum angle for sandblasting for both materials would be 90° and a distance of 10 mm, and (3) shear adhesive strength will increase as the surface roughness of the material increases.

2. Materials and methods

2.1. Preparation of zirconia and titanium specimens

Five blocks of zirconia with the approximate size of 25 mm × 44 mm × 6 mm were obtained from Aidite (Qinhuangdao Aidite High-Technical Ceramics, China). Each block was cut into seven equal planar slices and each block was cut in half again. These blocks were then eventually cut into pieces with a height of 6.0 mm and a length and width of 13.0 mm × 16.1 mm with the use of precision saw (Micro Slice machine, Cambridge, UK). After preparing the zirconia specimens into individual slices, each sample was individually wet-polished on the manual polisher (Lunn Major, Struers, Denmark) using a series of silicon carbide abrasive paper. Each piece was polished on the 500-grit abrasive paper under running water for 30 s, followed by the 1000-grit abrasive paper for additional 30 s. Following polishing the zirconia samples was sintered at the temperature of 1500 °C. After sintering zirconia the specimen sizes shrunk approximately 57.1% in volume. For titanium, pre-cut planar specimens of 150 mm × 30 mm × 1 mm were obtained.

2.2. Sandblasting treatment

A sandblasting machine (Shofu Pen-Blaster™, Shofu Dental MFC, Kyoto, Japan) with a silica-coated alumina powder, with a particle size of 110 µm (Rocatec™ Pre, 3M ESPE, St. Paul, MN, USA) were used. The sandblasting pen (*i.e.* wand) with the tip nozzle size 3 mm was used in rotational movements, and the operational pressure was constant (3.5 bar) for 15 s for a 1.0 cm^2 substrate area. These settings were used throughout the study. A custom-made device was used in order to ensure the consistency of distance and angle change. The design of the device is shown in Fig. 1. This device allowed for the sandblasting pen to hold in place at the desired angles (45°, 60°, 75°, and 90°). In addition, custom-made spacing blocks with different height were used in order to measure the desirable specimen distances (5.0 mm, 10.0 mm and 15.0 mm) from the sand-blasting pen.

Following sand-blasting, each specimen was washed and rinsed with 70% ethanol (BDH Reagents & Chemicals, Poole, UK), then rinsed with deionized water (Milli-Q, Millipore, MA, USA), and left to dry at room temperature overnight. Once the specimens were

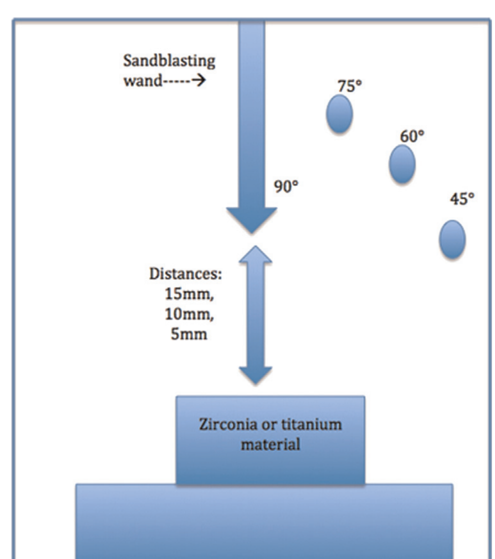

Fig. 1. Design of the device created to emulate the different sandblasting angles and distance.