The Effect of Different Combinations of Surface Treatments and Bonding Agents on the Shear Bond Strength Between Titanium Alloy and Lithium Disilicate Glass-Ceramic

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In order to obtain a more-natural esthetic prosthesis, the use of hybrid abutments is becoming widespread in implant dentistry. The aim of this in vitro study was to assess the effects of different surface treatments, as well as the effects of different combinations of surface treatments and cementation protocols, on the shear bond strength between titanium alloy disks and lithium disilicate glass-ceramics. Forty titanium-alloy disks (4 × 6.6 mm) were fabricated using computer-aided designed/computer-assisted manufacturing, and an identical number of lithium disilicate glass-ceramic disks of similar sizes were fabricated by a heat-pressing technique to be attached to the titanium disks. The specimens from each material group were divided into two groups (n = 20 each) according to the surface treatment type: alumina airborne-particle abrasion or etching with hydrofluoric acid. Each group was then divided into two subgroups (n = 10) depending on the resin-cement type: Multilink Hybrid Abutment Cement (Ivoclar Vivadent) or PANAVIA SA Cement Plus (Kuraray). After thermocycling (5,000 cycles), a shear bond strength (SBS) test was conducted using a universal testing machine. Statistical analysis was performed by analysis of one-way analysis of variance and unpaired tests (P < .05). Statistically, the highest SBS values were obtained using airborne-particle abrasion. The surface treatment of titanium alloys by sandblasting led to a higher SBS compared to etching with hydrofluoric acid. The cement type also had a significant influence on SBS results. Int J Periodontics Restorative Dent 2020;40:271–276. doi: 10.11607/prd.3893

The goal of implant dentistry is not only to place implants but also to restore the functions and esthetics lost by the patient. Therefore, when a clinician aims to provide function and esthetics via implants, the question of which materials to use for the abutment and crown becomes important.1

Generally, titanium-6aluminum-4vanadium alloys (Ti6Al4V) are used in both temporary and permanent implant abutments because of their physical and mechanical properties, biocompatibility, relatively low cost, and suitability for computer-aided design/computer-assisted manufacturing (CAD/CAM).2,3 However, the gray reflection of titanium alloys, especially in the submucosal region, causes esthetic issues.4,5

Therefore, zirconia abutments have been developed to achieve improved peri-implant tissue esthetics, especially in the esthetic zone.6 Zirconium abutments may consist of a single piece or two parts with a titanium platform.7,8

Lithium disilicate glass-ceramics can be used as esthetic abutments when applied on titanium platforms, such as zirconia, and they can be used as hybrid abutments in two different ways. In the first approach, the hybrid abutment is cemented on a titanium base, after which an all-ceramic crown is produced and applied. In the second approach, a
hybrid abutment-crown unit is produced in one piece and bonded to the titanium base. Later, this assembly is screwed to the implant.\\(^{3,9,10}\)

Such hybrid abutments require cementation to bond the Ti-base material to the ceramic component. Therefore, the bonding between the two materials becomes a crucial factor in determining the durability of definitive prostheses. Different surface treatments, such as airborne-particle abrasion\(^{11}\) and etching with hydrofluoric acid (HF),\(^{12}\) can be implemented on the Ti surface to improve surface bond strength. A standard cementation protocol is needed to ensure maximum bond strength between the two materials in order to increase the probability of successful and permanent prosthetic restorations.\(^{13}\)

The aim of this in vitro study is to assess the shear bond strength (SBS) between lithium disilicate ceramics and titanium CAD/CAM disks using two different surface treatments in combination with two types of cements. The hypotheses of this study were that the SBS at the titanium alloy–lithium disilicate ceramic interface is neither affected by (1) different surface treatments nor (2) different combinations of surface treatments and cementation procedures.

### Materials and Methods

In this study, 40 titanium-alloy disks (Ti6Al4V; Eisenbacher Dentalwaren ED) were fabricated by a CAD/CAM process, and an identical number of lithium disilicate glass-ceramic disks (IPS e.max Press, Ivoclar Vivadent) of similar sizes were fabricated by a heat-pressing technique to be attached to the titanium disks. The titanium disks were 4 mm thick with a diameter of 6.6 mm.

Titanium alloy samples were divided into two groups according to the surface treatment to be applied after production (n = 20 per group). Sandblasting was performed with 50-μm alumina at a pressure of 0.4 MPa for 10 seconds at a working distance of 20 mm according to the manufacturer’s instructions on the first group. Etching was conducted with 9.5% HF (Porcelain Etchant, Bisco) for 90 seconds on the second group. On the basis of the applied resin cement, the two groups were further divided into two subgroups (n = 10 per subgroup).

Two types of cements were used: Multilink Hybrid Abutment cement (Ivoclar Vivadent) and PANAVIA SA cement (Automix PANAVIA SA Cement Plus, Kuraray). To standardize the cementation procedure, a special epoxy glass device with a hole (6.7 × 7.0 mm) was designed to place the cemented disks in the correct position. A total of 4 groups were evaluated, with each group consisting of 10 samples. The test groups are listed in Table 1.

Meanwhile, all lithium disilicate glass-ceramic disks were subjected to chemical etching with 4.5% HF (IPS Ceramic Etching Gel, Ivoclar Vivadent) for 20 seconds and rinsed for 90 seconds, then air dried according to the manufacturer’s instructions. A silane (Bis-Silane, Bisco) coupling agent was applied on the bonding surface and allowed to react for 30 seconds, after which it was air dried for 5 seconds.

The bonding surfaces of half of the titanium disks and lithium disilicate glass-ceramics were cemented with an auto-polymerizing resin cement, Multilink Hybrid Abutment Cement (Group 1: airborne-particle abrasion and Multilink cement; Group 3: HF etching and Multilink cement). A mixing syringe was used to directly apply a thin layer of the cement onto the titanium and lithium disilicate bonding surfaces; subsequently, the specimens were positioned together in the hole of the device by applying light pressure with fingers for 10 seconds. Excess cement was gently removed with a microbrush, and a load of 5 kg was applied during auto-polymerization for 10 minutes at room temperature.

The bonding surfaces of the remaining titanium disks and lithium disilicate glass-ceramics were cemented with a thin layer of PANAVIA SA cement (Group 2: airborne-particle abrasion and PANAVIA cement; Group 4: HF etching and PANAVIA cement). A mixing syringe was used to directly apply the cement onto clean bonding surfaces, after which the specimens were lightly pressed together and held in the hole of the device. They were then light cured for 5 seconds using a blue LED light-curing unit while applying light pressure with fingers for 10 seconds. Excess cement was gently removed with a microbrush, and a load of 5 kg was applied during photopolymerization for 10 seconds per side. The cemented samples were removed from the
device and light-cured once again for about 10 seconds.

All cemented samples were stored in distilled water at 37°C for 24 hours before thermal cycling at water temperatures ranging from 5°C to 55°C for 5,000 cycles. The dwell time was 15 seconds, and the transfer time from one bath to another was 10 seconds. Then, the samples were embedded in blocks of a chemically cured acrylic resin (Self Cure, Imicryl) using a specially designed steel mold (12-mm depth × 20-mm diameter) to facilitate clamping on a universal testing machine.

SBS testing of all groups was carried out on a universal testing machine (model 3345, Instron) at a crosshead speed of 1 mm/minute (Fig 1). The shear debonding forces were registered in Newtons (N). The failure loads (N) were divided by the bonding areas (mm²), after which the shear debonding forces were converted into MPa.

Statistical calculations were performed with Number Cruncher Statistical System statistical software (2007) for Windows. Apart from the standard descriptive statistical calculations (mean and standard deviation [SD]), the four groups were compared using one-way analysis of variance (ANOVA). Unpaired t test was performed to compare the differences in shear bond strength between the two surface-treatment groups. Statistical significance was established at P < .05.

Results

The mean SBS value (MPa) of Group 1 was found to be 15.91 ± 3.23, while those of Group 2, Group 3, and Group 4 were 13.48 ± 1.65, 5.35 ± 1.12, and 3.89 ± 0.59, respectively. The values are shown in Table 2.

There was a significant difference between the two types of surface treatment with the same cement type (P = .0001). The SBS values were higher in the airborne particle–abraded groups than in the HF-etched groups. When airborne-particle abrasion was used as the surface-treatment procedure, there was a significant difference between the two cement types (P = .002), and for HF-etched samples, there was a
significant difference between the two cement types \((P = .048)\) (Fig 2).

**Discussion**

In the dental implant industry, longevity and esthetic acceptability are important clinical objectives. Since ceramic implant abutments were introduced in the 1990s, many researchers have attempted to replace metals with ceramics and evaluate their long-term performance, including success and possible complications, with respect to the patients’ demands for esthetics and availability of new materials.  

The hypotheses of this study were that the SBS at the titanium alloy–lithium disilicate ceramic interface is neither affected by (1) different surface treatments nor (2) different combinations of surface treatments and cementation procedures. The results of the present study indicated that airborne-particle abrasion yielded higher bond strengths than etching with 9.5% HF for 90 seconds, irrespective of the cementation procedure. The first hypothesis was rejected. The two resin-cement systems used were significantly different from one another when subjected to either airborne-particle abrasion or etching with 9.5% HF. The second hypothesis was also rejected.

The bonding between titanium alloys and resin materials can be improved by different surface-modification treatments, including airborne-particle abrasion, silica coating, chemical etching, electrolytic etching, plasma exposure, and primer application. Airborne-particle abrasion is the most commonly used method for micromechanical retention. It can be applied alone or in combination with HF or different methods. Some studies suggest that acid etching is facile and increases the bond strength significantly, while some other studies report that the enhancement is not significant. In the present study, the authors used two types of surface treatments and found that the SBSs were higher in the airborne particle–abraded groups.

Hybrid abutments can exhibit high strengths due to internal metallic connections with the implant; further, they display a natural appearance near the root and a transition area to the crown, which is especially important for anterior implant treatments. The use of lithium disilicate glass-ceramics in combination with titanium alloys to form hybrid abutments and restorations for implants is likely to increase, primarily to improve the esthetics of implant restoration. Apart from esthetic considerations, lithium
disilicate ceramic–titanium alloy disks should exhibit a high strength at the interface when used as inserts in implants. The bond between these two materials determines the long-term performance of the insert; it is mainly dependent on the type of cement and the surface treatment procedure. In this context, there are many reports available on the clinical use of such hybrid abutments. Elsayed et al stated that lithium disilicate hybrid abutments exhibit a high fracture resistance and their bending behavior is similar to that of zirconia abutments.

In several studies, thermal cycling was used to simulate clinical conditions. Mair and Padipatvuthikul reported that the oral temperature ranges from −4°C to 0°C when eating cold foods, such as ice cream, to 60°C to 65°C when eating hot foods, such as a hot cheese sandwich. Testing the samples by thermocycling expedites the diffusion of water, and the change in temperature produces stress at the interface of the two materials because of their different coefficients of thermal expansion. The ISO TR 11450 standard (2003) recommends a short regimen of thermocycling (500 cycles). In some previous studies, it was calculated that 6,000 thermal cycles are equal to 5 years of clinical use. Therefore, the 5,000 cycles used in the present study are equal to about 4 years of clinical function. Still, there are other methods of aging, such as thermocycling, water storage, and mechanical fatigue, which were compared by Celik et al. On the basis of the available literature, the present authors used thermocycling as the method of aging for this study.

It can be seen from the obtained results that Group 1 exhibited the highest SBS (mean ± SD: 15.91 ± 3.23 MPa), while Group 4 exhibited the lowest SBS (3.89 ± 0.59 MPa). The mean SBS value of Group 1 (15.91 MPa) was compared with that reported in a previous study (53.0 MPa). The difference in the results can be ascribed to the additional procedures carried out in the referenced study; a Monobond Plus (Ivoclar Vivadent) universal primer was used, which may have led to the high bond strength.

A limitation of this in vitro study lies in the low number of specimens tested; further, disk-shaped specimens were used instead of complete dental restorations. The medium used to perform thermal and mechanical cycling tests was distilled water instead of the saliva in the oral cavity, which has different chemical properties compared to water; the bond strength between titanium alloys and lithium disilicate glass-ceramics is sensitive to chemical and mechanical influences in intraoral conditions. Another limitation is that no chewing simulator was used to simulate dynamic forces in the oral environment. Even though thermocycling was adopted as the aging process, it cannot simulate ideal oral cavity conditions. Therefore, the authors are of the opinion that this study can be improved by using a larger number of samples and metal-alloy primers with different types of resin cements.

Conclusions

Within the limitations of this study, the following conclusions can be drawn.

Surface treatment of titanium alloys has a significant influence on the SBS of the titanium alloy–lithium disilicate glass-ceramic interface.

The cement type also has a significant influence on the SBS.

Regardless of the cement used, airborne-particle abrasion is more effective than HF etching in improving the bond strength of titanium alloy–lithium disilicate glass-ceramic interfaces.

Therefore, the null hypothesis of this study, which states that different surface treatments do not affect the SBS of the titanium alloy–lithium disilicate ceramic interface, was rejected; the second hypothesis, which stated that different combinations of surface treatments and cementation procedures do not affect the SBS, was also rejected.

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References


