Effect of bonder application methods on titanium-ceramic bonding

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Introduction

Nowadays, metal ceramic restorations are usually fabricated with cast or machined titanium framework, because of its good biocompatibility and mechanical properties. With the development of casting and CAD/CAM techniques, a growing tendency involving the use of titanium as a biocompatible alternative to dental alloys has increased [2, 3, 8].

Coating agents have been used in conventional metal-ceramic systems to serve two purposes: promotion of adhesion and masking of the metal surface to prevent discoloration of opaque porcelain [9]. In the titanium-ceramic system, gold-containing materials and ceramic materials have been applied in order to improve the bond strength [1, 4]. Bonder has an important influence on the formation of reaction layers as ceramics are fused to titanium at firing temperatures. It should be applied a thin layer on the titanium surface to optimize titanium-ceramic bonding. In general, manufacturers recommend the application of bonder with a glass instrument or a brush.

Aim of the Study

The purpose of this study is to evaluate the influence of two different application methods of bonder on the bond strength.

Materials and Methods

Titanium strips were cut from a 0.5 mm-thick grade 2 cp titanium sheet (ChemPur). Prior to ceramic application, the surfaces to be veneered were sandblasted with 125 µm aluminium oxide (Al_2O_3), at a pressure of 2 bar and cleaned under steam according to the instruction. Two ceramics (Initial Ti, GC Europe and Triceram, Dentaurum, Germany), including bonder, were fused over a length of (8 ± 0.1) mm in the of each titanium strip. [Fig. 1] Each bonder was with two different methods: extreme thin layered with a fine brush and conventionally layered with a glass instrument. [Fig. 2]

Fig. 1: Bonder (left: Initial Ti, GC Europe; right: Triceram, Dentaurum, Germany).

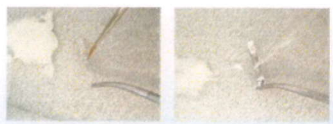

Fig. 2: Bonder application; a fine brush (left) and a glass instrument (right).

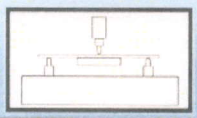

Fig. 3: Schematic illustration of the three-point crack initiation test. [8]

After the second opaque firing, dentin ceramic was build up and fired in a rectangular shape until a total ceramic dimension of (8 ± 0.1) × 3 × (1.1 ± 0.1) mm was achieved. Three-point crack initiation test according to ISO 9693 was performed to examine the bond strength. [Fig. 3] Ten specimens of each group were tested. (n=10) Results were analyzed using *t*-tests ($p<0.05$).

Results

The bond strength (standard deviation) of Triceram was respectively similar for both groups: 29.5 MPa (2.8 MPa) with a fine brush and 30.5 MPa (1.2 MPa) with a glass instrument. The t-test showed no significant difference between the means of the bond strength ($p>0.05$). However, the bond strengths of Initial Ti varied considerably between the two groups: 36.7 MPa (4.5 MPa) with a fine brush and 59.5 MPa (3.5 MPa) with a glass instrument. A t-test showed significant differences between both groups at a 95% confidence level ($p<0.05$). [Fig. 5] The results with both methods showed significantly higher bond strengths with Initial Ti than with Triceram ($p<0.05$). Visual inspection of the tested titanium surfaces appered differently. Triceram debonded completely with little remnants at the both ends of ceramic, which indicated the adhesive mode of bond failure mainly. [Fig. 6] On the other hands, Initial Ti left more residual ceramic on the titanium, which indicated a combination of cohesive and adhesive bond failure. [Fig. 7]

Fig. 4: Three-point crack initiation test; before (left) and after loading (right).

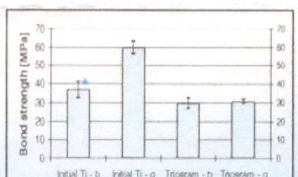

Fig. 5: Bond strengths between titanium and ceramics (b:fine brush, g:glass instrument).

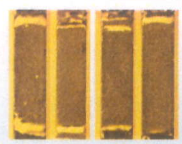

Fig. 6: Titanium surfaces after debonding of Triceram with a brush (left) and a glass instrument(right).

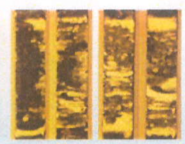

Fig. 7: Titanium surfaces after debonding of Initial Ti with a brush (left) and a glass instrument(right).

Discussion

The bond strength data obtained in this study exceeded the lower limit of 25 MPa stipulated in the ISO 9693 [5]. However, the group of Initial Ti with a glass instrument showed a relative high bond strength value (59.5MPa), when compared to ceramics fused to conventional dental alloys [6, 10].

For an optimal titanium-ceramic bond, some affecting factors should be considered, such as (1) growth of an oxide layer on titanium at high temperatures, (2) adherence of the self-formed oxide to the titanium substrate, (3) bonding by fusion of the self-formed oxide with the porcelain, and (4) stress generated during cooling from thermal contraction mismatch [11]. In the titanium-ceramic system, gold-containing materials and ceramic materials have been applied in order to improve bond strength [1, 4]. Gilbert et al. [4] described that titanium particles in the bonding agent might play as scavengers, resulting in protecting the titanium surface from excessive oxidation. Proper coating agents can reduce residual stresses of the titanium-ceramic system as a result of plastic deformation. Moreover they have an important influence on the formation of reaction layers as ceramics are fused to titanium at firing temperatures [7]. Reactivity in the titanium-ceramic interface is essential for chemical bonding, whereas brittle reaction products at the firing temperatures may be harmful to the mechanical compatibility. This is a primary problem to be solved, when dental ceramic is fused to titanium. Therefore, better comprehension of the chemical and physical characteristics of titanium-ceramic interface influenced by bonder is necessary to understand the titanium-ceramic bond.

Conclusion

TextIn Initial Ti the bonder application methods significantly influenced the bond strength values. In this case a glass instrument promoted optimal thickness of the bonder to enhance the titanium-ceramic binding.

There are also significant differences in bond strength between the both ceramics.

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