Bond strength between cast/machined titanium and ceramics

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Introduction

In recent years, titanium has become a material of great attention in dentistry. 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 [4]. Therefore, today metal ceramic restorations are usually fabricated with cast or machined titanium framework.

The mechanical properties of the cast titanium are different from those of the machined one. The oxide-rich layer (α-case layer) of cast titanium negatively influences the chemical and thermal adherence of ceramics [8]. In order to remove the α-case layer, the surfaces of the cast framework should be finished, what may influence the titanium-ceramic bonding. Thus, although commercial titanium-ceramic systems are available today, they still have unsolved problems related to the fusing of dental ceramics to titanium.

Aim of the Study

The purpose of this study is to evaluate the influence of titanium fabrication methods on titanium-ceramic bond strength.

Materials and methods

Cast titanium (cp titanium grade 2) was prepared in 0.6 mm strips using a vacuum-pressure casting unit (SymbioCast®; Girrbach Dental GmbH, Germany). The surfaces of the cast strips were grinded to remove the α-case layer and to achieve the final dimension of 0.5 mm in thickness. Machined 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 and cleaned under steam according to the manufacturer's instruction. Two ceramics (Initial Ti, GC Europe and Triceram, Dentaurum, Germany), including bonder, were fused to each titanium group. [Fig. 1]

Fig. 1: Left: Initial Ti, GC Europe; Right: Triceram, Dentaurum, Germany.

Three-point crack initiation test according to ISO 9693 was performed to examine the bond strength. [Fig. 2] Ten specimens of each group were tested. (n=10) Results were analyzed using *t*-tests ($p<0.05$).

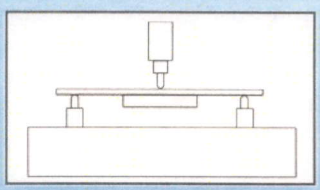

Fig. 2: Schematic illustration of the three-point crack initiation test. [8]

Results

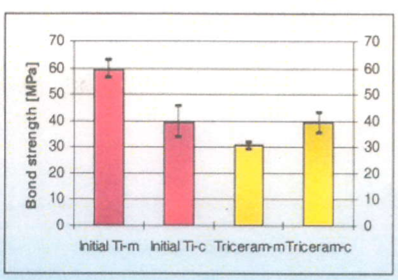

Fig. 3: Bond strength between cast/machined titanium and ceramics (m: machined, c: cast).

In the group with Initial Ti, the bond strengths (standard deviation) of machined titanium, 59.5 MPa (3.5 MPa), were significantly higher than those of cast titanium, 39.5 MPa (5.8 MPa) ($p<0.05$). On the other hand, the group with Triceram showed significantly higher bond strengths with cast titanium,

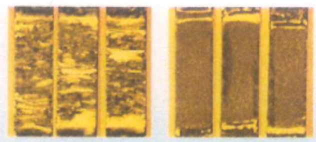

Fig. 4: Machined titanium surface after debonding of Initial Ti (left) and Triceram (right).

Visual inspection of the tested titanium surfaces appeared differently.Triceram on the machined titaium debonded completely with little remnants at the both ends of ceramic, which indicated the adhesive mode of bond failure mainly. On the other hands, Initial Ti on the machined titanium that showed the highest bond strength value, left more residual ceramic on the titanium, which indicated a combination of cohesive and adhesive bond failure.

Discussion

This study evaluated the bond strengths of two ceramics on cast/machined titanium plates using three-point crack initiation test according to ISO 9693. [Fig. 5] The bond strength data obtained in this study exceeded the lower limit of 25 MPa stipulated in the ISO 9693 [6]. However, among the four groups, the group with Initial Ti fused on machined titanium showed a relative high bond strength value (59.5MPa), when compared to ceramics fused to conventional dental alloys [7, 9]. The results indicate that there is significant difference in bond strength between cast and machined titanium groups, which contradicts the results of previous studies [1, 2, 3].

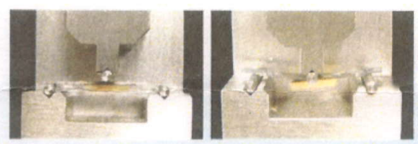

Fig. 5: Three-point crack initiation test; before (left) and after loading (right).

For an optimal titanium-ceramic bond, it is important to remove the α-case layer [8]. It has also been reported that no significant differences exist between cast and non-cast titanium specimens when the α-case layer is removed [1, 2, 3]. In this study, cast titanium plates were grinded to remove the α-case layer but machined titanium plates were prepared from a 0.5 mm thick industrial titanium sheet, what might influence the bond strength results.

The metal-ceramic bond strength, which derives from the residual stresses created in the metal-ceramic interface, depends upon the mechanical properties of both materials, e.g. the elastic modulus, thermal expansion/contraction coefficients, and high temperature behaviour, etc [8, 5]. Therefore, better comprehension of the mechanical characteristics of titanium influenced by surface treatment, such as grinding and sand blasting, is necessary to understand the titanium-ceramic bond.

Conclusion

The fabrication methods of titanium significantly influenced bond strength values. In the group with machined titanium, there are also significant differences in bond strength between the two ceramics. The matching of titanium-ceramic combinations seemed to be the principal factor for an optimal titanium-ceramic bond.

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