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Original Article

Tensile Bond Strength of Three Custom-made Tooth-Colored Implant Superstructures to Titanium Inserts

Mitra Zirak [1], Mahroo Vojdani [2], Amir Ali Reza Khaledi [2], Mitra Farzin [3]

[1] Postgraduate Student, Dept. of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.
[2] Dept. of Prosthodontics, Biomaterials Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.
[3] Dept. of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

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ABSTRACT

Statement of the Problem: Hybrid abutments are made of a titanium implant insert and a ceramic component. The tensile bond strength between the titanium implant insert and the ceramic component is not still clearly known.

Purpose: This *in vitro* study aimed to compare the tensile bond strength of the titanium insert to ceramic components made of milled lithium disilicate, milled zirconia, and pressable lithium disilicate.

Materials and Method: To standardize the shape and dimension of the ceramic components, a single computer-aided design/computer assisted manufacturing (CAD/CAM) superstructure was designed with Dental Designer software. Based on this model, CAD milled zirconia (Zr), CAD milled Lithium disilicate (CAD-LD) and heat-pressed lithium-disilicate (H-LD) superstructures were fabricated (n=10 per group). They were bonded to the titanium inserts by using self-adhesive resin cement. The prepared superstructure-titanium insert complexes (hybrid abutments) were screwed into the implants with 35 Ncm torque. The tensile bond strength of the ceramic superstructures to the titanium inserts were recorded by the universal testing machine with a crosshead speed of 2 mm/min. The data were analyzed by using one-way ANOVA and Tamhane post-hoc test ($p < 0.05$).

Results: The mean±SD of tensile bond strength was 328.50±30.4 N in CAD-LD, 257.30±23.8 N in H-LD, and 242.20±21.2 N in Zr groups. One-way ANOVA revealed the groups significantly different in terms of the tensile bond strength ($p < 0.001$). Tamhane post-hoc test showed a significant difference between the CAD-LD and the two other groups ($p<0.001$); however, no statistically significant difference was detected between the H-LD and Zr groups ($p= 0.39$).

Conclusion: It can be concluded that the CAD-LD has higher bond strength to titanium insert compared with the H-LD and Zr groups. Therefore, they might be clinically more beneficial in high-esthetic areas.

Corresponding Author: Khaledi AAR., Dept. of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran. Email: amiralireza_khaledi@yahoo.com Tel: +98-7136263193-4

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Introduction

Although metal abutments guarantee the dental implant strength over time, they may compromise the esthetics particularly when an implant crown is next to an all-ceramic restoration. This challenge arises from all-ceramic crown translucency and showing-up the underlying tooth structure, which gives them a more natural appearance. To cover up the dark color of metal abutment, the opacity of the ceramic restoration is increased, which consequently decreases the vitality

[1-3]. Sometimes the metal shows through, as a result of implant insertion with improper angle and depth, or because of the thinness of the surrounding soft tissue. In such cases, tooth-colored abutments are among the options of choice [4]. Besides that, the latest improvements in dentistry during the recent decades have increased the demand for metal-free implant abutments. These abutments such as zirconium oxide (Zr) or lithium disilicate (LD) provide a proper base for the overlying restoration, and therefore, allow the use of a more vital and translucent restoration [4]. In spite of the esthetic superiority of metal-free abutments, they are associated with two major concerns that need to be thoroughly reviewed before their overall substitution for titanium abutments. The first concern is the lack of a titanium-titanium interface in the implant body-abutment connection [4]. Stimmelmayr *et al.* and Klotz *et al.* [5-6] in two separate studies stated that the implant body wear at the implant-abutment interface was significantly higher in full-zirconia abutments compared with titanium abutments. This problem has been adequately addressed in hybrid abutment, which is made of two components; a titanium insert, which is screwed to the implant body and is in contact with the implant platform and abutment screw [7-10] and a superstructure, which is made of various tooth-colored materials such as lithium disilicate, zirconia, or resin-based composites [11]. The two components are extraorally assembled by either friction fit or bonding with resin- based cement [12-14]. Computer-aided design/ computer assisted manufacturing (CAD/CAM) or heat-pressing techniques are employed for superstructure construction [11]. The second concern with metal-free abutments is related to their functional load capacity [15-17]. Different studies reported high incidence of horizontal and vertical fracture during screw inserting or implant body function due to the thin zirconia walls of the abutment [18-21]. Hybrid abutments are mostly used in the maxillary anterior part because of the high esthetic demands. This area is subjected to detrimental horizontal occlusal loads, which are not directed along the long axis of the abutment. These loads predispose the abutment to tensile stresses, which tend to detach the superstructure from the titanium insert [22].

Although maximum load capacity, fatigue and fracture strength, reliability and failure mode of hybrid abutments were topics of interest in many studies [23-25]. To date, no research has investigated the tensile bond strength of CAD-milled zirconia (Zr), heat-pressed LD (H-LD), and CAD-milled LD (CAD-LD) superstructures to the titanium implant inserts. Therefore, this study was conducted to compare the tensile dislodging force needed to detach Zr, H-LD and CAD-LD superstructures from the titanium inserts in hybrid abutments. The null hypothesis was that no difference would be found in tensile bond strength of ceramic superstructures made of Zr, H-LD and CAD-LD to titanium inserts.

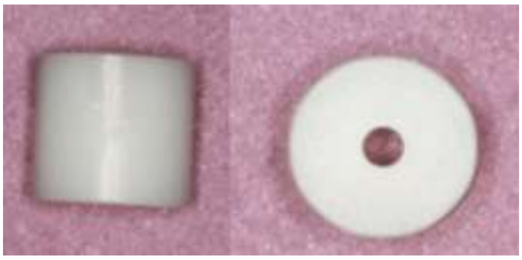

Figure 1: CAD/CAM Superstructure

Materials and Method

The present study replicated the method used in Gehrke *et al.'s* investigation [10] for fabrication of superstructures and evaluation of the tensile bond strength of titanium implant insert to ceramic superstructures. Accordingly, a single CAD/CAM ceramic superstructure was designed by using Dental Designer software (3Shape’s CAD Design software; 3Shape, Denmark). This allowed for standardization and identical superstructure shape and dimension (outer diameter: 11.7mm; inner diameter: 3.42mm and height: 10.3mm) in all tested groups.

Ceramic superstructures for the first group (Zr) and the second group (CAD-LD) were fabricated by CAD milling of zirconia blanks (IPS e.max ZirCAD; Ivoclar Vivadent, Germany) and milling of LD blocks (IPS e.max CAD; Ivoclar Vivadent, Germany) respectively (Figure 1).

For the third group (H-LD), pressable lithium disilicate (IPS e.max Press; Ivoclar Vivadent, Germany) was used for fabricating the superstructures. For this purpose, wax patterns were prepared by using wax pattern 3D printer (Solidscape D76+; Solidscape, USA)

Figure 2: Heat-pressed Lithium-disilicate

according to the shape and dimensions previously designed by CAD software. The wax patterns were sprued, invested, burned out, and ultimately lithium disilicate was pressed into the burned-out mold (Figure 2).

The implants (Anyone; regular thread; 4*10mm; Megagen, South Korea) were embedded in autopolymerizing acrylic resin (Crown & Bridge Resin; Dentsply International Inc. USA) based on ISO standard 14801 [26]. The bonding surface of insert (ZrGEN; Anyone; Megagen, South Korea) was particle abraded by using 50-µm aluminum oxide at 10-mm distance for 10 second (0.4 MPa) (Figure 3).

Figure 3: Titanium insert

Figure 4: Superstructure cemented to titanium insert

Figure 5: Hybrid abutment screwed to implant body

In CAD-LD and H-LD groups, 5% hydrofluoric acid gel (IPS Ceramic Etching Gel; Ivoclar Vivadent, Germany) was applied on the inner surface of the superstructures for 20 seconds, rinsed, and air dried for 10 seconds. Then, the inner surface of both LD groups was covered with ceramic primer (Rely X; 3M ESPE, USA) and left to dry. The zirconia group did not undergo acid treatment, but it was subjected to airborne-particle abrasion with 30-µm silica-coated aluminum oxide (Rocatec Soft; 3M ESPE, USA). A light-cure flexible provisional material (Telio CS Inlay; Ivoclar Vivadent, Germany) was injected into the titanium sleeve on the insert and light polymerized to prevent penetration of cement into the sleeve when the superstructure was cemented.

The abutments were then light polymerized for 20 seconds .A total of 30 custom-made superstructures (n=10 per each group) were screwed to the implants at 35 Ncm torque (Figure 5).

Finally, the abutments were bonded to titanium inserts by using dual-cure self-adhesive resin cement (RelyX$^{\text{TM}}$ U200; 3M ESPE, USA) (Figure 4).

The tensile bond strength was measured by using a calibrated universal testing machine (Zwick-Roell 2020; Zwick, Germany). The implants embedded in autopolymerizing resin block and hybrid superstructure were grasped by the lower and upper parts of the machine respectively. The force was applied at a crosshead speed of 2 mm/min. The maximum tensile force leading to detachment of the two components of hybrid abutment from each other was recorded in Newton. The mean values and standard deviations (±SD) were calculated for each group.

The data were fed into SPSS software, version 18.0 (SPSS Inc.; Chicago, IL, USA) for statistical ana-

Table 1: The mean, standard deviation, minimum and maximum of tensile bond strength of the ceramic superstructure to the titanium insert

Group	Number	Mean(N)	SD	Min(N)	Max(N)
CAD-LD	10	328.5^a	±30.42	297	372
H-LD	10	257.3^b	±23.87	220	284
ZR	10	242.2^b	±21.22	220	280

CAD-LD, CAD milled Lithium-disilicate; H-LD, heat-pressed lithium- disilicate; ZR, CAD milled zirconia; SD, Standard deviation

lyses. One-way ANOVA and Tamhane post-hoc test were used to compare the tensile bond strength of the three study groups. In this study, $p< 0.05$ was considered to be statistically significant.

Results

The mean±SD tensile bond strength needed to detach the ceramic superstructure from the titanium insert was 328.50±30.4 N in CAD-LD, 257.30 ±23.8 N in H-LD, and 242.20±21.2 N in Zr group (Table 1). One-way ANOVA test revealed a significant difference among the groups regarding the mean tensile bond strength ($p< 0.001$). According to the results of Tamhane post-hoc test, the tensile bond strength of CAD-LD group was significantly higher compared to the two other groups ($p< 0.001$) and the difference between H-LD and Zr groups was not statistically significant ($p= 0.39$).

Discussion

This study investigated the tensile bond strength of titanium implant insert to three different types of tooth-colored custom-made superstructures used for hybrid abutment construction. The results of the present study revealed a significant difference in the tensile bond strength of different tested ceramic superstructures to titanium insert. Therefore, the null hypothesis of the study was rejected. The highest tensile bond strength was observed in CAD-LD group, followed by H-LD and Zr group, respectively. However, the difference between the H-LD and Zr groups was not statistically significant.

If the popular trend is to use tooth-colored abutments for esthetic reasons, there are two options to fulfill this purpose; one is the prefabricated one-piece tooth-colored abutments, and the other is the custom-made two-piece (hybrid) abutments. The hybrid abutments are known to be superior to one-piece abutments due to their shape and contour, which is custom-designed for providing ideal esthetic and function, the gingival margin for definitive crown, which can be away from the implant and even placed supragingivally, and consequently decrease the risk of peri-implantitis due to excess cement [3, 27]. In addition, the metal-metal connection of abutment-implant in the hybrid abutments provides a more wear-resistant interface, which enhances the system reliability [5-6]. Unlike the prefabricated one-piece zirconia abutments, the hybrid abutment allows selection of various materials such as zirconia, lithium-disilicate, and resin composite [11]. Furthermore, the lithium-disilicate can be dentin-shaded and, therefore, offer an esthetic advantage compared with the bright white zirconia [3]. Several studies reported that the fracture strength and maximum load capacity of two-piece zirconia abutments were significantly higher than that of the one-piece systems [7, 23, 25]. It was also reported that screw failure in hybrid abutment was similar to that in titanium abutments; thus, they can be used in high-load areas [23, 25]. Guilherme *et al.* [11] evaluated the reliability of zirconia and lithium disilicate hybrid abutments under compressive loading. They found that zirconia group had significantly higher reliability under static and cyclic loadings. However, the results of the present study showed that the interface of zirconia abutments to titanium cores was not as reliable as lithium disilicate abutments. The more reliable tensile bond strength for the two LD groups could be related to proper etching/adhesive capacity of lithium disilicate restorations. Compared with zirconia, it is noticeable that the adhesive cementation of lithium disilicate glass ceramic onto the titanium base reinforces the restoration [28]. The silica content and inherent micromechanical interlocking structure allows favorable adhesive cementation of lithium disilicate restorations. Since the superficial glass content can be removed through etching, investigations demonstrated that glass- ceramics could withstand tensile forces without cement failure even in non-retentive forms [29].

The current study found the bond strength of CAD-LD to be significantly higher than H-LD and Zr abutments. Dimensional changes of the wax patterns, investment process, and pressing procedure could be the sources of error [30-31]. Fabrication technique and machinability would affect the quality of lithium disilicate glass ceramics [32]. In our study, wax fabrication for H-LD group was performed by using wax pattern 3D printer. Two different studies showed that the copings fabricated by wax pattern 3D printer technology had higher marginal and internal misfit compared with copings resulted by conventional wax-up techniques [33-34]. Despite the manufacturer's claim regarding the smooth curvature printing technology of the system, which could provide superior restoration fit, the minimum build layer thickness in Z-axis was 25.4 µm that might adversely affect the fit of final product [33]. Concerning the limitations, this investigation did not define the effect of other resins/adhesive systems, nor did it evaluate the bond strength of titanium base to tooth-colored abutment after thermomechanical cycling; therefore, further clinical studies are suggested. It is also recommended to assess the bond strength of titanium inserts to heat-pressed lithium-disilicate fabricated by using handmade wax-up techniques.

Conclusion

Within the limitations of this *in-vitro* study, it can be concluded that CAD-LD has significantly higher bond strength to titanium implant insert compared with H-LD and Zr superstructure. Therefore, the CAD-milled lithium-disilicate can be a favorable tooth-colored abutment in high esthetic areas. However, all CAD-LD, H-LD, and Zr superstructures bonded to titanium implant inserts have the potential to act reliable when subjected to tensile forces.

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Conflict of Interest

None declared.

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