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Shear Bond Strength of Dental Cements on Titanium Alloy: Use of Different Restorative Materials

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Abstract

Different dental cements and restorative materials may have various impacts on the shear bond strength (SBS) to titanium alloy of dental implants, and some fluoride-containing cements may destroy the oxide layer of Ti alloys. The aim of this study was to evaluate the retention and SBS of different dental cements to titanium alloy using different restorative materials and also the corrosive effect of dental cements on titanium alloy. In this in-vitro study, a total of ninety titanium alloy discs (10×3 mm) and restorative material discs (7×3mm) consisting of Co-Cr soft metal, zirconia, and Ni-Cr were constructed. Three dental cement of 2 different compositional classes, glass ionomer (GI) and zinc phosphate (ZP), were used to cement the discs (n=10 in each paired disks). SBS was evaluated using a universal testing machine with a cross-head speed of 1mm/min. A stereomicroscope (×32) and a scanning electron microscope were used to determine the fracture pattern and titanium corrosion, respectively. Data were then analyzed statistically using one-way ANOVA and Tamhane comparison test ($P<0.05$). The mean SBS of studied groups ranged from 0.12±0.07 to 6.2±0.97 Mpa, with the Ni-Cr and zirconia were demonstrated as the materials with the highest and lowest SBS to GI and ZP, respectively. The cements created a strong bond to the Co-Cr soft metal while the GI cement remained on restorative material disc surfaces in all samples, except in the zirconia sample. Mixed patterns were mostly seen in ZP cement groups. To conclude, applying fluoride-containing cements have no effect on titanium.

Keywords: Bond strength, corrosion, lutting cement, titanium alloy

Introduction

Three types of retention have been determined for fixed implant supported restorations: cement retention, screw retention, and combination of both.[1] Cemented restorations have some advantages such as elimination of screw loosening of prothesis, more esthetics, high fracture resistance of veneering porcelain, simplicity and passive fit.[1] Temporary cements which are usually used for implant supported restorations have poor physical properties and sometimes we have to use permanent cements like Glass Ionomers(GI) and Zinc Phosphate(ZP).[2]

Ni-Cr is one of the traditional alloys used for indirect restorations fabrication. In recent years Ni-Cr alloys replaced by all ceramic restoration materials such as Zirconia; because of their esthetics, chemical stability and mechanical properties.[3] Another novel restoration material is Co-Cr soft metal. Co-Cr soft metal is a pre-sintered Co-Cr alloy by special formulation, which is milled by CAD/CAM technology and sintered in argon furnace.[4] Titanium alloy (Ti-6Al-4Va) is used to fabricate dental implants and behaves like a noble metal due to the formation of superficial protective oxide film. But this oxide film can be destroyed by some contained cements which leading to titanium discoloration and esthetic problems.[5] It has been showed that titanium corrosion increased with decrease of pH and increase of fluoride concentration .[6]

There are few studies about shear bond strength (SBS) of different dental cements to titanium and recent restorative materials such as zirconia and Co-Cr soft metal. Also, the effects of dental cements on titanium are not yet fully understood. In this study, an attempt was made to evaluate the effect of different cements on the cut surface of titanium. Cutting the surface of titanium that occur in clinical conditions

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can change the adhesion of cement as well as titanium corrosion. On the other hand, the use of different restorative materials as substras in combination with different cements is one of the strength point of the study. The purpose of this study was to determine SBS of three different dental cements adhered restorative materials (Ni-Cr, zirconia and Co-Cr soft metal) to abutment titanium alloy and to examine the corrosive effect of fluoride releasing cements on titanium alloy. There would be 2 null hypotheses: 1- There is no difference between bond strength of different dental cements to titanium by using different restorative materials and 2- Dental cements used in this study have same corrosion effect on titanium alloy.

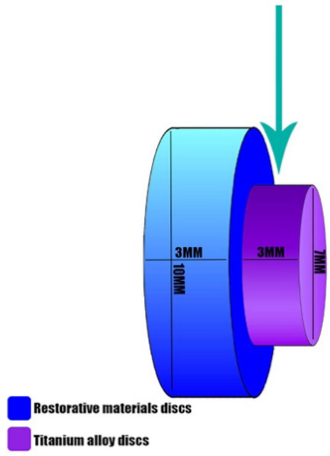

Figure 1 Shematic Diagram of Shear Bond Strength (SBS) Test

Methods

This in-vitro study was done at Dental School of Isfahan (ethical committee code: 296080) in 2017. Ninety titanium discs (10×3 mm) were prepared by cutting a stock Ti-6Al-4Va alloy rod (ASTM F136 ELI) (Magellan Co, Norwalk, USA) and divided in three group to bond with restorative material discs (Ni-Cr, Zirconia, Co-Cr soft metal).

Ni-Cr discs (5×2 mm) were made by using plastic patterns which casted by Ni-Cr alloy (Yadent, Zhengzhou, China). Co-Cr soft metal (Ceramill Sintron, Amann Girrbach, Pforzheim, Germany) and zirconia (Amann Girrbach, Pforzheim, Germany) pre-sintered discs were prepared by CAD/CAM technology (coriTEC340i; imes-icore, GmbH, Eterfeld, Germany) and then sintered according to their manufacturer's instructions. All samples were sandblasted according to the manufacture instruction by 110µm aluminum oxide (Cobra, Renfert, Hilzingen, Germany) at 4 bar pressure for 10 seconds with 5 cm distance.Three commercially dental luting cements with two different compositions including GI Fuji1 (GC Co, Tokyo, Japan), GI Meron (Voco, Rosemont, America), Hoffmann´s ZP (Hoffmann, Berlin, Germany).

Each group of restoration material discs was divided in to three subgroups according to type of cement used for adhering to titanium discs (n=10). Cement mixing ratio was followed by the manufacture's recommendations and then applied on titanium surface discs with micro brush. The restorative material discs adhered to the titanium discs. [7] Two joined discs were loaded with a 50 N force for 10 minutes at room temperature. Once set, the paired samples were incubated (01154, Behdad, Tehran, Iran) in water bath at 37ºC for 24 h.

After incubation, species were subjected to thermocycling (Delta Tpo2, Nemo, Mashhad, Iran) with PH 7 and temperature alternating between 5ºC and 55ºC with 20-second dwell and 10-second transfer time for 20,000 cycles.

Paired discs connected to universal testing machine (K-21046, Walter+Bai Co, Lohringen, Switzerland) by a clip and were subjected to shear bond strength test at 1mm/min crosshead speed (Figure 1).

Samples were observed under a stereomicroscope (Trinocular Zoom Stereomicroscope, SMP200, HP, USA) at ×32 magnification to determine the mode of fracture. Modes of fracture were classified as: 1- cement remained on the titanium discs (T) 2- cement remained on the restorative discs (S) and 3- cement remained on both titanium and restorative discs (M).

Nine titanium discs after separation were selected from each group randomly (numerical allocation), sputtered with gold and observed under SEM (SEM; XL 30 CP; Philips, Eindhoven, Netherlands) with ×500 magnification to evaluate titanium corrosion.

Obtained data were analyzed statistically by one-way ANOVA and post hoc Tamhane's test ($p<0.05$). The statistical analysis was performed using IBM SPSS (Version 20, IBM Corp, Armonk, NY) statistical software.

Table 1 Mean±SD Shear Bond Strength Values (MPa) of Studied Subgroups (n=10)

Group	Mean±SD	Min	Max	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
GCS	4.19±0.73^{A}	2.99	5.31	3.67	4.72
GCZ	0.12±0.07^{B}	0.05	0.27	0.07	0.18
GCN	6.2±0.91^{C}	4.34	7.7	5.46	6.95
VOS	1.17±0.29^{D}	0.64	6.21	0.59	2.66
VOZ	0.13±0.03^{E,B}	0.08	0.2	0.10	0.16
VON	1.79±0.24^{F}	1.39	2.2	1.61	1.96
ZPS	4.01±0.44^{G,A}	3.49	4.74	3.7	4.33
ZPZ	0.13±0.03^{H,B,E}	0.09	0.2	0.10	0.15
ZPN	4.19±0.53^{I,A,G}	3.5	5.17	3.81	4.57

* GCS: GI-GC+Sintron; GCZ: GI-GC+Zirconia; GCN: GI-GC+Ni-Cr; VOS: GI-Voco+Sintron; VOZ: GI-Voco+Zirconia; VON: GI-Voco+Ni-Cr; ZPS: ZincPhosphate+Sintron; ZPZ: Zinc Phosphate+Zirconia; ZPN: Zinc Phosphate+Ni-Cr; *Different capital letters show significant difference between groups (*P*<0.05)

Results

One-way ANOVA showed a statistically significant difference between the studied groups (p<0.05). The SBS mean values for Fuji1 GI ranged from 0.12 to 6.2 MPa, 0.13 to 1.79 MPa for Meron GI and 0.13 to 4.19 for Hoffmann´s ZP. Table 1 shows Mean±SD SBS values (MPa) of studied subgroups.

SBS values of zirconia and Co-Cr soft metal groups showed significant differences with Ni-Cr in GI (GC) group (p<0.05). In GI (Voco) and ZP (Hoffman) groups, difference of bond strength values between zirconia and Ni-Cr was statistically significant (p<0.05; Figure 2).

GI cement remained on Co-Cr soft metal and Ni-Cr disc surfaces of all samples, but on the surface of Zirconia discs there was no remained cement. There was mostly a mix pattern in ZP cement groups (Figure 3).

Scanning electron microscope (SEM) analysis: Examination by SEM (×500 magnification)

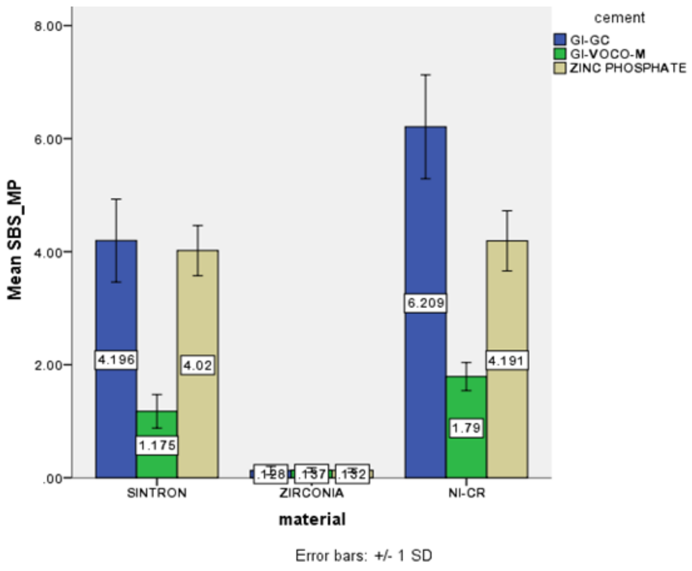

Figure 2 Mean±SD Shear Bond Strength Values(MPa) of Studied Subgroups(n=10)

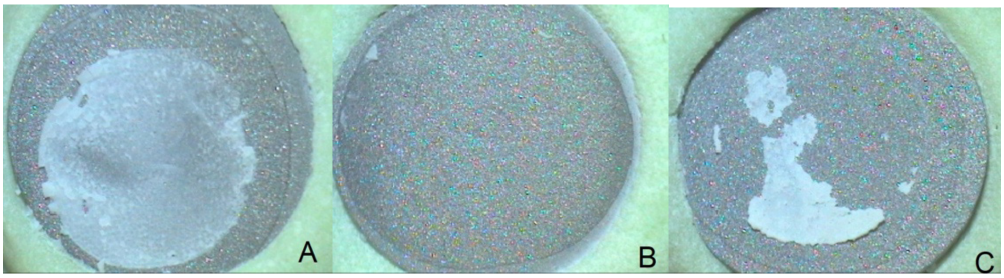

Figure 3 GI Cement Remained on Ti Discs Coupled with Co-Cr Soft Metal (A), Zirconia (B) and Ni-Cr Disc (C)

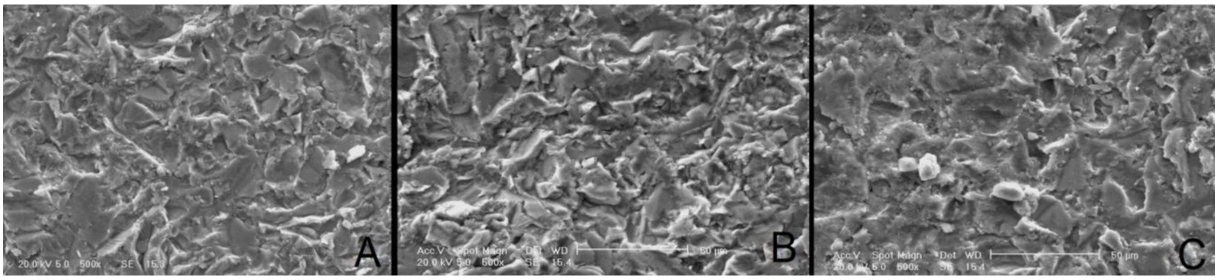

Figure 4 SEM Image of Titanium Surface

Original magnification ×500 : A. Representative of Fuji 1 B. Representative of Meron C. Representative of Hoffmann´s Zinc Phosphate

did not show any corrosion and pitting on the titanium surfaces (Figure 4).

Discussion

According to findings of present study, first null hypothesis stated that there is no difference between bond strength of different dental cements to titanium by using different restorative materials was rejected. However, the second null hypothesis stated that the corrosion of titanium oxide was similar by using different cements was accepted.

In present study, the effect of abutment geometry and taper on the restoration retention was eliminated by using restorative materials and titanium abutments as flat shape discs, and the obtained results merely indicated SBS between the surfaces of two bonded materials.

Two types of cement, including ZP and GI were used in this study. The mechanism of bonding of ZP cement to tooth structure is through mechanical interlocking and dentin surface depressions. It has shown the amount of ZP cement retention is higher in air-abraded and etched implant's abutments.[8] Bonding mechanism of GI cement to metal and tooth structure is similar, which is done by chelation of tooth and metal surface ions with cement. That is why bond strength of GI cement, owing to chemical bond to the surface of material, is higher than that of ZP.[9] In present study, the bond strength of Fuji1 GI cement in Ni-Cr and Co-Cr soft metal groups was higher than ZP. However, the results were different in Meron cement and maybe due to inherent strength of this cement and size of cement powder.

The SBS of Fuji1 GI cement was higher than two other cements, but differences were not significant in some group (in GCZ with VOZ and ZPZ and GCS with ZPS) ($p>0.05$).

Two glass ionomer cement resulted in different strength significantly (such as GCS and VOS or GCN and VON) because chemical composition of these two cements are different.

The mean values of SBS in all three cements was higher in Ni-Cr and Co-Cr soft metal than zirconia ($p<0.05$).

Consistent with this study, Hakan[10] reported that Cavitan Cem (GI) had higher bond strength than Adhesor (ZP) and Meron (GI). However, Deepthi et al.[11] reported that retention of GI and ZP cement in zirconia and metal coping to titanium abutment was not different significantly; additionally, mean tensile retention force in zirconia coping was higher than metal coping. It may be due to: 1) sample's shape 2) different material of metal coping

In Sayin et al.[12] study the SBS was lower for zirconia in comparison to Ni-Cr That is probably due to the higher resistance of zirconia surface against sandblasting, as a result of which less porosity was created in zirconia surface and bonding was reduced. Another reason is chemical bonding of GI to metal substrate whereas zirconia has an inert surface and is not react with cements. Also, a study conclude that zinc-phosphate cement demonstrated significantly lower shear bond strength values for zirconia groups.[13]

However Schiessl et al.[14] showed SBS between titanium and zirconia and metal (Co-Cr) sandblasted with 50 µm alumina was not different significantly; it may due to two reasons: 1) preparation of species on abutment in Schiessl et al study (with 4 to 8 taper degree). 2) smaller sandblast particle (50 µm in comparision of 120 µm) have lower effect on SBS and difference in pressure and distance of sandblasting, and 3) difference in cement which was studied.

The fracture patterns of samples were different in various groups. In GI cement groups, cement was remained on Co-Cr soft metal and Ni-Cr discs in all samples, but did not remain on any surface of zirconia discs. In ZP cement groups, the fracture pattern was mainly mixed type (cohesive in cement layer).

These results were in line with above findings of inert surface of zirconia and also different mechanism of retention in ZP and GI. Two types of GI cements were used in present study, in both of them fluoride compound was in the form of NaF.

Two important factors involved in titanium corrosion by fluoride-containing compounds: fluoride concentration and acidity of the compounds.[15]

It has been showed that the adverse effect of fluoride on the protective layer of titanium surface is increased with fluoride concentration (NaF), although it occurs in concentration of fluoride more than 0.1%. Also fluoride acidic pH is effective, pH between 4.8 to 4 can impair the corrosion resistance of titanium.[16]

Therefore, it can be concluded that we need a high concentration of fluoride in acidic environment to create corrosion on titanium surface, and in absence of any of these two factors, maybe destruction of protective oxide layer will not be happened. Since ZP cement contains no fluoride, no corrosion was observed on the surface of titanium samples cemented with ZP. Thus, only cement acidity cannot cause corrosion on titanium surface. Both acidity and fluoride are present in GI cement. But fluoride is gradually released from the cement over time and cement pH does not have a high acidity. Therefore, the combination of low concentrated released fluoride and weak acid potential cannot affect titanium oxide layer. Aging could influence Titanium corrosion and shear bond strength of different cements. The aim of this study was to evaluate long term effects and stimulated oral condition.

Present study did not show any corrosion on titanium surface in SEM image. Wadhawani and Chung[17] reported that GI and ZP could not affect titanium oxide layer. This study stated that this result may be due to short time investigation (in comparison to other studies) and didn't have consideration on differences in fluoride additives.

According to limitations of this study we suggest future in vivo studies by using other dental cements such as resin cements, tapered titanium abutments and simulating oral condition (humidity, temperature, load) in prolonged time will be done.

Within the limitations of this in vitro study, the following results were obtained: (1) Ni-Cr showed the highest and zirconia indicated the lowest shear bond strength to titanium when two types of GI and ZP were used; (2) The method is too weak to result in this conclusion

This study by only microscopic evaluation did not show any corrosion on titanium surfaces.

References

1. Jivraj S. Screw versus cemented implant restorations: The decision-making process. J Dent Implant 2018;8:9–19.
2. Pameijer CH. A review of luting agents. Int J Dent. 2012;2012:752861.
3. Qasim TQ, El-Masoud BM, Laban AMA. The effect of resistance grooves on the fracture toughness of zirconia-based crowns from mono and cyclic loading. Eur J Dent. 2018;12(4):491–5.
4. Lee DH, Lee BJ, Kim SH, Lee KB. Shear bond strength of porcelain to a new millable alloy and a conventional castable alloy. J Prosthet Dent. 2015;113(4):329–35.
5. Avinash KVN, Reddy V, Shetty J, Nitin HC. Evaluation of the effect of fluoride-containing luting cements on titanium and its effect on

the shear bond strength. Contemp Clin Dent. 2019;10(1):47–51.
6. Sasikumar Y, Rajendran N. Effect of fluoride concentration and pH on corrosion behavior of Ti–15Mo in Artificial Saliva. J Bio Tribo Corros. 2018;4(1):3–15.
7. Degirmenci K, Saridag S. Effect of different surface treatments on the shear bond strength of luting cements used with implant-supported prosthesis: An in vitro study. J Adv Prosthodont. 2020;12(2):75–82.
8. Ajay R, Rakshagan V, Kamatchi M, SelvaBalaji A, Sivakumar JSK, Kumar MS. Effect of Implant abutment acid etching on the retention of crowns luted with different cements: an in vitro comparative evaluation. J Pharm Bioallied Sci. 2019;11(Suppl 2):S360–64.
9. Sathyanarayan S, Balavadivel T, Guru RC, Sande AR, Rajendran V, Sengottaiyan AK. Retention of various luting agents used with implant-supported crowns. J Pharm BioAllied Sci. 2021;13(Suppl 2):S1206–9.
10. Hakan A. Retention properties of six different luting cements on titanium surface. Cumhur Dent J. 2013;17(1):48–54.
11. Deepthi B C, Mallikarjuna D M, Shetty MS. Comparative evaluation of retention of zirconia copings and cast metal copings cemented onto titanium abutments: An in vitro study. J Interdiscip Dent. 2019;9:8–14.
12. Sayin Ozel G, Okutan Y, Oguz Ahmet BS, Ozdere E. Effect of combined surface treatments on surface roughness and resin bond strength to Y-TZP ceramic and nickel–chromium metal alloy. Photobiomodulation Photomed Laser Surg. 2019;37(7):442–50.
13. Ayyildiz S, Emir F, Pak Tunc E, Sen D. Shear bond strength of various luting cements to fixed prosthodontic restorative materials. Appl Adhes Sci. 2015;3(1):13–21.
14. Schiessl C, Schaefer L, Winter C, Fuerst J, Rosentritt M, Zeman F, et al. Factors determining the retentiveness of luting agents used with metal-and ceramic-based implant components. Clin Oral Investig. 2013;17(4):1179–90.
15. Anwar EM, Kheiralla LS, Tammam RH. Effect of fluoride on the corrosion behavior of Ti and Ti6Al4V dental implants coupled with different superstructures. J Oral Implantol. 2013;37(3):309–17.
16. Noguti J, de Oliveira F, Peres RC, Renno AC, Ribeiro DA. The role of fluoride on the process of titanium corrosion in oral cavity. BioMetals. 2012;25(5):859–62.
17. Wadhwani C, Chung K-H. Bond strength and interactions of machined titanium-based alloy with dental cements. J Prosthet Dent. 2015;114(5):660–5.