Evaluation of the Effect of Fluoride-containing Luting Cements on Titanium and Its Effect on the Shear Bond Strength

Abstract

Context: The most appropriate luting agent for titanium crowns is yet to be determined. Commonly used cements for luting titanium restorations give off leachable ions which may cause surface interaction with the titanium. **Aims:** The purpose of this study was to determine the shear bond strength of four grades of commercially pure titanium and Ti 6Al 4V with different cements and to examine for any surface physical changes. **Settings and Design:** The three luting cements, i.e., zinc polycarboxylate cement, glass ionomer cement, and zinc phosphate cement, were used to evaluate their effect on titanium. Ni Cr was used as a control. **Methods and Material:** The metal rods were milled to discs of 6 mm diameter and 4 mm height. Freshly extracted maxillary first molars, mounted in resin blocks, were sliced horizontally at occlusal third of the tooth. The discs were cemented to the sliced surface of the tooth with the three luting cements. The models were subjected to the shear bond strength test. Statistical analysis used: The data collected were analyzed statistically with one way ANOVA. A representative specimen of each group was observed under a scanning electron microscope. **Results:** The mean values ranged from 0.31 to 15.6 MPa. The shear bond strength values of the zinc polycarboxylate cement group were significantly high ($P < 0.05$). Corrosion of the titanium alloy luted with zinc polycarboxylate cement was observed. **Conclusions:** Cementation with zinc polycarboxylate cement provided high shear bond strength, but showed corrosion on titanium.

Keywords: *Luting cements, shear bond strength, titanium*

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Introduction

Titanium is a metallic element known to possess several attractive properties such as excellent corrosion resistance and mechanical resistance. Titanium exhibits low thermal conductivity and high electrical conductivity. It is a light and strong metal, easy to manufacture, and has low density. Pure titanium is ductile and easy to work with. It is useful as a refractory metal because of its relatively favorable fusion point. Titanium also forms a passive layer of oxide when exposed to air. In addition, titanium is as strong as steel. These features make titanium to resist the usual types of fatigue.[1]

Four grades of commercially pure titanium (CP-Ti), or Ti, and three titanium alloys (Ti-6Al-4V, Ti-6Al-4V extra low interstitial [low components], and Ti-Al-Nb) are recognized by the American Society for Testing and Materials International. The difference among them is the concentration of the oxygen (0.18–0.40 wt%) and iron (0.20–0.50 wt%). These slight differences in concentration have a considerable effect on physical and mechanical properties. The most widely used titanium alloy is the Ti-6Al-4V.[2]

Abutments for implant-supported restorations are commonly fabricated by machining Ti-6Al-4V rods with a lathe. Computer-aided design/computer-aided manufacturing is being used to fabricate the metal frameworks for porcelain application.[3]

Several studies have also reported unexpectedly high bond strength values between titanium abutment and restoration when luted with zinc polycarboxylate cement.[4-7]

The purpose of this study was:
- To determine the shear bond strength of four grades of CP-Ti and Ti-6Al-4V to different fluoride-containing luting cements
- To examine with a scanning electron microscopic (SEM) for any surface physical changes that may occur on the different prepared surfaces.

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Access this article online
Website: www.contempclindent.org
DOI: 10.4103/ccd.ccd_207_18
Quick Response Code:

How to cite this article: Avinash KV, 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;10:47-51.

The null hypotheses tested in this study were that the types of cements do not affect the tooth–titanium surface shear bond strength and that the cements do not react with titanium alloy surfaces.

Methodology

Freshly extracted maxillary first molars were used for the study [Figure 1]. They were mounted in resin blocks [Figure 2]. The mounted teeth were sliced horizontally at an occlusal third of the tooth, such that 1 mm of sound dentin remained [Figure 3]. Ni-Cr was selected as a control group, and Grades 1, 2, 3, 4, and 5 variants of titanium were selected as test groups [Figure 4]. A Ni-Cr rod and Grades 1, 2, 3, 4, and 5 variants of titanium rods were milled to discs of 6 mm diameter and 4 mm height [Figure 5]. The titanium discs were cemented to the sliced surface of the tooth with the three luting cements, i.e., zinc polycarboxylate cement, glass ionomer cement, and zinc phosphate cement [Figure 6].

Once the cement had set, the specimens were incubated in a water bath at 37°C for 7 days. The models were subjected to the shear bond strength test in a universal testing machine (MultiTest 10-I, Mecmesin) with a crosshead speed of 1 mm/min [Figures 7 and 8]. The representative specimen of each group was sputtered with a carbon conductive layer of approximately 30 nm and observed under an SEM [Figure 9].

Results

The mean shear bond strength values ranged from 0.31 to 2.6 MPa for specimens luted with zinc phosphate, 3.45 to 11.52 MPa for specimens luted with glass ionomer, and 4.32 to 15.6 MPa for specimens luted with zinc polycarboxylate. Statistical analysis with one-way ANOVA indicated significant differences among the groups [Graph 1]. The shear bond strength values of the zinc polycarboxylate cement group were significantly higher than all the other tested groups ($P < 0.05$).

The fracture surfaces were observed and examined with an SEM. Discoloration or blackening of the titanium alloy luted with zinc polycarboxylate cement was observed. This discoloration was not observed with the other cements.

Figure 1: Freshly extracted mandibular molar

Figure 2: Mandibular molar mounted in resin block

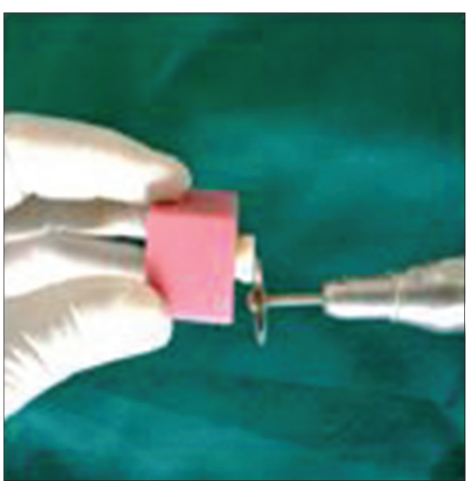


Figure 3: Slicing of the tooth

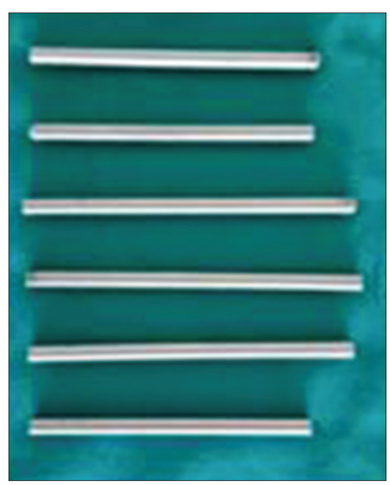


Figure 4: Titanium rods and Ni-Cr rod

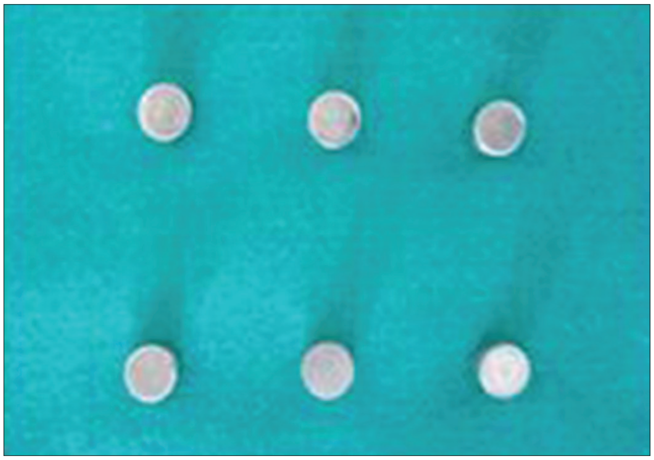


Figure 5: Discs of the rods

Figure 6: Cementation of the discs to the tooth

Figure 7: Universal Testing Machine

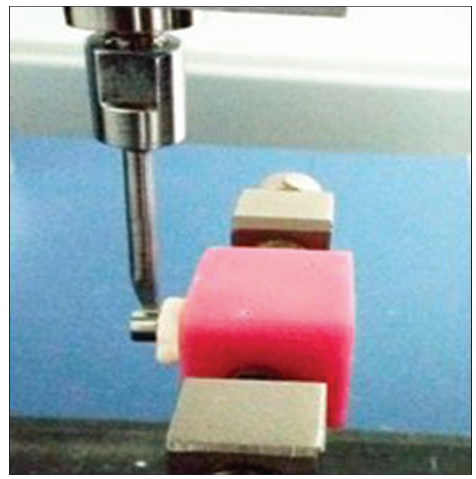


Figure 8: Application of Shear pressure

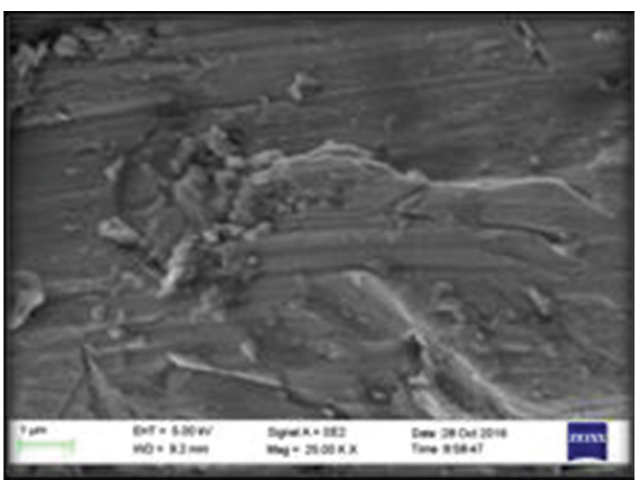
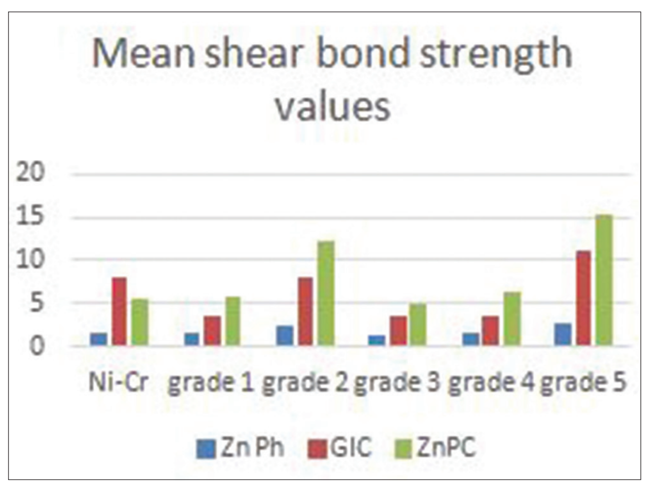


Figure 9: Scanning Electronic Microscope picture of representative specimen



Graph 1: Mean Shear Bond Strength Values

Discussion

Significant differences in shear bond strength were found within the test cement groups, and surface reactions were noted on the specimen surfaces of the zinc polycarboxylate cement group. Hence, the null hypothesis could be rejected.

In this study, the shear bond strength of zinc polycarboxylate cement group is significantly higher than other cement groups, which indicates its higher retentive capacity.

During setting, zinc polycarboxylate cement can adhere to tooth structure by chelation of calcium ions and to metal substrates by chelation of metallic ions. This suggests that the significantly higher retention obtained by zinc polycarboxylate cement could be due to adhesion of the cement to the titanium.[6]

In the present study also, it was found that the zinc polycarboxylate cement provided higher shear bond strength values.

Glass ionomer cements adhere to dentine and metal in the similar manner as zinc polycarboxylate cements. However, setting reaction may last for 24 h or more. Water contact before that time may result in weakening of the cementing agent by the dissolution of matrix. This explains the finding that glass ionomer cement has not offered higher retention values than zinc polycarboxylate cement.[5] The similar observations were made in this study.

In this study, it was noted that the Grade 2 of CP-Ti has bond strength values similar to the Grade 5 titanium.

On visual examination, discoloration was observed on the zinc polycarboxylate cement group discs. This was not observed in the remaining groups. This reaction could be due to the stannous fluoride in the zinc polycarboxylate cement; however, this needs to be confirmed by testing with some other types of zinc polycarboxylate cement that does not contain stannous fluoride.[8]

The glass ionomer cement used in this study also contains fluoride, but not in the stannous fluoride form and no interactions were observed. However, in some studies, glass ionomer cement has caused corrosion.[9-11] In a study,[9] the authors measured the release of ions from resin-modified and conventional glass ionomers over a period of up to 24 weeks. The authors suggested that discoloration occurred if the titanium oxide layer was either decreased with the action of a high fluoride ion concentration release or increased when a lower concentration of the ion was released from the glass ionomer cement.

However, such changes were not observed in any grade of titanium in this study. This may probably due to the short duration of this study, i.e., 1 week. Time-dependent actions were not included in this study. Hence, the idea of increased time of incubation can be incorporated in the further studies.

No surface treatment was carried out on titanium. Therefore, they were relatively smooth. This could have decreased cement–titanium micromechanical interlocking, which probably explains the decreased cement retention values.

Unalloyed CP-Ti is available in four different grades, 1, 2, 3, and 4, which are used based on the corrosion resistance, ductility, and strength requirements of the specific application. Grade 1 has the highest formability, while Grade 4 has the highest strength and moderate formability. CP Titanium users utilize its excellent corrosion resistance, formability, and weldable characteristics in many critical applications. Titanium Grade 2 is stronger than Grade 1 and equally corrosion resistant against most applications. Titanium Grade 2 has numerous applications in the medical industry. Biocompatibility of titanium Grade 2 is excellent, especially when direct contact with tissue or bone is required. Although different grades of titanium were tested, Grades 1, 3, and 4 did not show significant differences. Grade 2 titanium has shown significant bond strength with luting agent.

If zinc polycarboxylate cement is selected to be used for luting, a similar chemical reaction may occur, provided the conditions similar to this study. For implant restoration, the cement selection should be done with utmost care because of the issues related to periimplant disease[12] and implant loss[13] that could be due to the corrosion caused by cement. Corrosive changes to titanium alloy also increase porphyromonas gingivalis count.[14] It is a known etiological agent for periimplant and periodontal diseases. Since the majority of dental implants are titanium based, the corrosive effect of the zinc polycarboxylate cements tested on the implant surface must be carefully considered.[15] Similar considerations should be applied for titanium crowns or titanium metal copings.

Conclusions

Within the limitations of this study, the following conclusions can be made:

1. Cementation with zinc polycarboxylate cement provided higher shear bond strength compared with those values of glass ionomer and zinc phosphate cement
2. Titanium alloy surfaces cemented with zinc polycarboxylate cement showed discoloration of surfaces indicating corrosion.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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