The Potential for Bonding Titanium Restorations

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Purpose: **The use of titanium for implants has shown the biological acceptance of the metal. Recently, methods of using titanium for restorations, crowns, and bridges have been introduced using both cast and spark erosion systems for fabrication. A potential also exists for using titanium for bonded (Maryland) bridges.**

Materials and Methods: **In this study, the potential for bonding titanium was investigated by cementing with various adhesives: (A) metal to metal, (B) metal to enamel, and (C) comparing with a known procedure of bonding nickel-chromium. Truncated cones of pure titanium were fabricated with a 5-mm circular face for bonding to a larger titanium disc embedded in a plastic ring. A special jig was used to pull the bonded cone from the disc on an Instron tensile testing machine (Instron Corporation, Canton, MA). The resin-metal adhesives used were: (1) Infinity, (2) Metabond, (3) All-Bond 2, and (4) Panavia. These were compared with (5) nickel-chromium cones sandblasted and bonded to nickel-chromium with Panavia. Titanium cones were also bonded to human enamel with (6) Panavia and (7) Metabond. The 10 samples in each group were subjected to tensile force, and point of fracture was recorded. The data were subjected to an analysis of variance with a Scheffe F test at the 95% level of significance.**

Results: **The results of tensile forces in MPa were (1) Infinity, 28.1 ± 3.6; (2) Metabond, 28.1 ± 1; (3) All-Bond 2, 49.5 ± 4.3; (4) Panavia, 57.9 ± 3.1; (5) Panavia to nickel-chromium, 42.9 ± 6.6; (6) Panavia to enamel, 18.5 ± 4.7; and (7) Metabond to enamel, 19.3 ± 3.5. Titanium was most effectively bonded with All-Bond 2 and Panavia, with Panavia samples significantly better than Panavia to nickel-chromium samples.**

Conclusions: **It was concluded that titanium bonded restorations with certain adhesive cements were a definite possibility.**

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INDEX WORDS: adhesives, Maryland bridge, tensile strength, cements

THE INTRODUCTION by Buonocore[1] of the technique of acid etching enamel and the development by Bowen[2] of a bisphenol-A glycidyl methacrylate (bis-GMA) monomer resin system resulted in the explosive use of composite resins in restorative dentistry.

In the early 1970s, the use of composite resin technology in prosthodontics began when Rochette[3] introduced a fixed partial denture with perforated cast-gold retainers attached to the lingual surfaces of the abutment teeth using composite resin as a luting medium. An improved design was developed by Thompson[4] where various base metal alloys were electrochemically etched to increase retentive bond strength. Nickel-chromium-beryllium (Ni-Cr-Be) alloys gave the strongest bond to composite resin. The potential health hazards of nickel- and beryllium-containing alloys[5] fueled the search for alternative alloys with comparable bond strength.

Titanium alloys show promise in dentistry because of their biocompatibility and corrosion resistance.[6-8] Various techniques have been developed to fabricate prostheses with this metal in fixed prosthodontics. One technique involves a machine duplication of casts and electric discharge machining of the metal to fabricate crowns.[9] The development of a casting machine for casting titanium and nickel-titanium alloys using conventional casting techniques and investments[10] shows great promise as a means for using these alloys to fabricate conven-

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Figure 1. Resin-retained fixed partial dentures (Maryland bridges) may be cast in titanium alloy using conventional phosphate-bonded investment. The internal surface of a titanium Maryland bridge is shown.

tional fixed prosthodontic prostheses. With this development, a potential exists for using titanium for resin-retained fixed partial dentures (Maryland bridges) (Fig 1). In this study, the potential for bonding titanium restorations was investigated by cementing titanium to titanium and to natural enamel with various metal adhesives and comparing the bond strengths with bonded nickel-chromium (Ni-Cr) samples.

Materials and Methods

Commercially pure titanium was used to fabricate 60 truncated cones with a 5-mm circular face and 40 10-mm discs with threaded stems (Fig 2). The cones were constructed to fit in a special holding jig (Fig 3). Buehler Sampl-Kups (Buehler Company, Lakebluff, IL) were used to form a resin base in which the discs with threaded stems were embedded with casting resin from ETI (Fieldsland-

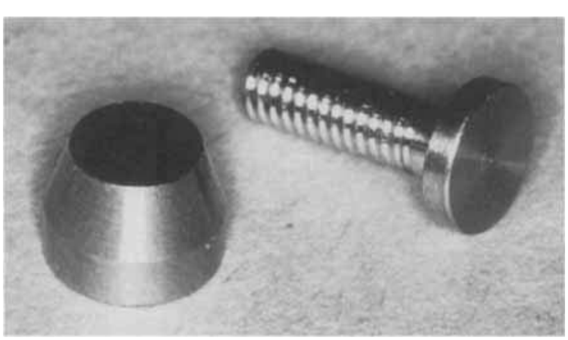

Figure 2. Commercially pure titanium was used to fabricate truncated cones with a 5-mm circular face and 10-mm discs with threaded stems.

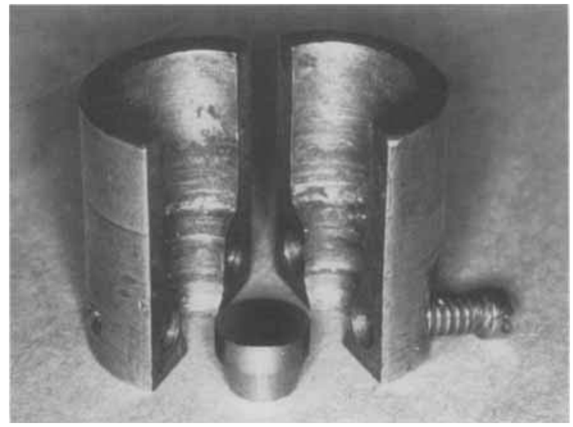

Figure 3. A special jig was designed to hold the titanium cones for the tensile test.

ing, CA) (Fig 4). Groups of 10 of these cones and discs of titanium were bonded together with various resin adhesives using a split mold (Fig 5) to orient the cones and discs. The split mold oriented the truncated cones in the same position over their respective discs with threaded stems allowing identical test sample reproduction. The same size and thickness of alloy-resin-alloy interface was thus accomplished. Two groups of titanium cones were bonded to human enamel by embedding a human central incisor in resin (Fig 6). The teeth were obtained from the University of Michigan School of Dentistry Tooth Bank, where teeth are stored in a solution of ethyl alcohol and glycerin until used. After embedding, the samples were stored in 20°C water for 24 hours. The facial enamel surface of the incisor was flattened and polished to 600 grit on a Polimet Polisher. Ten nickel-chromium (William's LiteCast B, Williams Dental, Amherst, NY) truncated cones of similar size were sandblasted and bonded to 10 discs of sandblasted nickel-chromium. The samples (Fig 7) were fitted it a special jig, as described by Barakat and Powers,[11] (Fig

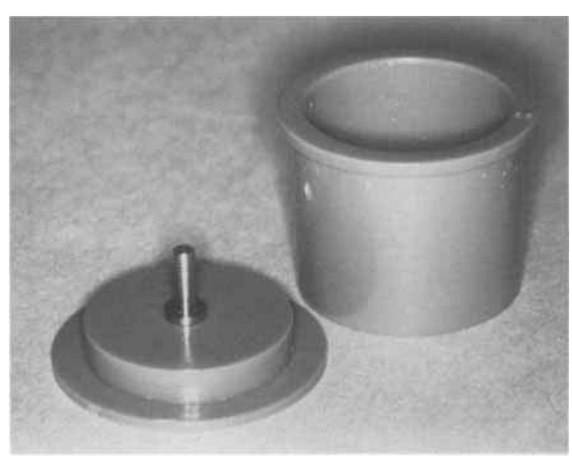

Figure 4. Buehler Sampl-Kups were used to form a resin base in which the discs were embedded with casting resin.

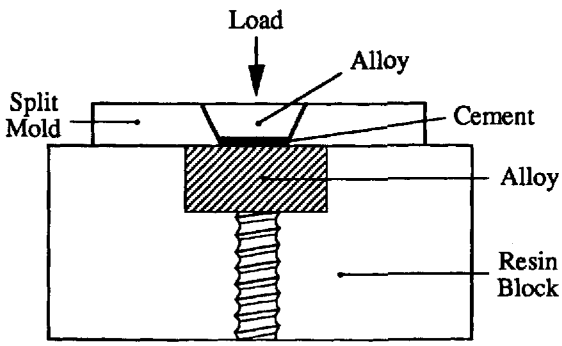

Figure 5. The split mold oriented the truncated cones in the same position over their respective discs, with threaded stems allowing identical test sample reproduction. The same size and thickness of alloy-resin-alloy interface was thus accomplished.

8) and subjected to tensile stress fracture using an Instron tensile testing machine (Instron Corporation, Canton, MA) (Fig 9) at a rate of 0.005 mm per minute. The four resin-metal adhesives (Table 1) used to bond the titanium cones to the titanium discs were (1) Infinity, (2) Metabond, (3) All-Bond 2, and (4) Panavia. The metal samples were all sandblasted with 50-μm aluminum oxide (Comco, Inc, Burbank, CA) at 90 psi before cementation (Fig 10). Sandblasted (5) nickel-chromium cones were bonded to the sandblasted nickel-chromium discs with Panavia. The titanium cones were bonded to the human enamel with (6) Panavia and (7) Metabond. The resins were mixed according to manufacturers instructions. There were 10 samples in each group, and each sample was cemented using a 367-gram weight (Fig 5) as pressure to hold the two sample units together during the prescribed time for setting of the individual cements in order to obtain a consistent film thickness as described by Watanabe.[12] The samples were stored for 24 hours in 20°C water until they were separated on the Instron tensile testing machine with the special jig designed to hold the titanium cones. Bond strengths were calculated as the load at failure. Optical magnification was used to determine the locations of failure as either within the adhesive or at the adhesive:alloy or adhesive:enamel interface.

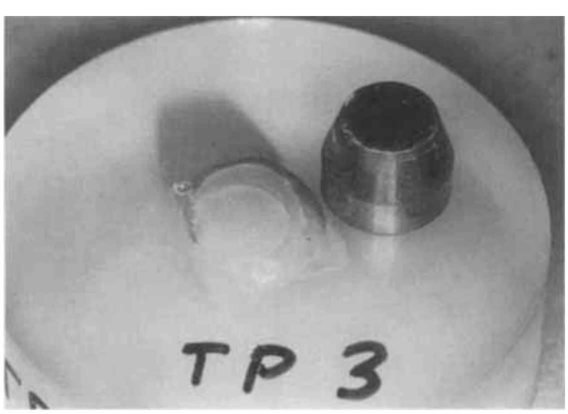

Figure 6. Two groups of titanium cones were bonded to human enamel by embedding a human central incisor in resin. The facial enamel surface of the incisor was flattened and polished to 600 grit on a Polimet Polisher.

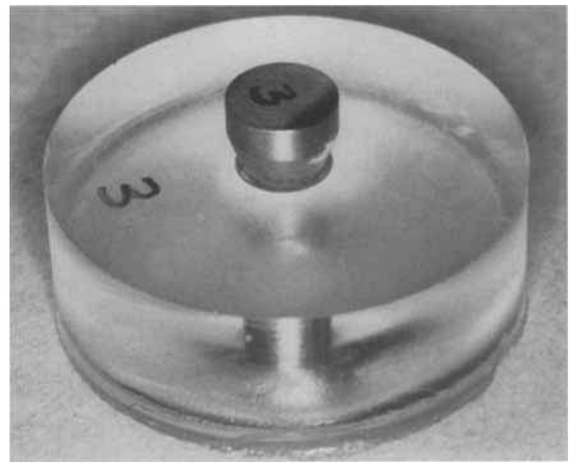

Figure 7. The titanium cones were bonded to the discs that were retained in resin blocks.

Results

The 10 samples in each group were subjected to tensile force with the Instron tensile testing machine, and the point of fracture (Fig 11) of each specimen was recorded. The results of the tensile forces on the tested specimens are shown in Figure 12. The data were subjected to an analysis of variance with a Scheffe F test at the 95% level of significance. When the data was analyzed, it was found that the samples

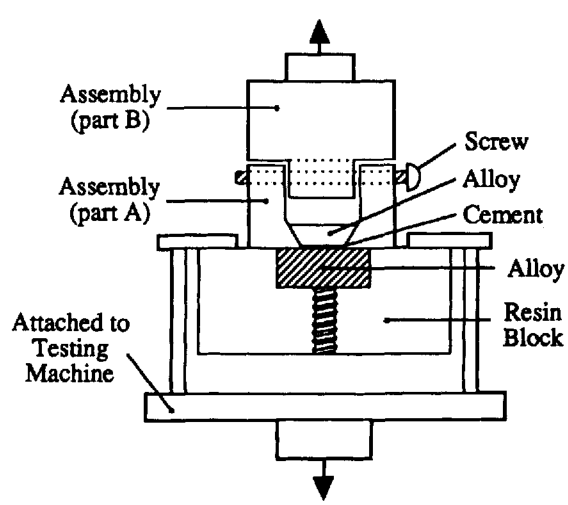

Figure 8. The special jig designed to hold the titanium cones and discs after bonding in the tensile testing machine.

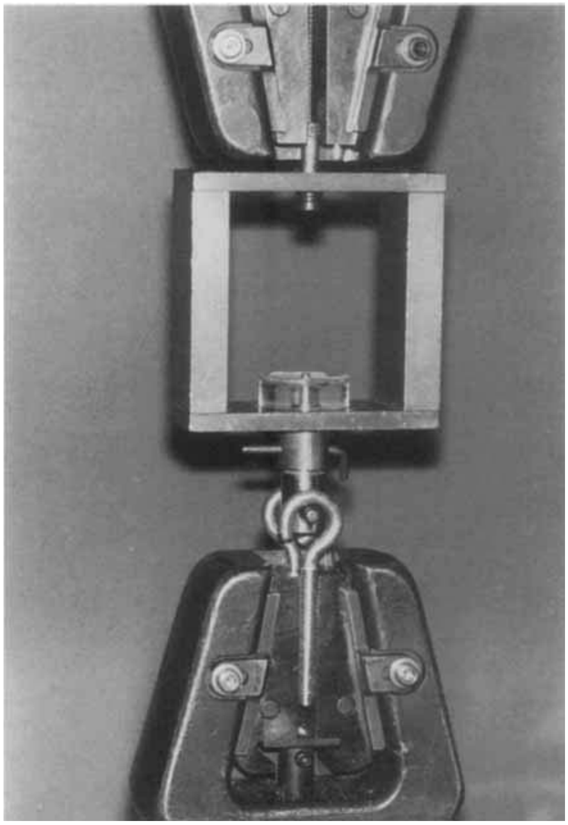

Figure 9. The samples were separated on the Instron tensile testing machine with the special jig designed to hold the titanium cones.

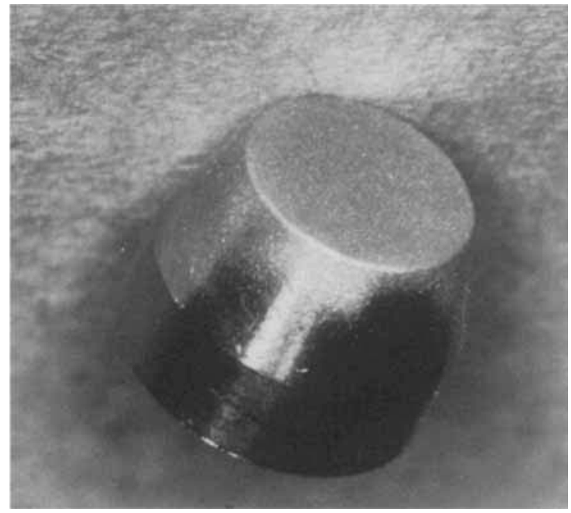

Figure 10. The metal samples were all sandblasted with 50-μm aluminum oxide before cementation.

bonded to enamel were statistically the same, and this could be easily explained because the weak link in the system is the bond to enamel that would fracture at essentially the same point with most cements. The bond between titanium and Panavia was greater than that of nickel-chromium bonded to Panavia. Titanium bonded with All-Bond 2 was equal or the same statistically as bonded nickel-chromium. Titanium samples bonded with Infinity and Metabond were significantly weaker than samples bonded to nickel-chromium. All sample alloy bonded surfaces debonded cohesively and were covered with adhesive.

The better bonding of Panavia to titanium than to nickel-chromium suggests that the adhesive components in Panavia have a greater affinity to the oxides available at the surface of the titanium alloy than to the oxides of nickel-chromium. All the adhesives bonded to all the metal samples better than to tooth structure.

Table 1. The Four Resin-Metal Adhesives Used to Bond the Titanium Cones to the Titanium Disks

Infinity Bonding Cementation Kit	Den-Mat Corporation Santa Maria, CA
C&B Metabond	Parkell Biomaterials Division Farmingdale, NY
All-Bond 2 Bisco C&B Luting Composite	Bisco, Inc Itasca, IL
Panavia	J. Morita USA, Inc Tustin, CA

Discussion

Until recently, titanium has been considered a difficult metal to cast routinely for use in fixed prosth-

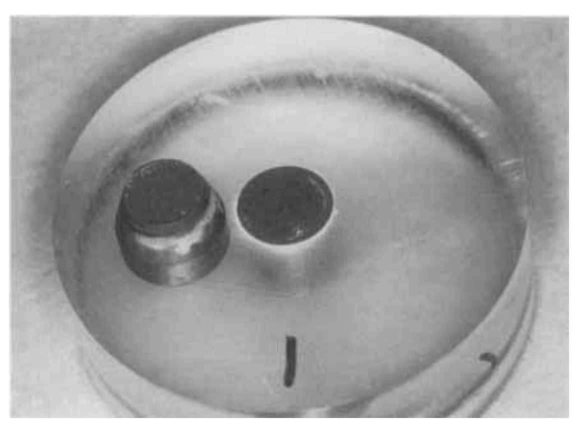

Figure 11. Ten samples from each group were subjected to tensile force with the Instron tensile testing machine, and the point of fracture of each specimen was recorded.

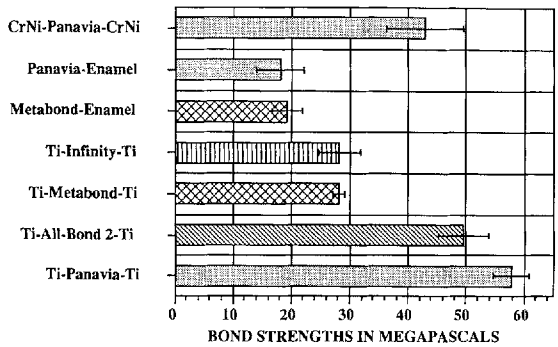

Figure 12. The tensile strengths of resin-bonded titanium samples using various metal adhesives.

odontics. By using newly developed casting machines, titanium and nickel-titanium alloys may be accurately cast using the lost-wax technique with commercial phosphate bonded silica investment. The use of titanium and titanium alloy in the construction of frameworks for etched-metal resin-retained fixed partial dentures may solve some of the problems encountered in the use of nickel-chromium alloy intraorally. Commercial composite resin cements seem to bond to the oxides of titanium with an affinity approaching that of their bond to nickel-chromium alloys. It would seem that the materials tested that are currently available for bonding to metal (Infinity, Metabond, All-Bond 2 and Panavia) are significantly stronger at 24 hours from bonding than the bond to enamel. Further study should be done on the hydration effect of cements and their bond to metal, and on the strength of titanium alloy relative to the size and thickness of bonded retainer wings.

Summary and Conclusions

Titanium can be bonded with some currently available metal adhesives. Panavia bonds significantly more strongly to titanium than to nickel-chromium alloy. All-Bond 2 bonding values are close to those of Panavia when bonding to nickel-chromium. Infinity and Metabond bonded to titanium gave values less than those of Panavia bonded to nickel-chromium. Further testing is required using hydration and its effect on fracture rates, metal bending, and metal fatigue.

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