Comparison of the effectiveness of Tokuyama and GC II metal primer on the bond strength of acrylic resins to Ti-6Al-7Nb

ABSTRACT

Statement of Problem: Because of the toxicity of vanadium in Ti-6Al-4V alloy, next generation of titanium alloys is proposed to focus on niobium-containing alloy, but for clinical applications, it is crucial for this alloy to bond with acrylic resins with or without the use of primers. However, literature was lacking about the effect of primers on bonding of autopolymerizing resins to Ti-6Al-7Nb.

Objectives: To evaluate the effect of different metal primers on the shear bond strength of acrylic resin to Ti-6Al-7Nb.

Materials and Methods: A total of 30 dis-shaped wax patterns (10 mm in diameter and 2 mm thickness) were prepared and casted using Ti-6Al-7Nb. After casting, the disk surfaces were finished with abrasive paper under water. Specimens were equally divided into three groups on the basis of the use of primer: metal primer (GC II metal primer) (Group 1), Universal Tokuyama primer (Group 2), no primer (Group 3). Tape of 50 µm thickness was applied on each of the specimens. Then, self-cure acrylic resin was mixed and applied on the center part of the tape, on which Bernouilles tube was placed. The tensile bond strength was measured with a universal testing machine. The data were obtained for all the specimens and analyzed using Statistical Package for Social Sciences version 17.0 at a statistically significance level of <0.05.

Results: Mean tensile force was maximum for Group 2 (28.58 ± 39.40 N) and minimum for control Group 3 (6.24 ± 10.97 N), thereby showing a significant inter-group difference (P<0.001). On applying post hoc test (Tukey HSD), both the Group 1 and Group 2 showed a statistically significant difference as compared to control Group 3; however, the difference between two experimental groups was not statistically significant (P>0.05).

Conclusions: Tokuyama primer and GC II metal primer had a significant effect on improving the bond strength between autopolymerizing denture base resin and Ti-6Al-7Nb.

Keywords: Autopolymerizing resin, bond strength, in vitro, primer, titanium alloy
Resin-to-metal and resin-to-denture tooth bonds are stressed by laboratory procedures during the fabrication of RPDs. The use of titanium and titanium alloys for cast restorations, denture frameworks, and milled prostheses has increased substantially and several systems have been introduced increasing the bond strength between acrylic resin and RPD casting alloys.

One important improvement in resin bonding techniques has been the introduction of chemical metal-resin bonding systems. Recently, Ohkubo et al. studied the effect of the application of metal conditioners to cast commercially pure (CP) titanium, titanium alloy (Ti-6Al-4V), and Co–Cr alloy. Semlitsch et al. developed a titanium-aluminum alloy with the inert alloying element niobium and found the optimal composition should be Ti-6Al-7Nb. This alloy had outstanding biocompatibility, good mechanical properties and corrosion resistance, reliable casting properties, and improved wear resistance. Yanagida et al. evaluated the adhesive performance of metal conditioners and a surface modification system on the bond durability between a light-activated prosthetic composite material and Ti-6Al-7Nb. In their study, the use of the primers was found to enhance bonding. Furthermore, Yanagida et al. evaluated the adhesive performance of metal conditioners used for bonding between autopolymerizing methacrylate resins and a titanium alloy, and reported that the use of one of the three conditioners (Alloy Primer, Cesead II Opaque Primer, and Metal Prime II) in combination with autopolymerizing luting resin consisting of methyl methacrylate and tri-n-butylborane with 4-methacryloyloxyethyl trimellitate anhydride (Super-Bond C and B) is recommended for bonding to the Ti-6Al-7Nb alloy. Several adhesive primers, including Meta Fast (Sun Medical Co., Ltd., Shiga, Japan), containing 4-META monomer, and metal primer (Ivoclar Vivadent AG, Schaan, Liechtenstein), containing 10-methacryloyloxyethyl dihydrogen phosphate, have been developed and are commercially available for resin-bonded prostheses, composite-veneered prostheses, and RPDs. Numerous studies have evaluated the effect of such primers on bonding acrylic resin to Ti-6Al-4V and CP-Ti. However, there is insufficient information about the effect of such primers on bonding of autopolymerizing polymethyl methacrylate (PMMA) resins to Ti-6Al-7Nb.

Hence, the purpose of this study was to compare the effectiveness of Tokuyama primer and GC II primer on tensile bond strength of autopolymerizing PMMA resins to Ti-6Al-7Nb.

MATERIALS AND METHODS

A total of 30 disk-shaped wax patterns (10 mm in diameter and 2 mm thickness) were prepared and casted using a titanium alloy (Ti-6Al-7Nb), according to the manufacturer’s instructions. After casting, the disk surfaces were finished with 600-grit SiC abrasive paper (CarbiMet; Buehler Ltd., Lake Bluff, Ill.) under water. To each titanium disc, nuts were fixed with araldite (fixing material), and they were sandblasted with 50 μm particle sized sand at 2.5 bar pressure. After sandblasting, all specimens were steam-cleaned and kept in temperature bath for at 37°C for 24 h. The discs were then removed from temperature bath and tape of 50 μm thickness (bearing central hole) was applied on all the specimens. The specimens were now ready for testing [Figure 1], and equally divided into three groups with ten titanium plates in each group: Group 1 with GC II metal primer, Group 2 with Universal Tokuyama primer, Group 3 with no primer which acts as control group.

The metal primer (GC Corporation Ltd., Tokyo, Japan) was applied with the applicator tip on all the 10 specimens of Group 1. Then, self-cure acrylic resin (UNIFAST III; GC Corp., Tokyo, Japan) was mixed in ratio 1 g powder/0.5 ml liquid and applied on the center part of the tape, on which Bernouilles tube was placed. It was cured at room temperature (23 ± 1°C; humidity 50–60%) and after keeping undisturbed for about 10–15 min, all the specimens with the attached tubes as shown in Figure 2, was placed in hot air oven at 37°C for 24 h. The universal primer (Tokuyama Dental Corp., Japan) was applied over all the specimens of Group 2 and similar procedure was performed as described for Group 1. Same procedure was performed for Group 3 specimens, but without applying any primer over the disc surface.

The tensile bond strength was measured with a universal testing machine (TSTM 02500; Elista, Istanbul, Turkey), using a crosshead speed of 0.5 mm/min [Figure 3]. The data were obtained for all the specimens, and it was analyzed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL). Intergroup comparison was done using analysis of variance followed by Tukey HSD test as the post hoc assessment tool. The confidence level of the study was kept at 95%, hence a $P < 0.05$ indicated a statistically significant difference.

RESULTS

Graph 1 summarizes the means and standard deviations of the tensile force of the three groups. The results indicate that the mean tensile force was maximum for Universal Tokuyama primer (28.58 ± 39.40 N) and minimum for control group (6.24 ± 10.97 N), thereby showing a significant intergroup difference ($F = 41.966; P < 0.001$). On applying post hoc test (Tukey HSD), GC II metal primer and Universal
Tokuyama primer showed a statistically significant difference as compared to control group. However, the difference between two GC II metal primer and Universal Tokuyama primer was not significant statistically ($P > 0.05$).

**DISCUSSION**

The current study evaluated the effect of GC Primer II and Tokuyama Primer on tensile bond strengths between an autopolymerizing PMMA resin to Ti-6Al-7Nb.

As there are serious concerns on the toxicity of vanadium in Ti-6Al-4V alloy, so the next generation of titanium alloys is proposed to focus on niobium-containing alloy.$^{[20]}$ However, the superior biological$^{[20]}$ and mechanical$^{[21]}$ properties of Ti-6Al-7Nb do not warrant their extensive application in dentistry unless this alloy can be used as an alternative to Ti-6Al-4V or CP-Ti. For practical applications of Ti-6Al-7Nb in prosthodontics, it is crucial for this alloy to bond with acrylic resins with or without the use of primers.

Numerous studies have established that application of primers significantly improve the bond strength of the acrylic resin to the cast metals, Ti-6Al-4 V, CP-Ti, composites, and ceramics.$^{[8-10,23-32]}$ However, the comparative evaluations of bond strength between acrylic resin and Ti-6Al-7Nb with the use of Tokuyama primer and GC II metal primer have never been documented. In the present study, the tensile bond strength of Ti-6Al-7Nb to acrylic resin was significantly ($P < 0.001$) improved by primer application.
compared to control group [Graph 1]. The mean tensile force was maximum for Group 2 (28.58 ± 39.40 N) and minimum for control Group 3 (6.24 ± 10.97 N), thereby showing a statistically significant intergroup difference (F = 41.966; P < 0.001) Therefore, both Tokuyama primer and GC II metal primer had a statistically significant effect on improving the bond between the autopolymerizing denture base resin and Ti-6Al-7Nb, which can make this alloy feasible for use in removable prosthodontics.

However, as tensile bond strength is not the only factor that may influence the durability of resin-metal bonds, so careful interpretation in the clinical application of these results is suggested, as the design of the present study, did not consider factors existing in the oral environment, such as dynamic fatigue loading and pH changes. The efficacy of the tested systems in providing reliable bond strength needs to be confirmed by long-term clinical studies.

CONCLUSIONS

Within the limitation of this in vitro study, it can be concluded that both Tokuyama primer and GC II metal primer had a statistically significant effect on improving the bond strength between autopolymerizing denture base resin and Ti-6Al-7Nb, which can make this alloy feasible for the use in removable prosthodontics as a safe alternative to Ti-6Al-4V.

Acknowledgement

Dr. Sunit Jurel is thankful to Dr Chikaihiro Ohkubo, Professor and chairman and Dr. Shigeru Hanatani, Associate Professor from Department of Removable Prosthodontics, Tsurumi University, School of Dental Medicine, Yokohama, Japan.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Lawson JR. Alternative alloys for resin-bonded retainers. J Prosthet Dent 1991;65:97-9.
2. Lino Carracho AJ, Chappell RP, Glaros AG, Purk JH, Eick JD. The effect of storage and thermocycling on the shear bond strength of three dentinal adhesives. Quintessence Int 1991;22:745-52.
3. Yoshida K, Kamada K, Atsuta M. Adhesive primers for bonding cobalt-chromium alloy to resin. J Oral Rehabil 1999;26:475-8.
4. Hansson O. Clinical results with resin-bonded prostheses and an adhesive cement. Quintessence Int 1994;25:125-32.
5. Behr M, Leibrock A, Stich W, Rammensberg P, Rosentritt M, Handel G. Adhesive-fixed partial dentures in anterior and posterior areas. Results of an on-going prospective study begun in 1985. Clin Oral Investig 1998;2:31-5.
6. Ozcan M, Pfeiffer P, Negiz I. A brief history and current status of metal-and-ceramic surface-conditioning concepts for resin bonding in dentistry. Quintessence Int 1998;29:713-24.
7. Stryglar H, Nicholls JJ, Townsend JD. Microleakage at the resin-alloy interface of chemically retained composite resins for cast restorations. J Prosthet Dent 1991;65:733-9.
8. Kim JY, Pfeiffer P, Niedermeier W. Effect of laboratory procedures and thermocycling on the shear bond strength of resin-metal bonding systems. J Prosthet Dent 2003;90:184-9.
9. Koizumi H, Furuchi M, Tanoue N, Yanagida H, Yoneyama T, Matsumura H. Bond strength to primed Ti-6Al-7Nb alloy of two acrylic resin adhesives. Dent Mater J 2006;25:286-90.
10. Nabatangang DP, Powers JM. Effectiveness of adhesive systems for a Co-Cr removable partial denture alloy. J Prosthodont 1998;7:17-25.
11. Ohkubo C, Watanabe I, Hosoi T, Okabe T. Shear bond strengths of polyethylene methacrylate to cast titanium and cobalt-chromium frameworks using five metal primers. J Prosthet Dent 2000;83:50-7.
12. Semlitsch MF, Weber H, Strehler RM, Schün R. Joint replacement components made of hot-forged and surface-treated Ti-6Al-7Nb alloy. Biomaterials 1992;13:781-8.
13. Lavos-Valereto IC, Wolynes S, Depoloni MC, König BJ. In vitro and in vivo biocompatibility testing of Ti-6Al-7Nb alloy with and without plasma-sprayed hydroxyapatite coating. J Biomed Mater Res 2001;58:727-33.
14. Kobayashi E, Wang TJ, Doi H, Yoneyama T, Hannawa H. Mechanical properties and corrosion resistance of Ti-6Al-7Nb alloy dental castings. J Mater Sci Mater Med 1998;9:567-74.
15. Wang TJ, Kobayashi E, Doi H, Yoneyama T. Castability of Ti-6Al-7Nb alloy for dental casting. J Med Dent Sci 1999;46:13-9.
16. Ohkubo C, Shimura I, Aoki T, Hanatani S, Hosoi T, Okabe T. In vitro wear assessment of titanium alloy teeth. J Prosthodont 2002;11:263-9.
17. Iijima D, Yoneyama T, Doi H, Hannawa H, Kurosaki N. Wear properties of Ti and Ti-6Al-7Nb castings for dental prostheses. Biomaterials 2003;24:1519-24.
18. Yanagida H, Matsumura H, Atsuta M. Bonding of prosthetic composite material to Ti-6Al-7Nb alloy with eight metal conditioners and a surface modification technique. Am J Dent 2001;14:291-4.
19. Yanagida H, Taira Y, Shimoe S, Atsuta M, Yoneyama T, Matsumura H. Adhesive bonding of titanium-aluminum-niobium alloy with nine surface preparations and three self-curing resins. Eur J Oral Sci 2003;111:170-4.
20. Challa VS, Mali S, Misra RD. Reduced toxicity and superior cellular response of preosteoblasts to Ti-6Al-7Nb alloy and comparison with Ti-6Al-4V. J Biomed Mater Res A 2013;101:2083-9.
21. Bolzoni L, Weissgaerber T, Kieback B, Ruiz-Navas EM, Gordo E. Mechanical behaviour of pressed and sintered CP Ti and Ti-6Al-7Nb alloy obtained from master alloy addition powder. J Mech Behav Biomater Mater 2013;20:149-61.
22. Rothfuss LG, Hinkett SD, Hondrum SO, Elrod CW. Resin to metal bond strengths using two commercial systems. J Prosthet Dent 1998;79:270-2.
23. Radhi A, Juszczyszyn AS, Curtis RV, Sherriff M, Radford DR, Clark RK. Effect of GC METALPRIMER II on bond strength of heat-cured acrylic resin to titanium alloy (Ti-6Al-4V) with two different surface treatments. Eur J Prosthodont Restor Dent 2008;16:132-7.
24. Poddar S, Goel P, Kar S, Bhattacharyya J. Investigation into the effect of use of metal primer on adhesion of heat cure acrylic resin to cast titanium: An in vitro study. J Indian Prosthodont Soc 2014;14:262-72.
25. Elzarrug YA, Galbit MB, Ali A, Finkelman M, Dam HG. An in vitro comparison of the shear bond strengths of two different gingiva-colored materials bonded to commercially pure titanium and acrylic artificial teeth. J Prosthodont 2014;23:313-9.
26. Almilhatti HJ, Neppelenbroek KH, Vergani CE, Machado AL,
Pavarina AC, Giampaolo ET. Adhesive bonding of resin composite to various titanium surfaces using different metal conditioners and a surface modification system. J Appl Oral Sci 2013;21:590-6.

27. Sanohkan S, Urapepon S, Harnirattisai C, Sirisinha C, Sunintaboon P. Shear bond strength between autopolymerizing acrylic resin and Co-Cr alloy using different primers. Dent Mater J 2012;31:765-71.

28. Di Francescantonio M, Oliveira MT, Daroz LG, Henriques GE, Giannini M. Adhesive bonding of resin cements to cast titanium with adhesive primers. Braz Dent J 2012;23:218-22.

29. Koizuka M, Komine F, Blatz MB, Fushiki R, Taguchi K, Matsumura H. The effect of different surface treatments on the bond strength of a gingiva-colored indirect composite veneering material to three implant framework materials. Clin Oral Implants Res 2013;24:977-84.

30. Bulbul M, Kesim B. The effect of primers on shear bond strength of acrylic resins to different types of metals. J Prosthodont 2010;103:303-8.

31. Matsuda Y, Yanagida H, Ide T, Matsumura H, Tanoue N. Bond strength of poly(methyl methacrylate) denture base material to cast titanium and cobalt-chromium alloy. J Adhes Dent 2010;12:223-9.

32. Lee G, Engelmeier RL, Gonzalez M, Powers JM, Perezous LF, O’Keefe KL. Force needed to separate acrylic resin from primed and unprimed frameworks of different designs. J Prosthodont 2010;19:14-9.