Effect of Different Finishing and Polishing Agents on the Surface Roughness of Cast Pure Titanium

E. Srinivas Reddy, MDS;[1] Narendra P. Patil, MDS;[2] Satyabodh S. Guttal, MDS, MFPT;[3] and H.G. Jagadish, MDS[4]

Purpose: **The aim of this study was to evaluate the effect of finishing and polishing agents on surface roughness of cast commercially pure titanium using scanning electron microscope (SEM) analysis.**

Materials and Methods: **A standardized square steel die measuring 10 × 10 mm with a thickness of 2 mm was machine cut. An impression of this die was used to create wax patterns for casting. Sixty specimens were cast in commercially pure titanium. These were divided into three groups (A, B, and C) of 20 specimens each. Group A specimens were polished with black, brown, and green rubber discs followed by green polishing compound with buff. Group B specimens were polished with black, brown, and green rubber cones, buffed with yellow polishing cake designed for gold alloy. Group C specimens were polished with silicium carbide cones and buffed with orange polishing cake. Surface roughness of the test specimens was measured in microns with a perthometer. Data were analyzed with ANOVA and Tukey's honest significant difference (HSD) multiple comparison tests among the different groups. Qualitative analysis was done by SEM photomicrographs.**

Results: **Surface roughness values R_a for Groups A, B, and C were 0.68 μm, 0.78 μm, and 0.27 μm, respectively. SEM photomicrographs and the statistical analysis revealed that the finishing and polishing were better with Group C test specimens with lower surface roughness values compared with groups A and B. Tests showed that Group C was statistically smoother ($p \leq 0.01$).**

Conclusion: **Within the limitations of this study, surface roughness was less on cast CpTi specimens that were finished and polished from the cutters designed specifically for titanium.**

J Prosthodont 2007;16:263-268. *Copyright © 2007 by The American College of Prosthodontists.*

INDEX WORDS: titanium, finishing and polishing, abrasives, surface roughness

IN RECENT years, titanium has drawn a great deal of attention from researchers in dental biomaterials. Titanium is extensively used for implants and fixed and removable partial dentures.[1] The increased use of titanium is due in part to the evolution of improved casting technologies.[2,3] In addition, titanium has excellent physical and mechanical properties, making it the most biologically compatible alloy.[4-6]

Studies on the surface roughness of titanium castings have been done by many investigators,[5,7,8] but most were concerned with variables other than the conventional finishing and polishing techniques. The art and science of abrasive finishing and polishing are important aspects of clinically successful restorations. The main advantage of accurate finishing and polishing is to enhance the esthetics and longevity of the restorations by inhibiting plaque accumulation. Although the literature is deficient with respect to studies concerning the effect of finishing and polishing on titanium, Aydin[9] assessed the effect of finishing and polishing on surface roughness of cobalt-chromium castings. He reported that appropriate smoothing techniques are fundamental for contouring. This may improve oral health, decrease plaque retention, and increase alloy resistance to corrosion. The shortcomings of a rough surface

[1]Reader, Sri Sai Dental College, Department of Prosthodontics, Vikarabad, Andra Pradesh, India

From SDM College of Dental Sciences and Hospital, Department of Prosthodontics, Dharwad, Karnataka, India.

[2]Professor and Chairman

[3]Reader

[4]Professor

Accepted January 18, 2006.

Correspondence to: Satyabodh S. Guttal, SDM College of Dental Sciences and Hospital – Prosthodontics, Dhavalnagar Sattur, Dharwad, Karnataka 580 009, India. E-mail: drsatyabodh@yahoo. co.in

Copyright © 2007 by The American College of Prosthodontists

1059-941X/07

doi: 10.1111/j.1532-849X.2007.00187.x

were demonstrated in an in vivo study by Quirynen et al.[10] They concluded that the surface roughness of implant-supported prostheses significantly increased the adhesion of supragingival bacterial plaque, increasing the incidence of dental caries, gingivitis, and periodontal disease.[11-15]

Finishing and polishing cast titanium are difficult procedures[14-16] because of high chemical reactivity, high strength, and low modulus of elasticity. Finishing and polishing affect the mechanical properties of the metal. The polished surface of cast titanium increases resistance to corrosion and governs fatigue strength.[17,18] The poorer the surface finish and polish, the lower the fatigue strength.

Hirata et al[19] used five dental abrasives, including carborundum points and silicon points, to evaluate polishing of titanium and Ag-Pd-Cu-Au alloys. They concluded that titanium was much more difficult to polish and that development of new abrasives for polishing titanium was required. A study on the grinding of titanium conducted by Miyakawa et al[20,21] reported that high-speed grinding results in both chemical wear of abrasives, grit, burn, discoloration, and contamination of the surface. The use of different abrasives can affect the surface of the titanium. Due to the difference in physical and chemical properties of titanium, the surface finish and polish obtained by using a finishing and polishing kit designed for gold alloys may result in a different quality of titanium surface. Therefore, the main objective of this study was to evaluate the surface roughness (using a perthometer and scanning electron micrograph [SEM] analysis) of cast commercially pure titanium after finishing and polishing with different materials.

Materials and Methods

A standardized square steel die measuring 10 × 10 mm with a thickness of 2 mm was machine cut. This was duplicated in putty to make an index. Standardized square wax patterns were made by pouring the inlay wax into the putty index. A total of 60 specimens were cast in a semiautomatic titanium-casting machine (Titec F210M, Orotig, Verona, Italy) according to the manufacturer's instructions. The cast specimens were carefully cleaned using airborne-particle abrasion with aluminum oxide (50 μm) for 15 seconds to remove investment residues. The specimens were divided into three groups of 20 each. All groups were treated with different finishing and polishing materials (Table 1). Group A specimens were finished using the tungsten carbide trimmer (KOMET Brasseler, Bremen, Germany) and brown stone point (Dentaurum, Ispringen, Germany). Finishing was done with a hand piece (Kavo Gmbh, Biberach, Germany), speed ranging from 15,000 to 20,000 rpm. A clinically acceptable surface finish was obtained. After finishing, each specimen was ultrasonically cleaned in acetone and mounted onto a stub using silver nitrate. The mounted specimens were subjected to SEM analysis. Further, the same test specimens were polished with black, brown, and green rubber polishing discs according to the order of fineness and buffed with green polishing compound. During polishing, the hand piece speed ranged from 2000 to 5000 rpm. The movement of the disc was unidirectional and held parallel to the specimen in the horizontal plane. Again, SEM analysis was carried out after polishing. Similarly, the same protocol was followed for Groups B and C using the finishing elements listed in Table 1. A methodology was followed in which each instrument or abrasive was used until its work had been completed before the next one was begun.

Surface roughness (in microns) was measured using a surface-analyzing instrument called a perthometer

Table 1. Finishing and Polishing Materials Used for Group A, B, and C Specimens

Test Group	*Number of Specimens*	*Finishing Materials*	*Polishing Materials*
A	20	Tungsten carbide trimmer (KOMET Brasseler, Hanau, Germany), brown stone point (Dentaurum, Ispringen, Germany)	Black, brown, and green rubber polishing discs followed by green polishing compound with buff
B	20	Green stone point (Dentaurum, Ispringen, Germany)	Gold polishing rubber cones (Shofu Co., Kyoto, Japan), yellow polishing cake with buff (Degussa, Hanau, Germany)
C	20	Tungsten carbide trimmer coated with titanium nitride and SiC sandpapering cones (Titec, Orotig, Verona, Italy)	Orange polishing cake with buff (Titec, Orotig, Verona, Italy)

Table 2. Mean, SD, Minimum and Maximum Values of R_a, R_z, and R_{max} in Microns

Test Specimen Groups ($n = 60$)	Mean	SD	Minimum	Maximum
Group A R_a	0.6810	0.09814	0.5300	0.8300
Group A R_z	3.361	0.1027	3.190	3.540
Group A R_{max}	5.157	0.1809	4.690	5.470
Group B R_a	0.7830	0.0758	0.6600	0.9100
Group B R_z	3.705	0.0876	3.540	3.850
Group B R_{max}	6.618	0.0968	6.420	6.750
Group C R_a	0.2775	0.09284	0.0900	0.4600
Group C R_z	1.408	0.1617	0.8100	1.580
Group C R_{max}	1.916	0.1119	1.640	2.190

(Mahr-Perten GmbH, Hannover, Germany). It gives an expression of an average surface roughness (R_a), average peak to valley height (R_z), and maximum depth of surface roughness (R_{max}). The center point of each specimen was subjected to perthometer analysis for surface evaluation. The data were statistically analyzed for differences among the three finishing and polishing materials. One-way variance of analysis (ANOVA) and Tukey's honest significant difference (HSD) multiple comparison tests were performed by statistical package software (SPSS for Windows version 10, SPSS Inc., Chicago, IL). The significance level was set at $\alpha = 0.01$. Test specimens examined by scanning electron microscope were photographed at ×1000 magnification.

Results

Mean and SD for surface roughness values for each group tested are provided in Table 2. ANOVA revealed a significant difference between groups for average surface roughness (R_a), peak-to-valley height (R_z), and maximum depth (R_{max}) (Table 3). Tukey's HSD post hoc comparison test results between groups are listed in Table 4.

Scanning electron photomicrographs of the specimens after finishing are shown in Figure 1. The SEM images further substantiate the results obtained from statistical analysis of the data. Figure 2 shows the SEM photographs for specimens after polishing. The specimens of group C appeared to have a smoother surface than the other groups.

Discussion

Enormous research efforts for the development of titanium casting technology for dental applications have culminated in a level of technology that has almost overcome many difficult aspects of producing titanium frameworks by casting; however, the number of studies concerning the techniques of conventional finishing and polishing of titanium are limited. It is even more difficult to finish and polish Cp titanium than titanium alloy.[22] There are many finishing and polishing instruments routinely available in dental laboratories designed to

Table 3. One-way ANOVA of R_a, R_z, R_{max}

Source	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio	P-Value	Significance
Analysis of variance of average surface roughness (R_a)						
Between groups	2	2.8583	1.4292	178.5760	<0.01	S
Within groups (error)	57	0.4562	0.0080			
Total	59	3.3145				
Analysis of variance of peak-to-valley height (R_z)						
Between groups	2	61.3634	30.6817	2081.203	<0.01	S
Within groups (error)	57	0.8403	0.0147			
Total	59	62.2037				
Analysis of variance of maximum depth of surface roughness (R_{max})						
Between groups	2	231.5846	115.7923	6358.352	<0.01	S
Within groups (error)	57	1.0380	0.0182			
Total	59	232.6226				

Table 4. Tukey's HSD Multiple Comparison Test Results of R_a, R_z, and $R_{\max}$

Group	*A*	*B*	*C*
Comparison of mean values of R_a in Groups A, B, and C			
Mean	0.6810	0.7830	0.2775
A	—	—	—
B	<0.01, S	—	—
C	<0.01, S	<0.01, S	—
Comparison of mean values of R_z in Groups A, B, and C			
Mean	3.3605	3.7045	1.4080
A	—	—	—
B	<0.01, S	—	—
C	<0.01, S	<0.01, S	—
Comparison of mean values of $R_{\max}$ in Groups A, B, and C			
Mean	5.1565	6.6180	1.9165
A	—	—	—
B	<0.01, S	—	—
C	<0.01, S	<0.01, S	—

finish other metals. The operator is tempted to use the same for titanium.

The literature[23–26] suggests that many finishing and polishing agents have been used for titanium. In this study, conventional polishing products were compared with products designed specifically for polishing titanium. Since titanium has a low thermal conductivity, the grinding temperature influencing titanium abrasive reaction should be kept from rising. The overheating of this metal may cause consequent allotropic transformation from α phase to the β phase at 882°C. The material becomes brittle and extremely hard. Therefore, for the efficient finishing and polishing of a cast titanium surface, low rotational speed and light forces are recommended with the inhibition of titanium abrasive reaction. There has been the perception that the existence of the α-case on the cast titanium makes the finishing processes very laborious compared with other dental casting alloys. This may prevent the operator from obtaining a smooth, shiny surface finish in this metal. Titanium nitride-coated tungsten carbide cutters and silicium carbide wheels or cones are better choices for finishing of titanium surfaces.[23,27] The cutters should have cross-edged shapes that are unlikely to be adhesive.

Rimondini et al[28] used three polishing groups and then evaluated the surface roughness using laser profilometer. They concluded that titanium surface with $R_a \leq 0.088\,\mu$m and $R_z \leq 1.027\,\mu$m strongly inhibits the accumulation of plaque. In this study, Group C specimens' average surface roughness R_a was 0.2777 μm, and average peak-to-valley $R_z = 1.408\,\mu$m. The slight differences in surface roughness in this study may be attributed to the accuracy of the perthometer used for the evaluation. The statistically significant results in this study may be because of the difference in instrumentation of Groups A, B, and C. Geis Gerstorfer et al[29] carried out a study on finishing of cast titanium crowns and bridges. The surface roughness of cast titanium was compared with a precious alloy (Au-Ag-Cu), two Pd-based alloys (Pd-Ag-Sn-In, Pd-Sn-Ga-Cu), and two base metal alloys (Ni-Cr-Mo, Co-Cr-Mo). Profilometer measurements were done after polishing with six polishing pastes. The results revealed that the surface roughness was greater with the titanium surface, indicating the need for a specific finishing and polishing kit for titanium.

The scanning electron micrographs in this study closely support the findings of the statistical analysis. The best surface finish and polish were produced in Group C specimens, which were finished and polished with a specific titanium finishing and polishing kit supplied by the titanium manufacturer.

A limitation of this study is that the specimens were finished without measuring the time spent for each specimen. This might cause loss of mass after finishing and polishing, consequently weakening the specimen structure due to finishing and polishing; this may be of interest to other researchers.

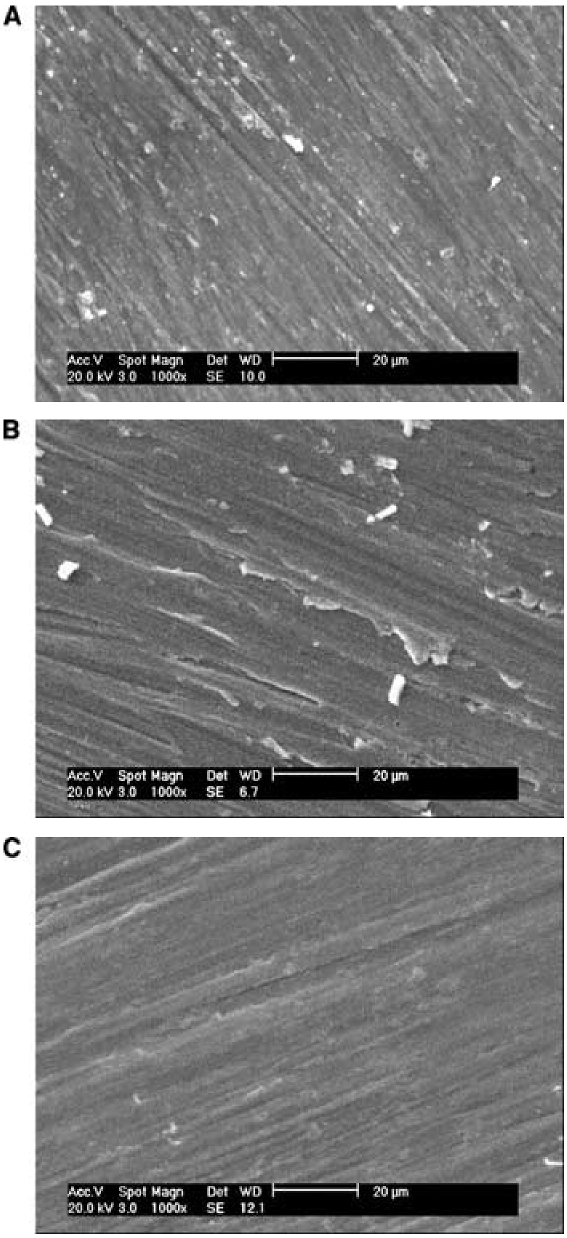

Figure 1. Scanning electron photomicrographs of Groups A through C specimens after finishing (original magnification ×1000). *(A)* Surface of specimen finished using Group A instrumentation. *(B)* Surface of specimen finished using Group B instrumentation. *(C)* Surface of specimen finished using Group C instrumentation.

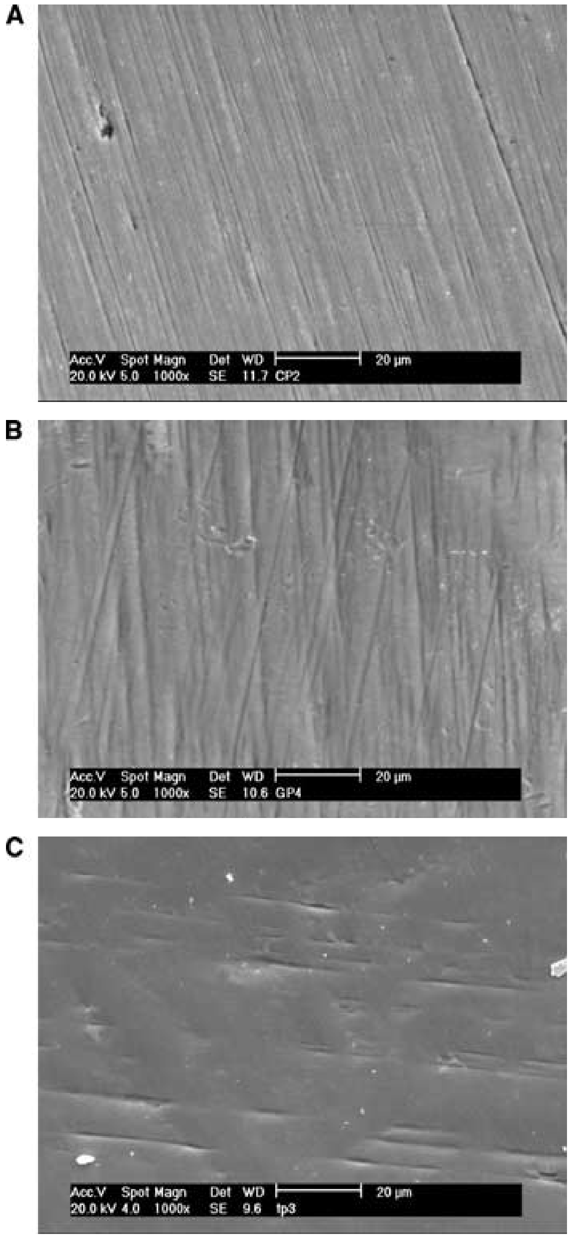

Figure 2. Scanning electron photomicrographs of Groups A through C specimens after polishing (original magnification ×1000). *(A)* Surface of specimen polished using group A instrumentation. *(B)* Surface of specimen polished using Group B instrumentation. *(C)* Surface of specimen polished using Group C instrumentation.

Conclusion

The effect of finishing and polishing agents on surface roughness of cast CpTi was evaluated using a perthometer. Perthometer evaluation showed that Group C specimens gave a statistically smoother finish and polish when compared with Groups A and B. The scanning electron photomicrographs of the specimens further substantiate the results obtained from statistical analysis of the data.

Acknowledgments

The authors gratefully acknowledge the support and encouragement given by Dr. D. Veerendra Heggade and Dr. C. Bhasker Rao. The authors acknowledge S. B. Javali for his assistance in statistical analysis.

References

1. Parr GR, Gardner LK, Toth RW: Titanium: the mystery metal of implant dentistry. Dental materials aspects. J Prosthet Dent 1985;54:410-414
2. Contreras EF, Henriques GE, Giolo SR, et al: Fit of cast commercially pure titanium and Ti-6 Al-4 V alloy crowns before and after marginal refinement by electrical discharge machining. J Prosthet Dent 2002;88:467-472
3. Wang RR, Fenton A: Titanium for prosthodontic applications: a review of the literature. Quintessence Int 1996;27:401-408
4. Miyakawa O, Watanabe K, Okawa S, et al: Surface contamination of titanium by abrading treatment. Dent Mater J 1996;15:11-21
5. Taborelli M, Jobin M, Francois P, et al: Influence of surface treatments developed for oral implants on the physical and biological properties of titanium. (1) Surface characterization. Clin Oral Implants Res 1997;8:208-216
6. Wakabayashi N, Ai M: A short-term clinical follow-up study of superplastic titanium alloy for major connectors of removable partial dentures. J Prosthet Dent 1997;77:583-587
7. Jang KS, Youn SJ, Kim YS: Comparison of castability and surface roughness of commercially pure titanium and cobalt-chromium denture frameworks. J Prosthet Dent 2001;86:93-98
8. Wu-Yuan CD, Eganhouse KJ, Keller JC: Oral bacterial accumulation on titanium surfaces with different textures. J Dent Res 1992;71:145
9. Aydin AK: Evaluation of finishing and polishing techniques on surface roughness of chromium-cobalt castings. J Prosthet Dent 1991;65:763-767
10. Quirynen M, Van Der Mei HC, Bollen CM, et al: An in vivo study of the influence of the surface roughness of implants on the microbiology of supra- and subgingival plaque. J Dent Res 1993;72:1304-1309
11. Tanner J, Carlen A, Soderling E, et al: Adsorption of parotid saliva proteins and adhesion of streptococcus mutans ATCC 21752 to dental fiber-reinforced composites. J Biomed Mater Res B Appl Biomater 2003;66: 391-398
12. Borchers L, Tavassol F, Tschernitschek H: Surface quality achieved by polishing and by varnishing of temporary crown and fixed partial denture resins. J Prosthet Dent 1999;82:550-556
13. Grossner-Schreiber B, Griepentrog M, Haustein I, et al: Plaque formation on surface modified dental implants. An in vitro study. Clin Oral Implants Res 2001;12:543-551
14. Quirynen M, Bollen CM: The influence of surface roughness and surface free energy on supra- and subgingival plaque formation in man: a review of the literature. J Clin Periodontol 1995;22:1-14
15. Bollen CM, Lambrechts P, Quirynen M: Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention; a review of the literature. Dent Mater 1997;13:258-269
16. Toumelin-Chemla F, Rouelle F, Burdairon G: Corrosive properties of fluoride-containing odontologic gels against titanium. J Dent 1996;24:109-115
17. Zavanelli RA, Pessanha Henriques GE, Ferreira I, et al: Corrosion-fatigue life of commercially pure titanium and Ti-6 Al-4 V alloys in different storage environments. J Prosthet Dent 2000;84:274-279
18. Dieter GE. Mechanical Metallurgy (ed 3). London, McGraw-Hill, 1986, pp. 375-431
19. Hirata T, Nakamura T, Takashima F, et al: Studies on polishing of Ti and Ag-Pd-Cu-Au alloy with five dental abrasives. J Oral Rehabil 2001;28:773-777
20. Miyakawa O, Watanabe K, Okawa S, et al: Grinding of titanium. 1. Commercial and experimental wheels made of silicon carbide abrasives. Shika Zairy Kikai 1990;9:30-41
21. Miyakawa O, Watanabe K, Okawa S, et al: Grinding of titanium. 2. Commercial vitrified wheels made of alumina abrasives. Shika Zairy Kikai 1990;9:42-52
22. Guilherme AS, Henriques GE, Zavanelli RA, et al: Surface roughness and fatigue performance of commercially pure titanium and Ti-6 Al-4 V alloy after different polishing protocols. J Prosthet Dent 2005;93:378-385
23. Okabe T, Ohkubo C, Watanabe I, et al: The present status of dental titanium casting. JOM 1998;50:24-29
24. Miyakawa O, Okawa S, Kobayashi M, et al: Surface contamination of titanium by abrading treatment. Dent Japan 1998;19:405-412
25. Shimakura M, Yamamoto M, Nakajima K, et al: Application of a centrifugal shooting type polishing system to polish pure titanium. Dent Mater J 2000;19:405-412
26. Tamaki Y, Miyazaki T, Suzuki E, et al: Polishing of titanium prosthesis (part 6). The chemical polishing baths containing hydrofluoric acid and nitric acid. Shika Zairy Kikai 1989;8:103-109
27. Titec 201 F by OROTIG™: Results and tests carried out on cast titanium prosthesis. Instruction manual. Verona, Italy. 1998
28. Rimondini L, Fare S, Brambilla E, et al: The effect of surface roughness on early in vivo plaque colonization on titanium. J Periodontol 1997;68:556-562
29. Geis Gerstorfer J, Eckhardt M, Lin W, et al: Finishing of cast titanium for crowns and bridges. Dtsch Zahnarztl Z 1989;44:882-884

Copyright of Journal of Prosthodontics is the property of Blackwell Publishing Limited and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.