



An Investigation of The Effect of Different Surface Treatments on Surface Roughness of The Titanium Alloy

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Abstract

The current study's objective was to assess the impact of etching titanium with various surface treatments in order to increase the surface roughness value. Materials and methods: - cylindrical shaped samples composed of metal were prepared by CAD/CAM milling technique, total 42 samples with different surface treatment, 6 groups each group 7samples according to surface treatment. A universal testing machine was used to determine the surface roughness value. One- way ANOVA test (analysis of variance) to verify if there any statistically significant difference within each group and among the six groups. Least significant difference (LSD) test to compare between each group when ANOVA test showed significant difference. t- test to examine the source of differences. Results: -On -way (ANOVA) test was used to analyses the results, there was highly significant differences between the groups. Conclusion: - In this study, all surface treatments provided adequate surface roughness values compared to control group (C), with the exception of combination of sandblast and KOH group (SB. K).

Introduction:

Commercially pure titanium (cp-Ti) and its alloys have been widely using as dental restoration biomaterials due to its biocompatibility (1-3) and good mechanical and corrosion resistance (4, 5) All the studies concluded that the titanium corrosion resistance (6) in these media is due to the formation of an adherent and

highly protective oxide film on its surface which is mainly formed of TiO₂(7). The combination of high strength-to-weight ratio, Lightweight, Non-toxic, Non-ferromagnetic, Cost-efficient and Long-range availability makes titanium the best material choice for many critical applications such as In industrial settings

where max strength ratios and excellent resistance to corrosion are necessary, such as in jet engines, fuselages, and the aerospace industry, titanium alloys are frequently used and extra applications(9). Today, The CP-Ti and Ti6Al4V alloy are the most used titanium material(2) in dental implants, surface coatings, and more recently for crown, partial and complete dentures, and orthodontic wires(10). They can be grouped into three major categories such as α -alloys, β -alloys and α + β alloys(11). Their properties are dependent on microstructure which, in turn, depends on the chemical composition and thermomechanical processing(12, 13).Titanium is an element which undergoes a phase transformation at 882° C (degree Celsius), which means that the firing temperature must be held well below this temperature in order to maintain its original properties and to avoid the α to β phase transition (14).

A surface treatment can also be classified into mechanical, chemical(15), and physical methods. In dental restoration, the surface treatment is used to modify the surface topography and surface energy, resulting in an improved wettability(16).

Many physical and chemical surface treatments for Ti have been proposed(17), including sandblasting, alkaline(18, 19), and acid etching. All of these surface treatments are the most commonly recommended methods for creating surface roughness(13, 20, 21) and provide desirable undercuts(22).

Titanium copings were made using a variety of methods, including casting, spark erosion, additive manufacturing, and CAD/CAM (23). To avoid formation of the α -case layer and to make coping fabrication process simpler and faster, computer aided design/computer aided machine (CAD/CAM) system have been used to mill coping from a prefabricated titanium block enables to control the uniformity of the alloy composition (24).

Materials and Methods:

Designing of specimens

In the present study, 42 cylindrical titanium (CupraTi-5 White peaks dental DE, Germany, 98 12 mm) parts were

produced using a computer-aided design/computer-aided manufacturing system. The titanium samples were made in the form of a cylinder with dimensions of 4x4mm and a base of 5x1mm (according to International Organization for Standardization (ISO) 9693:2019) Fig. (1) and were created utilizing specialized 3D modeling software (Sketchup 3D design software).

The wet milling process of the disc that uses the 5-axis milling unit Fig. (2). The milling process of titanium blocks Fig. (3) was done by using 5 burs Fig. (4), beginning with a 3.00mm diameter for cutting the outlines, then moving on to 2.00mm, 1.5mm, C), 1.00, and finally a 0.60 mm diameter for making the specimen's base.

The finishing of titanium specimens Following the manufacturer's recommendations, a sandblasting machine (Renforth, GmbH, Germany) was utilized to sandblast the specimen's surfaces of clean aluminum oxide (110 micrometer) (Dentify GmbH, Scheffelstr Germany) at 2-3 bar pressure. Finally, each sample was measured which use Vernia (United Kingdom), and the final form of the metal substructures is shown in Fig. (5).

The samples were classified into (six) groups based on their surface treatment. Each surface treatment group contained seven (7) samples, as shown in Fig (6)(25).

a. Control group(C)

This group, which consists of seven titanium specimens, did not receive any improved surface treatments after the 110-micrometer sandblasting that was applied to all groups. without treated.

b. Sandblasting with Al_2O_3 group (S.B)

Using a sandblasting unit, seven samples of titanium were air abraded with (50 micrometer) aluminum oxide (Al_2O_3) (Renfert, Germany) for ten seconds at 80 Pounds per Square Inch at a distance of 10 millimeter from the nozzle opening (26). After sandblasting, titanium samples were washed with boiling water to remove debris, oil, fingerprints, and other residues (27).

c. Titanium alloy soaking in sodium hydroxide group (Na)

In this group, a 5 M NaOH alkaline solution was first compiled in glass beakers. J.T. Baker Chemicals and Reagents, Germany, embedded every specimen in this solution for five minutes before thoroughly cleaning them with deionized water and continuing to allow them to air dry at room temperature (RT)(19).

d. Mixing of sandblasting with Al₂O₃ and sodium hydroxide group (SB. Na)

Also, every specimen in this group was sandblasted for ten seconds with Al₂O₃ particles at eighty pounds per square inch, ten millimeters away from the nozzle opening [28]. Furthermore, each specimen was washed of heat and dried at room temperature. J.T. Baker Chemicals and Reagents, Germany, embedded each sample in this solution for five minutes before thoroughly washing with deionized water and allowing it to air dry at room temperature (RT).

e. Titanium alloy soaking in potassium hydroxide group(K)

In this group, a 5 M NaOH alkaline solution was first compiled in glass beakers. J.T. Baker Chemicals and Reagents, Germany, embedded every specimen in this solution for five minutes before thoroughly cleaning them with deionized water and continuing to allow them to air dry at room temperature (RT)(19).

f. Mixing of sandblasting with Al₂O₃ and potassium hydroxide group KOH(SB.K)

Also, every specimen in this group was sandblasted for ten seconds with Al₂O₃ particles at eighty pounds per square inch, ten millimeters away from the nozzle opening [28]. Furthermore, each specimen was washed of heat and dried at room temperature. J.T. Baker Chemicals and Reagents, Germany, embedded each sample in this solution for five minutes before thoroughly washing with deionized water and allowing it to air dry at room temperature (RT).

Surface roughness measurement:

Each specimen's average surface roughness was calculated as a mean roughness profile (Ra). The specimens were secured by a unique metal base. Fig (7). The holder was attached to Profilometer surface roughness testing device (TR200, China).

Each specimen received three readings, and the mean Ra was calculated to determine the specimens' general surface characteristics(28, 29).

Result:

The data collected were subjected to computerized statistical analysis use (SPSS, version 42) and Excel program for doing graphic presentation.

Descriptive Statistics of surface roughness:

All specimens' Ra test results were expressed in (m) units. Tables (1), Fig. (7) give the descriptive statistics for the Ra values, including the minimum, maximum, means, standard deviation, and standard error for each Titanium group.

In Table (1), the highest mean of Ra values was in (Na) group, while the lowest mean of Ra values was for (C)and (SB.K.) groups respectively.

Inferential Statistics of surface roughness:

a. One-Way (ANOVA) test for Titanium groups

As shown in Table (2), a one-way analysis of variance (ANOVA) test was conducted to determine whether or not there was a statistically significant difference in the mean values among all the titanium groups. In Table (2), one- way ANOVA test manifested that there was statistically highly significant difference in roughness all among Titanium groups at level $P < 0.001$ in SPSS statistical analysis use one way (ANOVA)

b. Least Significant Difference test (LSD) For titanium groups:

Also, in Table (3), the results of the LSD manifested that there is a non- significant difference between (C) group with (SB.K.) and while for (Na), (S. B) (SB. Na) and (k) group, there was highly significant with (C). So that in Table (3), the results of the LSD manifested that there is a significant difference between (S. B) group with (Na) and while for (S B. Na), (K) and (SB. K) group, there was highly significant with (S.B). Also in Table (3), the results of the LSD manifested that there is a highly significant difference between (SB.Na), (K)and(SB.K) group with (Na).And show non-significant difference between (SB.Na) group with (SB.K) and while for(K) group, there was highly significant with(SB.Na). Finally, the results of the LSD manifested that there is a highly significant difference between (K) with (SB. K) group.

Discussion:

Surface roughness results from this study showed that the sodium hydroxide group (Na) had the highest mean Ra values, whereas the lowest (C) as well as (SB. K).

The influence of the sandblasting process:

All groups were sandblasted with airborne particles assessing 110 micrometer Al_2O_3 in accordance with the manufacturer's instructions, after which the control group received no further treatment.

In this research, the sandblast group (S.B) has been sandblasted by fifty micrometer of Al_2O_3 aluminum oxide particles at eighty Pounds per Square Inch (psi) for ten seconds, because it was noted to be the best sandblasting material in terms of mechanical bonding strength(30).

The findings of current study, that also revealed fifty micrometers of sandblasting particles with titanium samples sandblast group (S.B), produced a highly significant (HS) rise in the average roughness value when compared to the control group (C) with no treatment. The results of this research agree with those of Yuda et al., 2019, who reported the ability of fifty

micrometers Al_2O_3 particles to produce discrepancies on the surface of titanium, resulting in surface roughness but also elevated micromechanical retention.

The sodium hydroxide operation does have the following influences:

The current research found that (5M) five molarity sodium hydroxide alkaline solution created a highly significant (HS) difference in surface roughness values when compared to the control group (C).

This study's findings are consistent with those of Hu et al., 2019, who discovered that alkaline etching is a common treatment process for removing the mechanically weak surface oxide layers of alloys. Additionally, a scalloped surface morphology is produced, which may help mechanical adhesion. However, there have been relatively few studies looking at how alkaline etching influences adhesive bonding. Saleema et al, 2012. They came to the conclusion that the roughness of the micro scale surface texture could increase the adhesive bond strength by about 60%. Even so, the present study's findings contradicted those of (Fawzy and El-Askary, 2009), who claimed that Al_2O_3 produced more roughness than the sodium hydroxide group (Na), despite the fact that the substrate surface became rougher than the control group. Several explanations may be advanced to explain these differences in particles, including changes in study design and alloy composition; their study used commercial pure titanium, whereas the current study used titanium grade V.

The effects of the mixed sandblasting as well as sodium hydroxide procedures were as follows:

The present findings revealed that the roughness value for the combined treatment of sandblasting and alkaline treatment produced a high significant (HS) difference when compared to the control group.

The results of this study are consistent with those of Fawzy and El-Askary 2009, which discovered that the surface roughness values for the mixed treatment

of Al_2O_3 sandblasting particles as well as NaOH alkaline treatment generated surface roughness but also porous surface that would raise the shear bond strength value.

The potassium hydroxide operation does have the following influences:

The current study's findings revealed that, when compared to the control group, a (5 M) five molarity potassium hydroxide alkaline solution created a highly significant (HS) difference in the value of surface roughness.

The results of this research are consistent with Zhang et al., 2020a. In group potassium hydroxide, a significant surface roughness value has been discovered to be high (K). The usage of caustic solution potassium hydroxide (KOH), which would result in mechanical corrosion on titanium surfaces and chemical reactions with titanium alloy constituents, could be the explanation for this.

The current study's findings, however, diverged from those of Kim et al. 2013 because they had shown that KOH-treated samples exhibit distinctive microstructures made of a web of entangled nanotubes or nanofibers, whereas NaOH-soaked samples (at all temperatures) display a porous but much more cellular-looking morphology. They used a different temperature, made changes to the study's design, and used titanium grade V in the current study, whereas their study was using commercial pure titanium. These are just a few of the explanations put forth to explain these differences in the particles.

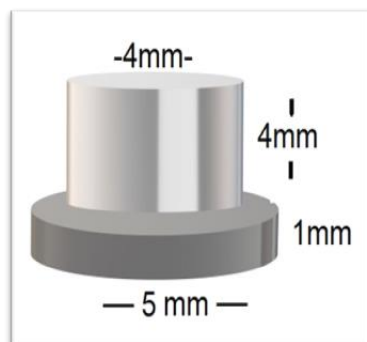


Fig. (1): The samples' dimensions

The effects of the mixed sandblasting as well as potassium hydroxide procedures were as follows:

According to the results of the current study, the surface roughness values for the combined sandblasting as well as alkaline treatment created a non-significant (NS) difference when compared to control group.

When specimens were submerged in KOH solution, there was no longer any aluminum oxide on the surface layer because it had reacted with the KOH solutions, which was described by the combination having a high value of Al_2O_3 on the surface roughness.

Rather than the metal alloy matrix, the peak was connected to the intermetallic that was present on the surface. The percentage shares of Al_2O_3 atoms on the surface layers and the amount of KOH etched surface both influence the metallic alloy peaks.

Conclusion

In the present study the used of effect with the combination of sandblast as well as potassium hydroxide the surface (sandblasting and NaOH), sandblasting, NaOH, and KOH subsequently provided sufficient bonding strength and obtained the best results with the control group.

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Fig. (2): The disc's wet milling procedure

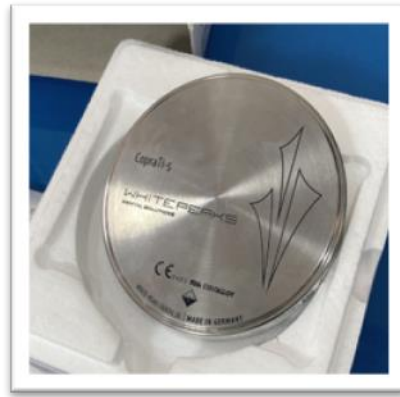


Fig. (3): Blocks made of titanium using a 5-axis milling unit.



Fig. (4): Consequently, the milling process.



Fig. (5): The metal substructures' ultimate form uses five burs using a 5-axis milling unit.

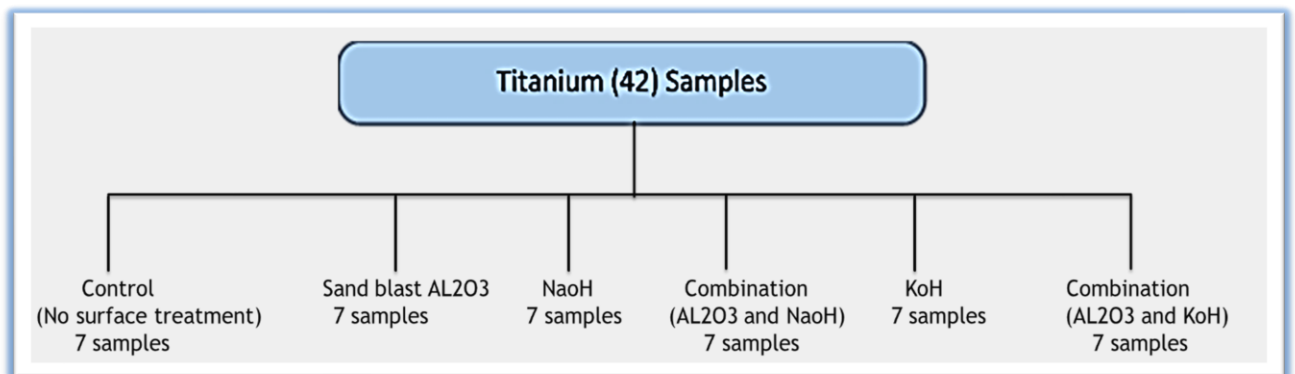


Fig. (6): sample grouping.

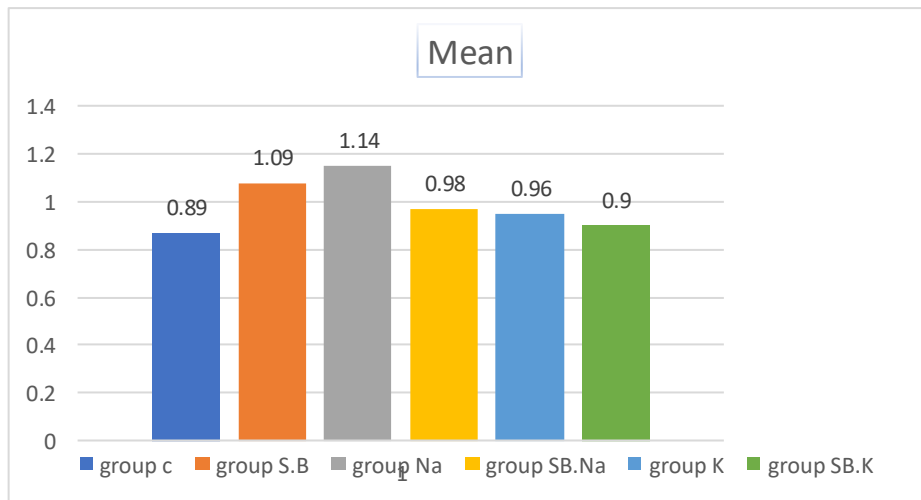


Fig. (7): Bar Chart Demonstrating the Means Difference in roughness of Titanium groups.

Table (1): Descriptive Statistics of roughness of all groups in micrometer (μm).

	N	Minimum	Maximum	Mean	SE	SD
Group (C)	7	.86	.92	.8900	.00816	.02160
Group (S.B)	7	.99	1.19	1.0900	.02236	.05916
Group (Na)	7	1.12	1.16	1.1400	.00655	.01732
Group (SB. Na)	7	.95	1.01	.9800	.00816	.02160
Group (K)	7	.94	.98	.9600	.00535	.01414
Group (S B.K)	7	.88	.92	.9000	.00535	.01414

Table (2): One-way ANOVA test between all groups of roughness.

	F	P-value	Sig.
Between Groups	84.327	0.000	P<0.001 HS

*P<0.001 High significant

Table (3): LSD between all groups of surface roughness.

(I) Variable(1)	Variable(2)	Mean Difference	Std. Error	P-value	P-value
Group(C)	Group (S.B)	-.20000	.01563	0.000	HS
	Group (Na)	-.25000	.01563	0.000	HS
	Group (SB. Na)	-.09000	.01563	0.000	HS
	Group (K)	-.07000	.01563	0.000	HS
	Group (S B.K)	-.01000	.01563	0.526	NS
Group (S.B)	Group (Na)	-.05000	.01563	0.003	S
	Group (SB. Na)	.11000	.01563	0.000	HS
	Group (K)	.13000	.01563	0.000	HS
	Group (S B.K)	.19000	.01563	0.000	HS
Group (Na)	Group (SB. Na)	.16000	.01563	0.000	HS
	Group (K)	.18000	.01563	0.000	HS
	Group (S B.K)	.24000	.01563	0.000	HS
Group (SB. Na)	Group (K)	.02000	.01563	0.209	NS
	Group (S B.K)	.08000	.01563	0.000	HS
Group (K)	Group (S B.K)	.06000	.01563	0.000	HS

*P<0.05 Significant

**P>0>05 Nonsignificant

***P<0.001 High significant

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