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A COMPARATIVE IN VITRO STUDY EVALUATING THE SURFACE ROUGHNESS OF ZIRCONIA Y-TZP BY SAND BLASTING WITH TWO SIZES OF GRANULES 150-250 MM

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ABSTRACT:

The current study compares the roughness of the Y-TZP surfaces of sandblasting with two sizes of granules with the roughness values of the titanium surfaces. The research sample consisted of 20 samples of Italian-made Zirconia Y-TZP with dimensions corresponding to the requirements of the computerized roughness-measuring device and it had two equal groups. The first group was exposed to sand blasting with granules of 150 microns and the second with 250 µm granules. Mahr MFW-250 Device measured the roughness of the sample surfaces before and after sanding for each sample separately. Results were arranged in specific tables for each group and analyzed statistically according to the SPSS software. They showed a significant difference in the roughness values before and after sanding with 150 µm granules and before and after sanding with 250 µm**.** Having compared the results with the standard values of roughness in titanium, the difference between the mean roughness values after sandblasting with 250 µm granules was great. There was a big difference between the mean roughness after sanding with 150 µm granules and the minimum standard value for titanium roughness. The mean roughness values of Y-TZP surface achieved after blasting with two particle sizes of 2.28 µm and 10.3517 µm, were higher than most of the data presented for the topography reported for sandblasting treated zirconia surface, and that the surface of zirconia can be scratched at many levels, but the topic needs further research to examine the effect of these levels on the cellular reaction in the surrounding bone tissue.

Key Words: Bone implant interactions, surface roughness, SLA-titanium, Y-TZP, surface modifications, surface analysis, topography, dental implants

INTRODUCTION:

The biological fixation between the dental implant surfaces and jaw bones should be considered a prerequisite for the long-term success of implant-supported prostheses. Implant surface modifications gained an important and decisive place in implant research over the last few years. As the most investigated topic, it contributed to the development of enhanced dental treatment modalities and the expansion of dental implant use. Nowadays, a large number of implant types with a great variety of surface properties and other features are commercially available. Various techniques of surface treatments have been studied and applied to improved biological surface properties.[1-2] This strategy aims at promotingthe mechanism of osseointegration with faster and stronger bone formation, to confer better stability during the healing process, thus allowing more rapid loading of the implant.[3-4] Some of the objectives for the development of implant surface modifications are:[18]

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- ✓ To improve the clinical performance in areas with poor quantity or quality of bone.
- ✓ To accelerate the bone healing and thereby allowing immediate or early loading protocols.
- ✓ In addition, stimulate bone growth in order to permit implant placement in sites that lack sufficient residual alveolar ridge.

Implant morphology influences bone metabolism: rougher surfaces stimulates differentiation, growth and attachment of bone cells, and increases mineralization. Taking into account the importance of roughness degree, the main methods to create implant roughness are:

- ❖ Acid etching.
- ❖ Sandblasting.
- ❖ Titanium plasma spraying.
- ❖ Hydroxyapatite coating (HA).

A current tendency is the manufacturing of implants with micro and submicro (nano) topography. Furthermore, the biofunctionalization of implants surfaces was conducted by adding different substances to improve its biological characteristics.[4-5]

While abrasive technologies can easily be used to create a micro-topography on titanium surfaces, the preparation of rough ceramic surfaces is more challenging. Typically, abrasive treatments of yttria- stabilized tetragonal zirconia polycrystal (Y-TZP) surfaces result in rather smooth topographies (Ra < 0.6 µm).[6]

The smoothness of the zirconia surface seems to be one of its disadvantages. However, the high rigidity of zirconia implants makes surface roughening very difficult in spite of carrying out several studies to increase surface roughness using sandblasting, by varying particle size and the air pressure, acid etching[7] or laser.[8]

More research is needed on ways to increase the surface roughness of zirconia to enhance osseoimtegration and permanence. Thus, the importance of this study comes from the fact that it measures the surface roughness of Y-TZP implants that were treated by sandblasting with two different sizes of granules, compared with the roughness values published for the surface of titanium sandblasting, which are mostly within the field (3-5) µm,[9] and listed in the table (1).

Previous studies:

- In 2003, Hermann Gotz and colleagues conducted a study to evaluate the topography of the implant surfaces from several systems treated in different ways using a laser microscope to read the roughness of these surfaces. They found the average roughness values for sand blasting and acid etching 3.1 µm, 6.0 µm for titanium plasma sprayed surfaces, 5.8

µm for Surfaces covered with hydroxyapatite.[9]

- There was an increase in the roughness of (SLA) Zirconia implants in a study conducted by Kohal R and colleagues in 2007 to evaluate machined zirconia, sand-blasted zirconia and sand blasted-acid etched zirconia (SLA). Cell proliferation showed statistically significant values after 3 days in treated zirconia surfaces compared with only mashined samples. However, there were no differences between zirconia groups and (SLA) titanium implants after 6-12 days.[10]

- In 2007, Gahlert et al did a comparative study of sand blasted and Machined zirconia implants with sand-blasted and acid-etched titanium implants (SLA). Surface analyzes showed that SLA titanium surfaces had the highest roughness values, followed by sandblasted zirconia surfaces and, finally, machined zirconia implants without any surface treatment.[11]

- In a recent study by Stubinger et al, 2008, the effect of erbium-doped yttrium aluminum garnet, CO2 and diode lazer was assessed on the surface properties of polished zirconia implants. SEM analysis revealed that diode laser and ER-YAG did not cause visible surface changes. However, the CO2 laser has made significant modifications to the zirconia surface. Surface analysis of the electron microscope (SEM) showed that diode, ER-YAG lazers did not cause any changes in zirconia surfaces, while CO2 lazer caused distinct changes on the zirconia surface.[12]

- In 2005, Sennerby et al studied the effect of micro topography on the surface of zirconia implants on the osseointegration of these implants using titanium implants with oxidizing surfaces as a control sample. The resistance of removal torque observed with modified zirconia implants was similar to that of oxidized titanium implants and significantly higher than that of non-modified and machined zirconia implants. However, no significant difference has been reported in the bone-to-bone contact (BIC) between different substances.[13]

- Langhoff et al. 2008 compared BIC Bone Implant Contact of chemically modified titanium implants (plasma oxide or calcium phosphate coated), with Medicinal-coated titanium implants (Bisphosphonate or type I collagen with conduit sulfate) and with titanium implants and sand blasted-acid-etched zirconia implants. Zirconia implants showed 20% more osseointegration than titanium implants after 2 weeks and improved after about 4 weeks,[14]

MATERIALS AND METHODS:

Research Materials:

- 20 samples of Italian-made zirconia (Zahn) were prepared with geometrical shapes of dimensions that meet the requirements of the measurement device.

- The sample was divided into two groups according to the size of the granules used in the sand blasting process.
- The samples of the first group were numbered from (1-10) figure (1), and the second group from (11-20) figure (2).

- **Mahr Perthometer MFW- 250** was used to measure roughness levels figure (3).

- A digital camera was used to keep track of work stages.

Research Methods:

- Using specialized laboratories, samples of the first group of sand blasting were exposed to granules of size 150 µm figure (1), and samples of the second group of sand blasting with granules of size 250 µm figure (2).

- The roughness of the sample surfaces before and after sandblasting for each sample was measured using Mahr MFW-250 in the Faculty of Technical Engineering - Tartus University figures (3-4-5).

- Results were arranged in special tables (2-6) for each group to be examined statistically according to the SPSS software.

RESULTS AND DISCUSSION:

The table (2) shows the results of the samples roughness of zirconia before and after sandblasting treatment with granules of 150 µm. These values are graphically represented in figure (6). Table (3) describes the variables related to these values. The mean roughness values before the sanding show 1.7945 µm and after the rocking 2.2852 µm.
To determine whether there were significant differences in the degree of roughness before and after sandblasting with 150 µm granules, two assumptions were made:

- The null hypothesis: There are no fundamental differences.

- Alternative hypothesis: There are substantial differences.
In order to judge this hypothesis, a T-student test was performed for two independent samples, as shown in Table (4). Since the sig = 0.037 value shown in Table (5) is smaller than the significance of 0.05, we reject the null hypothesis and accept the hypothesis of a fundamental difference in roughness before and after sandblasting with 150 micron granules.

For the roughness of the surfaces of the second group of samples whose surface was treated with sand blasting with granules of 250 µm size, as shown in Table (6). These values are graphically represented in figure (7). Table (7) shows the characterization of the variables related to these values. The mean roughness values before sanding are 1.9813 µm and after the sanding 10.3517 microns. To determine whether there were significant differences in the degree of roughness before and after sandblasting with 250 µm granules, two assumptions were made:

- The null hypothesis: There are no fundamental differences.

- Alternative Hypothesis: There are substantial differences.

In order to judge this hypothesis, a test of two independent samples was performed as shown in Table (8). Since the sig = 0.000 value shown in Table 9 is smaller than the significance level of 0.05, we reject the null hypothesis and accept the hypothesis of a significant difference in the degree of roughness before and after sanding with granules of 250 microns.

Comparison of results with standard values of roughness:

First, compare the degree of roughness after sandblasting with granules (150 µm) with published standard values, ranging from (3-5 µm).[9] The mean roughness resulting from sandblasting with granules (150 µm) was 2.28 µm and there is a clear difference between its value and the standard maximum value (5 µm). However, the question is, is the difference between the value of this mean (2.28 µm) and the minimum standard value (3 µm) a significant difference? From here and to a moral test, we use A t-student test for one sample as shown in Table (10-11) where the value of sig = 0.003 is smaller than the significance of 0.05, meaning that the difference is significant and valid.
Second, comparing the degree of roughness after sandblasting with 250 µm granules with standard values (3-5 µm) we find that the resulting mean value is 10.35 µm and the difference is clear and clear from the standard values.

The mean values of Y-TZP surface roughness achieved after blasting with two particle sizes; are higher than most of the data provided for micro-topographies that were previously reported for sandblasted zirconia ceramics, which ranged between 0.56 µm (ZrO_2 [19), 0.96 µm (Y-TZP [20]), 1.1 µm (Y-TZP [21]); ~ 1.5 µm (ZrO_2 [22, 23]) and 1.78 µm and 3.19 µm.[18]
It should also be noted that in all of the above studies the Ti-SLA roughness was higher than sandblasting zirconia, whereas in Arthur B et al 2010 [18] the roughness of Ti-SLA (Titanium- Sand blasted and Asid etched) and Y-TZP-SS(Y-TZP Sand blasted with Small grits) was very similar 1.72 µm and 1.78 µm). This was the case even though titanium was sandblasted with a large grit similar to the Y-TZP surface that was sandblasted with fine particles (Y-TZP-SS). Again, this difference may be due to differences in toughness and brittleness of the bulk materials.

The published research has reported several ways to change the surface and surface chemistry of the Titanium.[17] The plasma-coated surface of titanium shows an acceptable roughness, but it is no better than surface topography created by sand blasting or acid etched titanium.[16] Surfaces treated with sand blasting and acid etching showed better osseointegration .These studies indicate that surface modification suggests a synergistic mechanism to promote bone formation between the topography (due to sandblasting) and fine matter (due to acidification).[17] However, there is a possible solution to the problem of zirconia smooth surfaces in order to use zirconia implants more widely by comparing the average roughness values obtained in this study in both groups, 2.28 and 10.35 µm, with roughness obtained by Grohmann S et al. 2017 by applying the abrasive treatments of Y-TZP zirconia surfaces, which produced a smooth surface (Ra <0.6 µm).[6]

Since most implant systems rely on the fact that bone tissue can adapt to surface roughness in the 1 - 100 µm range, changing surface topography of the implant can significantly improve its stability.[15] Due to the average surface roughness of the zirconia we obtained when sandblasting with granules 150 and 250 µm, we find that the results of this study correspond to the findings of Langhoff et al l. In 2008.[14] The sandblasted and acid-etched zirconia implants showed a 20% improvement in osseointegration when compared to chemically modified titanium implants (plasma oxides or calcium phosphate coated) and chemical-coated titanium (bisphosphonate or collagen type I with conduit sulfate) and with sandblasted-acid etched zirconia implants.

In a similar case to Sennerby in 2005, [13] the removal torque strength observed with modified zirconia implants was similar to that of oxidized titanium implants and significantly higher than that of non-modified zirconia implants when examining the effect of micro-structure of zirconia implants on the Osseo integration of these implants using titanium dioxide-coated titanium implants as a control sample.

The data verified in this laboratory study allow us to conclude that Y-TZP zirconia has achieved better results for surface roughness levels using sandblasting than titanium in vitro. However, these results seem to be different from the results of Arthur B. et al. 2010 study that revealed a more pronounced nano-topography on Ti-SLA surfaces compared with Y-TZP, although similar in roughness values.

In vivo studies of the effect of these surface topography, noticed that BIC was increased from 61.4% (Y-TZP) without treatment to 79.3% with moderate sandblasting with small granules (Y-TZP-SS).[18]

However, another increase in surface roughness through a severe sandblasting procedure with large granules reduces the BIC to 48.4% (Y-TZP-SL).

CONCLUSION:

Zirconia may therefore be widely used in dental implants and this requires further clinical research supported by the laboratory results of this study.

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TABLES:

Surface roughness value (µm)	Treatment Method	Implant system
0.37+/-0.07	Machined without treatment	SWMADOS
0.75+/- 0.22	Machined without treatment	Branemark MK
1.67+/- 0.30	Double etched	Steri Oss Uncoated
1.82 +/-0.08	Double etched	3I
1.91 +/- 0.22	TiO2 blasted	ASTRA fST
1.95+/- 0.24	TiO2 blasted	ASTRA fST OBI
2.90 +/- 0.22	Anodic oxidation	ZL Ticer
1.96 +/- 0.05		BICON uncoated
2.91 +/-0.26	Etched& HA blasted	PARAGON SBM
2.95+/- 0.20	Ca Phosphate blasted	Life core RBM
3.12+/- 0.39	Ca Phosphate blasted	BIO HORISON D2
3.14+/- 0.11	Anodic oxidation	Branemark Ti Unite
3.30+/- 0.22	MTX blasted	CALCITEK MTX
3.32+/- 0.22	Blasted& etched	ITI SLA
3.57+/- 0.18	Al2O3 blasted	SEMADOS rough
3.94+/-0.38	Blasted& etched	Frialit-2 Tiefenstr
4.53+/-0.23	Blasted& etched	IMZ Tiefenstr
4.94+/-0.28	Al2O3 blasted	TIOLOX
4.97+/- 0.32	blasted	ANKYLOS
3.60+/- 0.30	TPS	ORALTRONICS kit
4.05+/- 0.48	TPS	BICON TPS
3.67+/- 0.48	FBR;TPS& CaP coated	ORAL TRONICS Pitteasy
4.28+/- 1.37	TPS	ITI TPS
6.63+/- 0.36	TPS	Frialit-2 TPS
6.65+/- 0.35	TPS	IMZ TPS
7.14+/-0.58	TPS	SteriOss TPS
8.71+/- 2.16	TPS	BIO HORISON D3

Table (1) shows the surfaces roughness of processed titanium precipitates in different ways.

Sample number	Roughness degree before sanding (µm)	Roughness degree after sanding with granules of (150µm)
1	1.343	1.512
2	1.930	1.583
3	1.853	2.630
4	1.865	2.018
5	1.830	2.835
6	1.863	2.011
7	1.349	1.763
8	1.931	2.830
9	1.343	2.835
10	2.638	2.835

Table (2) shows roughness values of the samples before and after sanding with 150 µm granules.

	Mean	N	Std. Deviation	Minimum	Maximum	Range
Before	1.7945	10	.39001	1.34	2.64	1.30
After	2.2852	10	.56102	1.51	2.84	1.32
Total	2.0399	20	.53339	1.34	2.84	1.49

Table (3) shows characterization of the variables related to roughness values of the first group samples.

Roughness degree	N	Mean	Std. Deviation	Std. Error Mean
Before	10	1.7945	.39001	.12333
After	10	2.2852	.56102	.17741

Table (4) shows roughness mean values before and after sanding with 150 µm for T-student test.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	5.696	.028	-2.271	18	.036	-.49070	.21607	-.94464	-.03676
Equal variances not assumed			-2.271	16.05	.037	-.49070	.21607	-.94863	-.03277

Table (5) shows results of T-student test of two independent samples before and after sanding with 150 µm.

Sample number	Roughness degree before sanding (μm)	Roughness degree after sanding with granules of (250μm)
11	1.934	8.530
12	2.601	10.530
13	1.828	11.853
14	1.830	10.534
15	1.833	10.529
16	1.961	8.908
17	2.636	8.533
18	1.829	11.820
19	2.018	11.850
20	1.343	10.430

Table (6) shows roughness values of the samples before and after sanding with 250 μm granules.

	Mean	N	Std. Deviation	Minimum	Maximum	Range
Before	1.9813	10	.38234	1.34	2.64	1.29
After	10.3517	10	1.31097	8.53	11.85	3.32
Total	6.1665	20	4.39558	1.34	11.85	10.51

Table (7) shows characterization of the variables related to roughness values of the second group samples.

Roughness degree	N	Mean	Std. Deviation	Std. Error Mean
Before	10	1.9813	.38234	.12091
After	10	10.3517	1.31097	.41457

Table (8) shows roughness mean values before and after sanding with 150 μm for T-student test.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	8.902	.008	-19.383	18	.000	-8.37040	.43184	-9.27766	-7.46314
Equal variances not assumed			-19.383	10.520	.000	-8.37040	.43184	-9.32618	-7.41462

Table (9) shows results of T-student test of two independent samples before and after sanding with 250 μm.

Roughness degree	N	Mean	Std. Deviation	Std. Error Mean
	10	2.2852	.56102	.17741

Table (10) shows characterization of the variables to compare roughness mean after sanding with 150 μm pellets with the minimum standard value.

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Roughness Degree	-4.029	9	.003	-.71480	-1.1161	-.3135

Table (11) shows T-student test results when compare roughness mean values after sanding with 150 µm granules with the minimum standard value.

FIGURES:

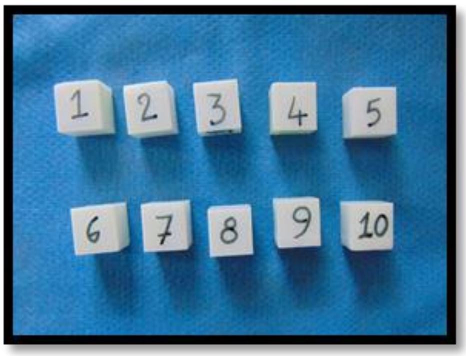


Figure (1) shows the samples of the first group.

Figure (2) shows the samples of the second group.

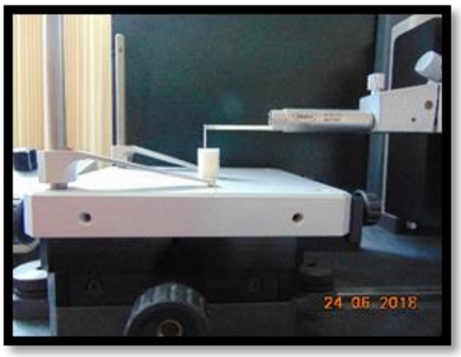
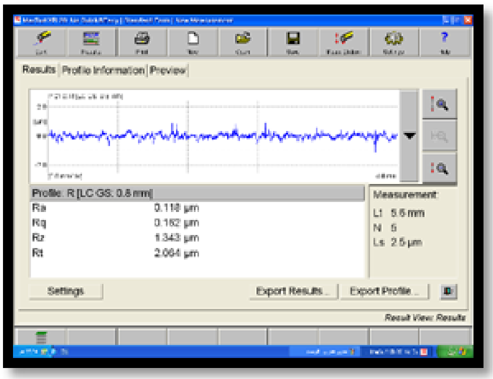


Figure (3) shows the sample during roughness measurement



Figure(4) shows The roughness of the surface and its diagram

Figure (5) shows roughness-measuring device Mahr MFW-250

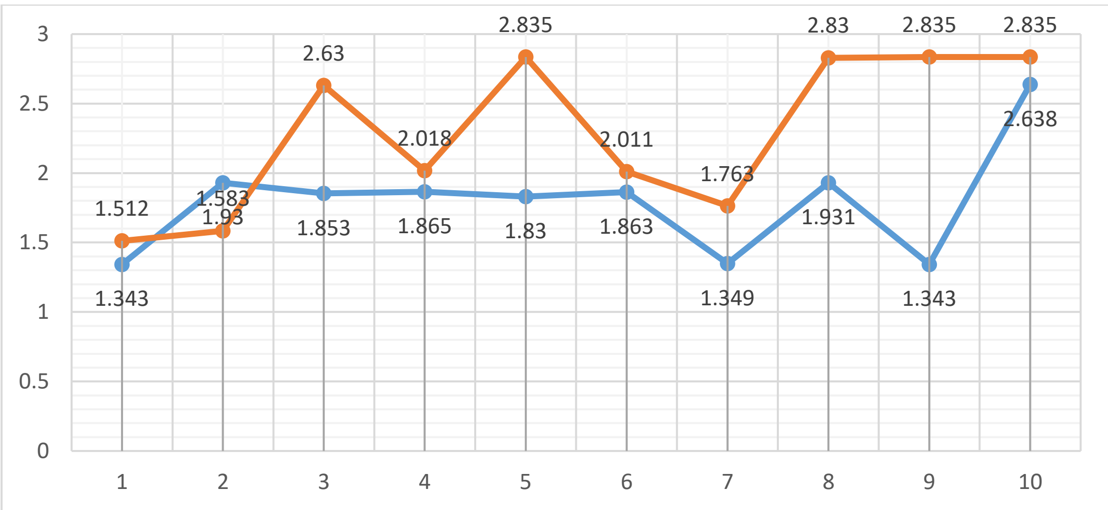


Figure (6) Diagram comparing the level of roughness before and after sanding with 150 µm granules.

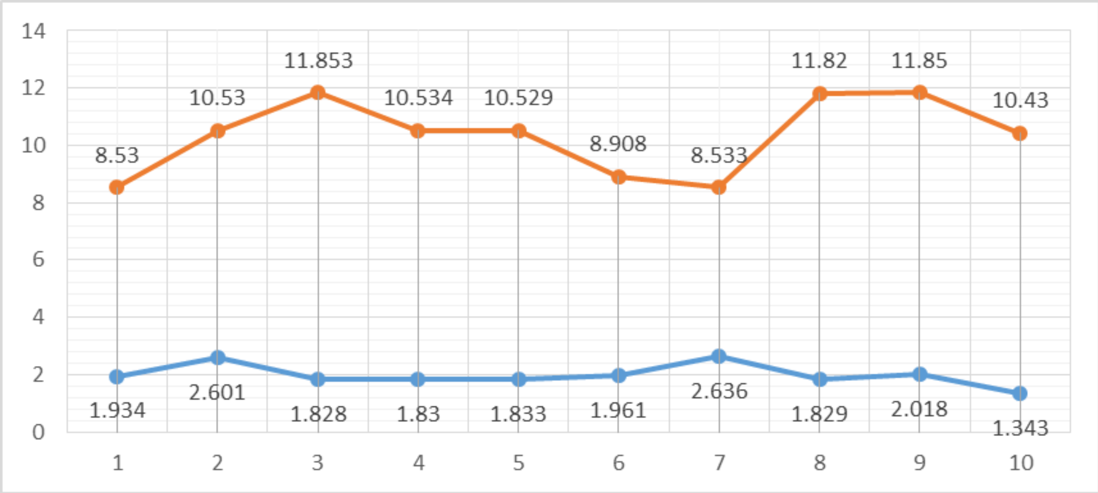


Figure (7) Diagram comparing the level of roughness before and after sanding with 250 µm granules.