Estimation of Surface Modification Methods Effect on Topography of Dental Implants by Using Metrological Observation Techniques

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Abstract. Over the last few decades the use of dental implants has been increasing everyday as a solution for partial or full edentulism. The osseointegration process has to be fully completed to reach a prosthetic phase so that patient can start to use the dental implants functionally. One of the most important factors affecting osseointegration is the surface properties of dental implants. Surface roughness of dental implant is vital to increase bone anchor and maintain the biomechanical stability. In addition to successful application of dental implant, rapid osseointegration has also been desired as a favorable situation. It is demonstrated that there is a strong correlation between the successful application and rapid osseointegration of dental implants and surface morphology and characteristics of dental implants. The aim of our study is to evaluate the surface topography and homogeneity of dental implants with different surface modifications through 2D and 3D observation methods.

Keywords: Surface Modification, Dental Implants, Biomaterials, Measurement

INTRODUCTION

After the osseointegration concept was first introduced by Branemark almost a half century ago, the use of dental implants has been increasing everyday as a solution for partial or full edentulism. Over the last few decades, the number of dental implant brands and technical knowledge has increased substantially. Dental implant has become a routine treatment option in dentistry. The success of a dental implant is mainly based on the osseointegration that is defined as 'the direct contact between the bone tissue and the dental implant surface, without fibrous tissue growing at the interface.' [1-2]. The quality of direct contact between the implant and surrounding bone is very important for short- and long-term clinical success of dental implants [3]

Right after implantation, implants interact with biological fluids and tissues. Direct bone apposition onto the surface of the titanium is critical before prosthetic phase of dental implants [4]. The first is formation of a fibrous tissue around the implant. This condition might break up fixation and stability of the implant which leads to clinical failure of the dental implant. The second type of tissue response is a direct bone–implant contact without an intervening connective tissue layer. This is called as osseointegration and is a prerequisite for prosthetic phase. Many different parameters contribute the osseointegration processes. One of the most important factors affecting osseointegration is the surface properties of dental implants [6-7]. There are numerous reports that display the surface roughness which is one of the most important factors contributing to dental implants affecting the rate of osseointegration [8-10].

Implant surface roughness can be evaluated in various ways depending on the dimension of the measured surface features as macro, micro, and nano-topographies. The surface modification methods of implants can be classified into three types: mechanical; chemical; and physical. These methods can be used to change the implant surface morphology, chemistry and structure. In order to improve the micro topography of the surface, many different advanced methods are being used by the implant manufacturers such as titanium plasma spraying, acid-etching or grit-blasting.

In this study our goal is to evaluate the surface topography and homogeneity of dental implants with different surface modifications through 2D and 3D observation methods.

MATERIAL AND METHODS

In order to quantify geometry changes for each treatment type, the roughness measurements with optical profilometer were performed (Table 1). Optical micrographs of surface topographies were obtained using a Veeco Wyko NT9300 optical profilometer. Titanium surfaces were prepared individually and 2D measurements were performed by the contact stylus profilometer roughness (Mitutoyo SJ 400) according to the ISO 4287. During the measurement procedure Gauss filter with 0.8 mm cut off value, and 0.8 mm length was selected for assessing the 2D profile roughness measurement.

Ti implant samples were prepared from 99.5% pure titanium grade 4 (CP Ti G4). All specimen groups were modified with blasting method. Third group was acid etched after blasting procedure. During the blasting procedure all specimens were attached to a radial forceps to enable homogeneous blasting procedure. First specimen group blasted with titanium oxide (TiO_2) particles approximately 150 µm in diameter with a blast pressure of 4 Bar for 40 seconds. Second group was HA/B-TCP Biphasic Calcium Phosphate blasted. According to the material technical report the composition includes >65% hydroxyl apatite, <35% b-TCP, A-TCP and TTCP, <5% Ca-P materials. The blasting particles were >95% bigger than 300 µm and <5% smaller than 300 µm. For blasting procedure the pressure was selected as 3.5 Bar and specimen was blasted for 50 second. 1.5 mm diameter nozzle was selected. Third specimen group was blasted with Biphasic Calcium Phosphate particles with a radius of smaller than 100 µm. For blasting procedure the pressure was selected as 3.5 Bar. Specimen was blasted for 40 second. Secondly specimen was etched in a hydrofluoric acid bath for 12 seconds to achieve hybrid surface. After surface modification of dental implant all specimen groups were stored in isolated containers before other surface modifications.

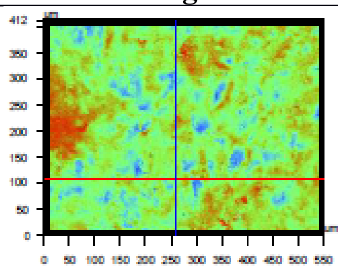
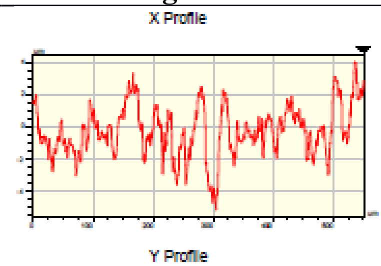
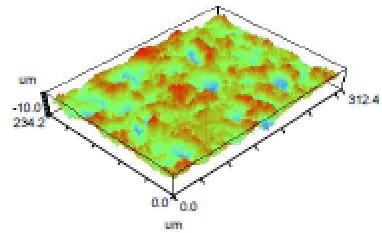
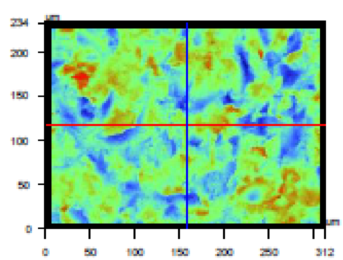
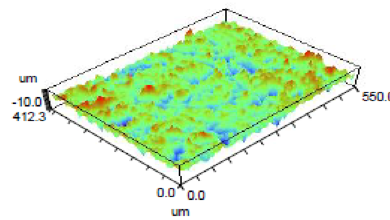
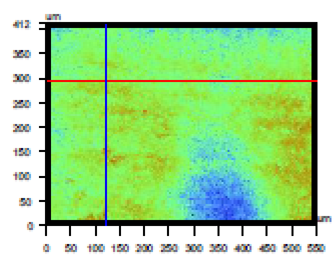
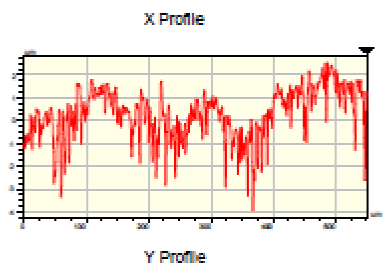
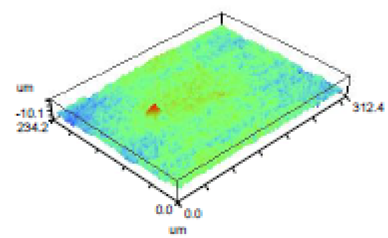
RESULTS AND DISCUSSION

Surface investigation method with optical profilometer and stylus profilometer suggested that there are critical morphological differences on the individual treated dental implant specimen groups. Blasting with TiO_2 material resulted with decreased surface damage which means smaller surface roughness than BCP blasted specimen.

Second group was BCP blasted with particles smaller than 300 µm resulted the highest surface roughness. Hybrid surface, third group, presents smallest surface roughness with smoother edges on the surface. According to the optical observation, the blasted surfaces and the residual particles are easily identified with profiles larger peaks and valley. Surface irregularities and roughness increase proportionally with the increase in blasting particle size. Blasting method provides valley with the damage of substrate and residual blasting materials. It is assumed that acid etching procedure decreased residual materials on the surface.

It can be concluded from optical profilometer profiles images that BCP surfaces and TiO_2 blasted surfaces present higher irregular profiles but BCP surface images indicated wider cavities between the peaks. Acid etched BCP surface points out smaller surface roughness with smaller peak and valley and a homogenous surface.

Table 1. Optical profilometer observations of specimen surfaces

	2D Image	2D Roughness Profil	3D Image
ecarfuS2OiT			
cearfuSPCB			
cearfuSdribyH			

The roughest surface observed from the second group BCP blasted surfaces (Table 1-2). Third group indicates smallest surface roughness with smooth edges. Blasted titanium surfaces present an irregular rough morphology. It can be derived from optical profilometer images that BCP surfaces and TiO2 blasted surfaces demonstrate similar sharp edges and pits but BCP surface images present bigger roughness which is produced by the blasting process with bigger particles.

Table 2. Roughness values of specimen surfaces

	1	2	3	4	5
Hybrid	1,21	1,1	1,05	0,95	1,35
BCP	1,665	1,815	1,725	1,575	1,815
TiO2	1,565	1,475	1,6	1,415	1,355

Table 3. Roughness values of specimen surfaces observed from Optical and Stylus Profilometer

	Stylus Profilometer μm	Optical Profilometer μm
TiO2	1,482	1,678
BCP	1,719	1,875
Hybrid	1,132	1,32

CONCLUSION

All specimens from the blasted groups had irregularities in the form of sharp edges and peaks resulted from surface modification procedure. Acid etching procedure decreased these irregularities. Moreover, in micron level flat areas have been observed which decrease surface contact angle. These changes have not been observed in the macron level.

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