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ORIGINAL RESEARCH

Post-Implantation Alterations in the Surface Topography of Different Implant Systems – A Cross Sectional Pilot Study

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ABSTRACT

Background: Micro-surface treatment is claimed to improve cell adhesion and enhance osseointegration. The retainability of the micro-surface treatment post-implantation needs to be assessed.

Purpose: The purpose of the study was to estimate the post-implantation changes in the surface topography of different implant surfaces created by the subtractive methods.

Material and Methods: Twelve patients aged between 22-45 years participated in the study. 3 different implant systems; MTX surface with hydroxyapatite grit blasting, Microgrip with sandblasting and DPS surface with alumina grit blasting were utilized. The test implants were placed with a torque of 35-40 N and retrieved immediately after placement, followed by placement of a larger diameter implant for delayed loading protocol. The surface topography of the retrieved implant surfaces was examined using a scanning electron microscope (SEM)(stereo scan 440) at high magnification (2000 nm).

Results: The post-implantation SEM image exhibited altered surface topography that varied between the different implant surface textures.

Conclusions: The surface topography varied between different implants based on the types of surface treatments. The sandblasting with acid etchin had better retention of surface topography post-implantation when compared to the other surface treatments.

Clinical implication: Torquing of an implant affects the surface topography and it varied for different implant surface treatments without affecting the osseointegration.

Keywords: *Implant surface; Surface treatment; Osseointegration; Scanning electron microscopy*

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INTRODUCTION

Endosseous dental implants integrate to the underlying bone through a sequence of cellular and molecular events that includes inflammation, repair, and remodeling initiated as a response to trauma.[1,2] To enhance the success of implant therapy clinically, a drastic improvement in implant biomaterials and design has evolved widely.[3] The primary stability of the implant depends on the surgical phase and the macro retention in the implant, while the secondary stability depends on the microsurface of the implant that promotes the cellular response of the host body. The factors that alter secondary implant stability includes modification of surface topography, type of cells, and the bioactive coating (adhesion matrix or growth factor such as a bone morphogenic protein) that may achieve osseointegration.[3,4]

The surface topography determines the bond strength of the implant with the living bone and has a direct effect on the rate and degree of osseointegration.[5] Bond strengths were defined by the forces required to remove an osseointegrated implant. Several studies have confirmed that removal torque was significantly greater for irregular surfaces than the machined surface and it has increased resistance to compressive, tensile and shear stress thereby denoting the efficacy of irregular surfaces in osseointegration. There is constant research in improving the surface details of an endosseous

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implant for better surface quality to enable predictable treatment outcomes, which led to the micro-roughened surface to fasten osseointegration.[5] The micro-roughness enhances the osseointegration not only by surface irregularity but also by an increase in surface area. The surface topographic studies claim that the micro-roughness on the implants varied in surface projections in the range of 10-30 µm interspaced at 20 – 30 µm.[6] Each implant system claimed itself to be superior to the other due to differences in surface modification.

Multiple factors affect implant success; implant design, surgical phase, prosthetic design, and patient maintenance. To obtain a predictable success rate, the insertion torque of an implant must exceed 30 Ncm.[7,8] The insertion torque is the frictional resistance an implant encounters when the implant is torqued apically through a rotatory movement on its axis.[9] Though it is the mechanical interlocking between the implant and bone, a higher insertional torque makes the clinician feel more comfortable and achieving implant primary stability.[10,11,12] However, torqueing the implant, also abrades the surface of the implant leading to alteration in surface topography. It was also observed that the varied surface modifications that aid in osseointegration could be affected by the torqueing of the implant during implantation in polyurethane foam.[13]

The subtractive technique is the most commonly employed surface treatment technique of implant, involving sandblasting, grit blasting, acid etching, or a combination. These techniques increase the microroughness by removal of particles from the implant surface and increase the surface chemistry.[14] Hence, an in-vivo study was proposed to find the changes in the implant surfaces modified with different types of subtractive techniques during placement. The objective of this study was to estimate the changes in the surface characteristics of an implant post-implantation in-vivo and evaluate the differences in the changes based on the type of subtractive implant surface treatment.

MATERIALS AND METHOD

An observational study was conducted in 12 participants aged between 22 – 35 years with missing maxillary anterior teeth reporting for replacement at Sri Ramachandra Institute of Higher Education and Research, Porur, Chennai. Written consent was obtained from the participants, and the study was approved for journal submission by the institutional Publication Oversight Committee with the reference number SRUPOC/2020/10089. The participants were included only when they had adequate width to accommodate a 3.8 to 4.3 mm diameter implant and the teeth adjacent to the edentulous ridge were healthy, without active periodontal disease. Patients with a history of diabetes or any other debilitating systemic disease or who required ridge augmentation with barrier membranes, or allogenic bone grafting were excluded from the study. Based on G-star power analysis, a sample size of 12 was selected for this pilot study. The participants were divided into 3 groups consisting of 4 in each group based on the 3 implant systems with different surface treatments. The protocol of the study was designed to torque-wrench the test implant before the final osteotomy and retrieve the implant for surface analysis. This was followed by completion of osteotomy with final drill and placement of a designated implant that was wider than the test implant. All patients were given detailed explanations of the study protocol and informed consent was obtained.

The 3 groups of test implants used for our study were; Group A - Grit blasted MTX was a non-coated surface that was formed by grit-blasting with hydroxyapatite particles followed by washing with non-etching acid and distilled water (Zimmer - 3.7 mm x 13 mm), Group B - Sandblasted Microgrip surface produced by sandblasting with microcrystal of pure alumina followed by chemical etching and passivation (UniTi - 3.7 mm x 10 mm) and Group C - Grit blasting DPS was a deep profile surface created by grit blast with corundum particles (Al_2O_3) and acid etching (Frialit-2 - 3.4 mm x 13 mm).

A full-thickness mucoperiosteal flap was elevated and after progressive osteotomy up to 13 mm length with the respective implant systems, the test fixtures were torqued to its full length manually with an insertion torque between 35 N to 40 N and then retrieved immediately. The test implants selected were smaller than the final implant size required for the patient. The final osteotomy was completed by Summer’s osteotome and the next higher size diameter implants (Zimmer - 4.1 mm x 13 mm, UniTi - 4.3 mm x 10 mm, Frialit-2 - 3.8 mm x 13 mm) were placed for the participants for rehabilitation by delayed loading protocol.

The retrieved implants were cleaned with hydrogen peroxide and ultrasonic cleanser[UC125 Ultrasonic Cleaning System, Coltene/Whaledent INC, USA]to remove organic tissues and unattached bone. The surface topography of the implant surfaces was examined using a scanning electron microscope (SEM) (stereo scan 440) at high magnification (2000 nm). SEM provided a three-dimensional image to evaluate changes in the surface topography of the implant after implantation.[15] Five micrographs were taken from a scanning electron microscope for all the four samples in each implant system post-implantation and were compared with its pre-implantation micrograph. Five regions in the implant that were taken for SEM analysis were; apical portion, junction of apical and middle third, middle third, junction of middle third and coronal portion, and the coronal portion of the implant surface.

RESULTS

The post-implantation changes in all the samples in each group appeared similar. The SEM image of group A before implantation appeared as micropits that were closely spaced with a uniform texture. But the post-implantation SEM image of group A showed a slight reduction in surface micropits and elevations in the apical portion of the implant. The surface micropits in the middle portion of the implant were almost obliterated. In comparison with the pre-implantation surface, the coronal portion of the implant appeared to be devoid of micro-roughness and appeared as a smooth surface.*(Fig. 1a, 1b, 1c, 1d, 1e, 1f)*

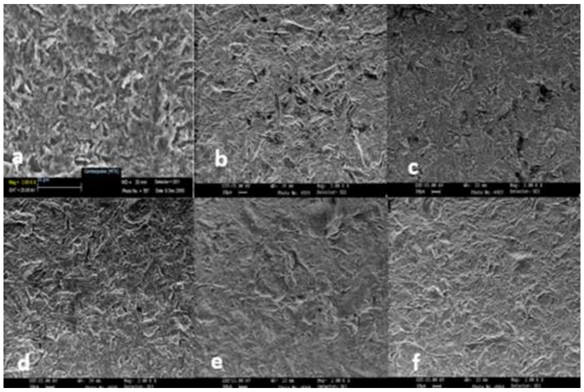

Figure 1.a, SEM image of MTX surface before implantation. b, SEM image of apical portion of MTX surface Zimmer implants post implantation. c, SEM image of apical and middle portion of MTX surface Zimmer implants post implantation. d, SEM image of middle portion of MTX surface Zimmer implants post implantation. e, SEM image of middle and coronal portion of MTX surface Zimmer implants post implantation. f, SEM image of coronal portion of MTX surface Zimmer implants post implantation

The SEM image of group B surface before implantation appeared to be more irregular with deep valleys whereas the post-implantation surface exhibited a slight reduction in surface irregularities and valleys in the apical portion of the implant. A greater reduction in surface irregularity was seen near the coronal portion and the particles were staggered together as a straight line at equal intervals.*(Fig. 2a, 2b, 2c, 2d, 2e, 2f)*

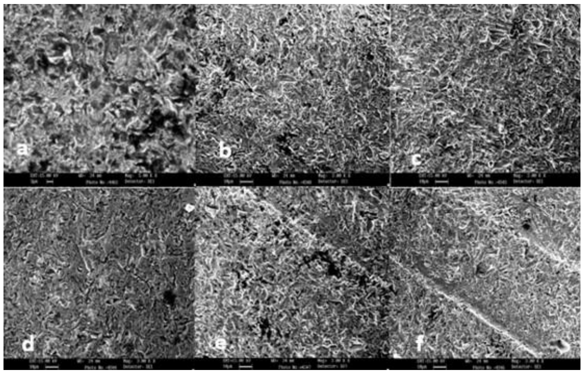

Figure 2.a, SEM image of Microgrip surface of UniTi before implantation. b, SEM image of apical portion of Microgrip surface UniTi implant post implantation. c, SEM image between apical and middle portion of Microgrip surface of UniTi implant post implantation. d, SEM image of middle portion of Microgrip surface UniTi implant post implantation. e, SEM image between middle and coronal portion of Microgrip surface of UniTi implant post implantation. f, SEM image of coronal portion of Microgrip surface UniTi implant post implantation

The SEM image of the group C implant had the micro-retentive surfaces with deep valleys in an irregular pattern. The post-implantation SEM image of the group C surface had only a slight dispersion of the particles in the apical portion of the implant than the pre-implantation image. Moreover, there was no much difference from the preimplantation image until the middle portion of the implant. Whereas, from the middle to coronal portion of the implant, the surface appears smoother without any surface irregularities in the implant surface depicting a total loss of the micro-retentive surface.*(Fig. 3a, 3b, 3c, 3d, 3e, 3f)*

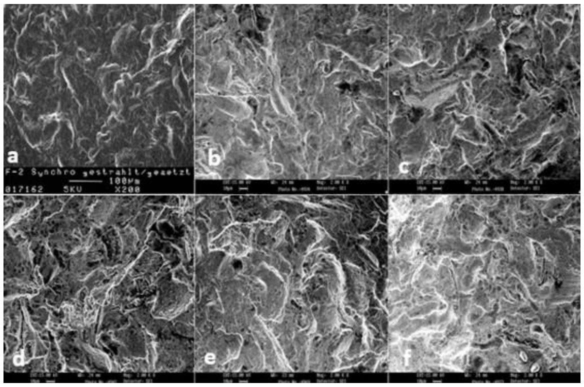

Figure 3.a, SEM image of DPS surface of Frialit -2 before implantation. b, SEM image of apical portion of DPS surface Frialit-2 implant post implantation. c, SEM image between apical and middle portion of DPS surface Frialit-2 implant post implantation. d, SEM image of middle portion of DPS surface Frialit-2 implant post implantation. e, SEM image between middle and coronal portion of DPS surface Frialit-2 implant post implantation. f, SEM image of coronal portion of DPS surface Frialit-2implant post implantation

DISCUSSION

Micromechanical features play a pivotal role in bone growth, turnover, and remodeling.[16] The surface-treated titanium implants get affixed to the bone by the cellular ingrowth into these irregular surfaces to create a biomechanical bonding.[17] Based on the average roughness (S_a), surfaces with $S_a \leq 1$ µm were considered smooth, and those with Sa>1 µm were described as rough surfaces.[18] Moderately roughened implants have greater biomechanical bonding compared to the machined surface.[17] Scientific papers presented confirmed that for a proper in-growth of bone, pores or cavities of minimum 50 - 100 µm is required and a greater biomechanical bonding was observed on surfaces with a roughness of 1.5 µm.[2,19] These microscopic features in congruence with the macroscopic implant thread profiles provides high compressive loading with lower shear implant interface.[20]

The surface treatment of the implant is classified as; additive or subtractive. Additive surface coating involves anodization, acid etching, and plasma coating, while subtractive involves sandblasting, grit blasting, laser etching, and nanoparticle compaction. Sandblasting, plasma spraying, and acid etching were the most common approaches used by the manufacturer to alter the surface topography and increase the surface area of an implant.[21] Dehua Li et al had enumerated that the micro-rough surface implant enhances the interfacial shear strength of implants compared to the machined surface.[22] Literature also suggests that in comparison with the machined surfaced implants, the sandblasted large grit acid-etched surface implants showed approximately 30 % higher removal torque value's during the healing periods, and also more than 5% higher interfacial stiffness.[22,23] Hence, we utilized three different implant systems with varied subtractive surface treatments, and the SEM revealed a more irregular and evenly spaced surface. These various surface modifications, which aid in osseointegration, could be affected even by an insertion torque up to 40 N during implantation. Hence, the present study was done to evaluate the surface characteristics post-implantation of the implant in human models.

Pre-implantation, the sandblasted and acid-etched surface (SLA) had a moderately rough surface with an average roughness of 1-2 µm.[24] Post-implantation under a scanning electron microscope, the grains on implant surfaces were more closely packed at the apical end of the implants. Whereas, towards the coronal portion, the grains were more widespread indicating that the rough surface observed during pre-implantation reduced at post-implantation due to the torque force. However, the literature reveals that at 3 and 6 weeks after insertion, the SLA implants showed superior bone-to-implant contact (50–60%) compared to various other surface modifications to indicate that the change in surface details while torquing did not affect the osseointegration.[25] The post-implantation SEM images of grit blasting with alumina and hydroxyapatite showed that the surfaces were rougher at the apical and smoother at the coronal portions of the implants. The study revealed the grit-blasted surfaces reduced its surface roughness on implant torquing. Grit blasting is considered similar to sandblasting, but compressed air was used to blast the surface. It has been found that the alumina used for grit blasting remained, and the blasting-modified surface energy of the implants encourages cell adhesion but impedes cell growth.[26] The greatest diversion from the pre-implantation surface topography was seen in the coronal portion of the implants. This could be due to the effect on the coronal portion of the implants while passing through the dense cortical bone near the coronal part with higher resistance. Moreover, the Microgrip (sandblasting with acid etching) surface had retained better morphology with minimal changes in the apical and middle third, while the MTX (grit blasting with hydroxyapatite) had a comparatively smoother surface post-implantation. This proves sandblasting with acid etching (SLA) was better in retaining the surface quality post-implantation than the grit blasting among the subtractive technique.

The study proves that the bone-implant contact alters surface roughness in-vivo. The micro rough surface was related to the bond strength of the implant to the bone [5] and also the literature reveals that the bone to implant contact was higher adjacent to micro rough titanium surfaces in in-vivo studies when compared with machined or polished titanium surfaces.[27] Osteoblast-like cells demonstrate significantly higher adherence to rougher surfaces than to smooth surfaces.[22,28] However our study reveals that the roughness of implant decreases with implant torquing. Our study also proved that the implant surface topography was not the only criterion for implant success; the other considerations include the type of bone, quality of bone, and host response place an important role in implant success. Previous studies examining the behavior of osteoblast cells on commercially pure titanium indicated that the proliferation decreased with increasing surface roughness, whereas differentiation increased.[29]

The present study showed that among the subtractive techniques, sandblasting with acid etching (Microgrip) was better in retaining the surface characteristics. Similarly, grit blasting with corundum (DPS surface grain) had microroughness more uniformly dispersed compared to the grit blasting with hydroxyapatite (MTX surface) post-implantation. The moderately roughened surfaces, though had some clinical advantages of improving cell adhesion for enhancing bone growth, our study revealed that the insertion torque affected the surface characteristics of the implant. The previous study showed that the sandblasted large grit acid-etched surface revealed better healing at 6 months with the mean removal torque value of 6.4 Nm, followed by the Titanium plasma-sprayed surface with 5.3 Nm while the polished or fine-textured surfaces showed a mean removal torque value of 0.4 – 0.7 Nm.[5]

The authors concur with Jokstad et al,[30] that the superiority of an implant over others should be based not only on surface design but also on long-term clinical scientific research. The limitations for the present study include; the implants were placed and retrieved and hence the removal torque could have also affected the surface topography. However, the effect of removal torque immediately after implantation will be minimal as there would not be an initiation of secondary stability. Moreover, the surface changes observed between implants in the same group were consistent since a similar protocol was undertaken for all the implant surfaces.

CONCLUSION

We conclude that the surface topography of the implant was affected by insertion torque. Similarly, the changes in the surface topography were influenced by the type of surface treatment; sandblasting and the acid-etched surface were better in retaining the surface details than grit blasting among all the subtractive surface treatments. The present study should be correlated with the clinical results in long-term follow-up.

CONFLICT OF INTEREST

There is no conflict of interest

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