A Study in a Rabbit Tibia Model

The effect of hydrophilic nano-scale surface compared with a sandblasted-acid etched surface on osseointegration.

Alpha-Bio Tec. R&D team, Israel | 2021

Introduction

Developing the ultimate implant surface that enhances osseointegration process is still challenging for many dental and orthopedic indications such as: hip or knee replacement, vertebral implants, stabilization pins, dental implants and more.

Dental implants are considered a successful treatment modality for oral rehabilitation. Yet there are different clinical cases where the procedure is more complex. e.g. compromised bone quality and quantity, osteoporosis or impaired wound healing from systemic medication, and immediate loading or shorter healing periods.

Biomaterial engineering, mainly of titanium alloy implant surfaces, is aiming to create bio-mimicking strategies, that improve osteogenic differentiation and bone apposition.

Implantology researchers have already established that surface modifications such as roughness, different chemical compositions, and energy enhance osteoblast proliferation, differentiation, gene expression and local factor production towards bone growth.

The submicron roughness (sandblasted-acid etched surface) of the implant is on a level smaller than cell diameter. The biological logic is that the osteoblasts will interact mechanically with a surface that mimics the lacuna that was previously resorbed by acidification reaction at the ruffled border of the osteoclast.

The next level of roughness is a nano scale surface which influences the cell-implant interface and reflects the cell-protein interactions Thus the nanotopography effect at the mechanical, chemical and biological level.

The aim of the research is to examine the influence of a hydrophilic nano-scale surface compared with a standard sandblasted-acid etched surface on the bone to implant contact (BIC) in a Rabbit Tibia Model.

Material and methods

This study was conducted under approval of the Institutional Animal Care and Use committee at the Tel Aviv University. All experiments were performed in accordance with approved procedure according to ARRIVE guidelines.

Seven New Zealand white female rabbits, 6 months old mature, weightings between 3.5-4.2 Kg were used for this study. The rabbits were collimated in their cages and held in adjusted enriched environment. The tibial bone was exposed and two osteotomies for 3.75 mm diameter and 8 mm length implants were prepared using the implant manufacturer's drilling protocol. Two commercial implants (Alpha-Bio Tec.) were inserted: one implant with nanoscale roughness (MultiNeO NH) and the other with microstructure roughness (Multineo CS), The distance between the two osteotomies was 8 mm apart.

3 weeks later, the same surgical procedure was performed on the other limb of each the seven rabbits.

Animals were euthanized 3 weeks following the last surgery (6 weeks following the first surgery), 14 tibiae were processed for non-decalcified histology and stained with Alizarin red, two from each implant.

Histology and histomorphometry

After rabbits were sacrificed, the tibial bone and surrounding tissue were collected, and samples were processed for blocks and sliced for histology.

Sections were analyzed and imaged, using Image-J software under light microscopy.

Bone to implant contact (BIC) measurements were performed on each slide. BIC was summarized and divided by the total implant perimeter.

Results

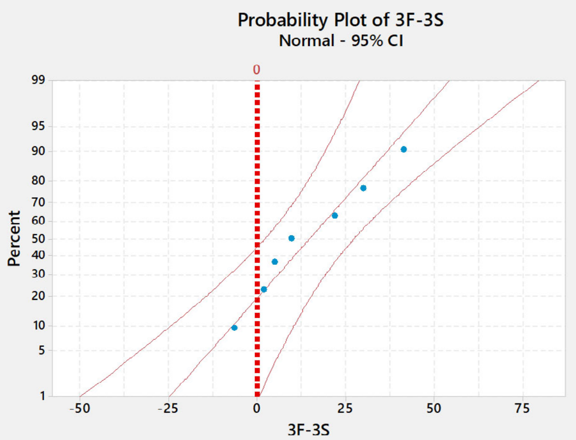
Fig 1

Statistical significance showing advantage of BIC in all animals when hydrophilic nanoscale surface implants were used compared to standard sandblasted-acid etched surface implants, 3 weeks following surgery.

Fig 2

BIC measurements comparison.

At 3 weeks, the nanoscale surface implants showed 55% BIC compared to 42% BIC with the SLA surface implants.



Mean	14.66
StDev	16.99
N	7
AD	0.208
P-Value	0.776

- 3F- hydrophilic nanoscale surface implants.
- 3S- standard sandblasted-acid etched surface (SLA).

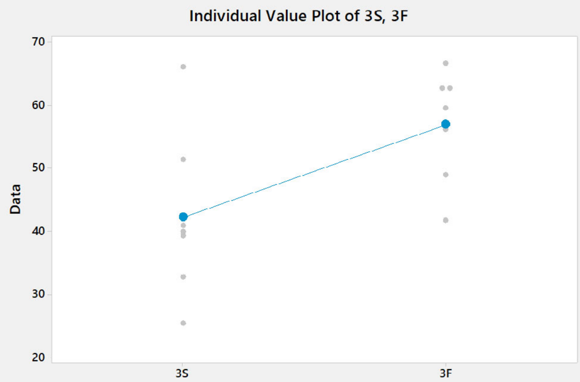


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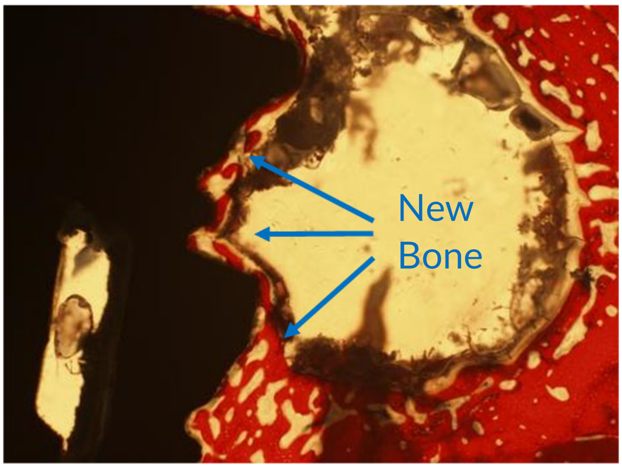
Fig 3

Histology of nano-scale roughness 3 weeks post operative. Blue arrows indicating new bone in contact with implant surface. Mag x10, (nondecalcified section, Alizarin red.

Fig 4

Histology of micron\submicron surface roughness 3 weeks post operative. Note that there is only small amount of new bone in contact with implant surface.

SLA surface implant Mag x10, (nondecalcified section, Alizarin red staining).



Discussion

High osteointegration ability requires several contemporary and synergistic functions. This is the reason why a multifunctional surface (hydrophilic and nanoscale roughness surface) was tested in this preclinical in-vivo study (rabbit tibiae).

Fast healing and new bone formation are a consequence of co-operative action of several phenomena: bioactivity of the surface and apatite precipitation on it (mineralization), fast cell adhesion and proliferation of osteoblastic cells, high degree of cell differentiation and polarization of macrophages leading to production and excretion of BMP2, resulting in enhanced BIC.

The surface topography, chemistry and wettability plays a crucial role in determining bone reaction to the titanium surface (BIC), and demonstrates itself in the early stages following implant insertion surgery, as was shown in this study.

Conclusion

It was clearly shown that early bone healing events, were found to be much more effective in the case of nanoscale surface roughness interaction with housing bone in the rabbit tibiae when compared to the sandblasting and acid etched surface. The advantage of hydrophilic nanoscale implants was dominant at 3 weeks, demonstrating a 30% increase in BIC (55% BIC , compared with 42%). 6 weeks later this advantage was maintained. One may assume that this enhanced healing phase may support early loading in humans due to a higher BIC score, achieved or influenced by the interaction between nanoscale roughness and bone wound healing cascade, both cellular and molecular mechanisms.

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