Designed Topographies Equal Osteogenic Performance Clinical Benchmark

Materiomics has identified surface topographies to promote osseointegration of orthopedic or dental implants by stimulating new bone formation at the site of the bone defect. The extra new bone formation results in highly improved implant anchorage into the bone when comparing to polished (flat) surfaces. Titanium samples were implanted into a well-established in vivo model revealing up to 5 times more direct contact with new bone at the implant surface when featuring Materiomics' uniquely designed topographies compared to polished surfaces. In accordance, the force required to detach the implants from the bone is also increased up to 5 times when including Materiomics' topographies vs. no patterning proving highly increased fixation strength of topography-featuring implants. This effect is not elicited by a coating/secondary material or change in chemical make-up, but by introducing our uniquely designed surface topography (designed roughness) into the core material of the device. Materiomics' unique and proprietary topographies bring excellent opportunities: incorporation into dental and orthopedic devices improves functionality and performance significantly.

Background

Materiomics has identified and *in vitro* validated topographies that promote osseointegration of orthopedic or dental implants (for details see white paper 'Designed Topographies Promote Osteogenic Performance of Medical Devices'). Now we proof the effectiveness of these osteogenesis stimulating topographies by showing enhanced *in vivo* implant performance. Aim in this specific application is to strengthen dental implant anchorage into the jaw bone or artificial joint implant fixation into the bone.

Materials & Methods

The applied *in vivo* model is a well-established rabbit model similar to one described in literature [Ronold, H.J., et. al., Biomaterials 23 (2002) 2201; M. Monjo, et. al., Biomaterials, 29 (2008) 3771]. The coin-shaped full titanium samples featured one of the 3 highest (osteogenesis stimulating) scoring topographies or the lowest (osteogenesis inhibiting) scoring topography (negative control) and nonpatterned (polished flat) surfaces were included as control. The samples were placed in pre-drilled holes of equal diameter to the samples, covered for stabilization and remained implanted for 4 and 8 weeks. Also, we included the commercially available benchmark surface with acclaimed strongly enhanced osseointegration properties [SLA®, Straumann AG, Basel, Switzerland]. These dental implants with a special, generic roughness show clinically relevant improved healing times through improved anchoring and osseointegration in the jaw bone [Novaes, A.B., et. al., Braz Dent J 21 (2010) 471].

The designed topography-featuring implants are analyzed for their effect on osseointegration performance through (I) retention analysis of the implants by pull-out tests - a mechanical test recording the force required to detach an implant from the bone as indication for mechanical fixation of the implant to the bone, and (II) histology of new bone formation in the defect surrounding the implants.

Results

The pull-out test, as presented in Figure 1, shows that the polished controls have the lowest level of osseointegration after both 4 and 8 weeks: the lowest level of force is required to detach the implants from the bone. At 4 weeks, all topography-featuring implants, including the commercial benchmark, require between 2-4 times the forces required for the nonpatterned implant (Low 1/NP) with one high-scoring topography standing out requiring over 5 times the force of the nonpatterned implant. At 8 weeks, the nonpatterned implant now still requires less force to be detached compared to the best scoring topography at 4 weeks. The other topography-featuring implants, including the commercial benchmark, require about 2 times the force of the nonpatterned implant (all week 8) except for one topography that stands out at 8 weeks: requiring over 3 times the force of the nonpatterned implant.

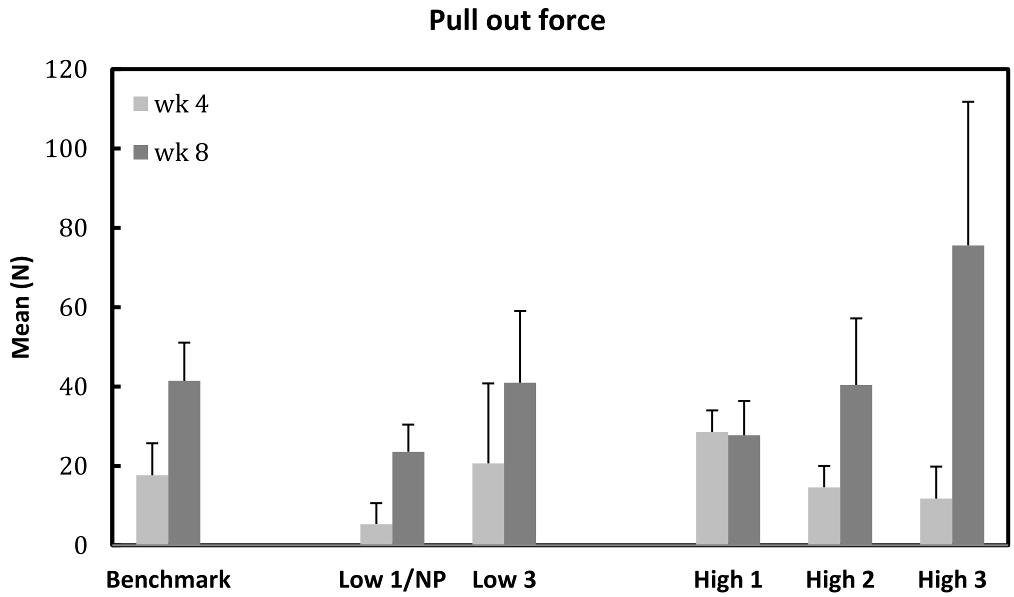

Figure 1: Topography-featuring implants have stronger fixation into bone compared to polished implants. Recorded pull-out forces required to detach implants from the bone after 4 weeks (4wk, light grey bars) and 8 weeks (8wk, dark grey bars) of implantation.

The histology data, as presented in Figure 2, has been quantified regarding the percentage of direct contact of the implants with regenerating bone at the site of the defect, i.e. the surface featuring the topography. At 4 weeks, all implants featuring high-scoring topographies have between 1.5-2 times more bone contact compared to the nonpatterned implant (Low 1/NP), while the commercial benchmark has 3 times that amount. The control low-scoring topography (Low 3) scores 1/3rd of the level of the nonpatterned implant. At 8 weeks, the nonpatterned implant shows no additional direct bone contact compared to 4 weeks. All high-scoring topographies now show about 4-5 times the amount of direct bone contact compared to the nonpatterned implant, which is 2-3 times the amount at 4 weeks. The commercial benchmark shows 6 times more bone contact compared to the nonpatterned implant, which is less than 2 times the amount at 4 weeks. The low-scoring topography shows at week 8 half of the level of direct bone contact compared to 4 weeks, which is a level of 1/6th of the nonpatterned implant.

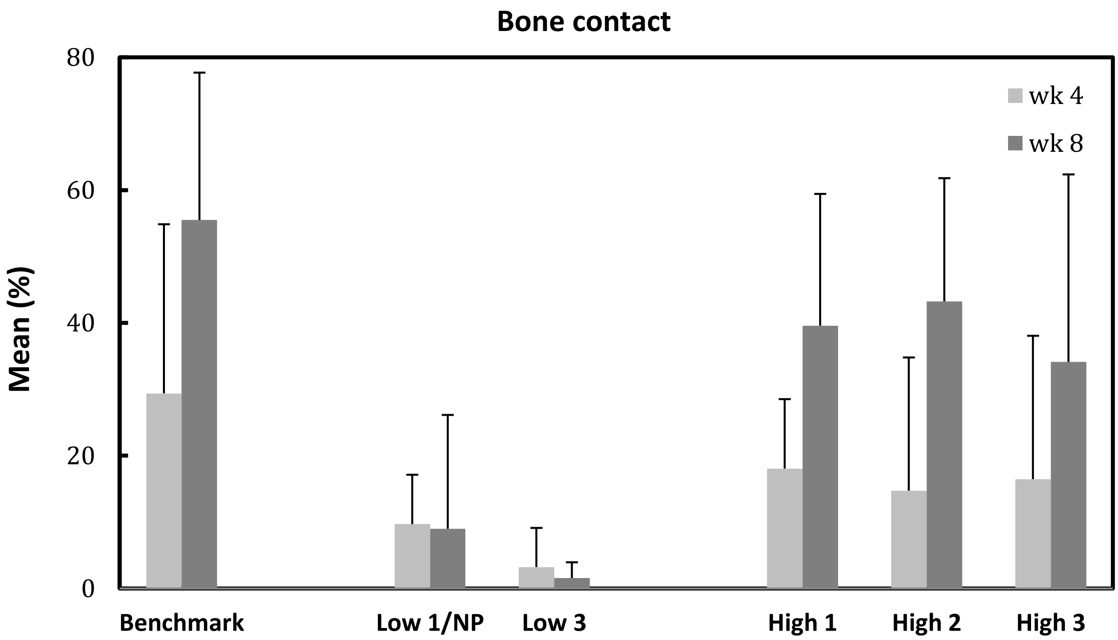

Figure 2: Topography-featuring implants stimulate new bone formation. Direct bone contact between implant and regenerated bone after 4 weeks (4wk, light grey bars) and 8 weeks (8wk, dark grey bars) of implantation quantified through histology.

Together, the pull-out force and bone contact data provide demonstration of the effectiveness of our osteogenic topographies to induce osseointegration in a relevant *in vivo* model. The force required to detach the implants featuring high-scoring topographies equals or is even higher compared to the commercial benchmark, which has proven to bring clinically relevant healing times and anchoring quality in the bone, even though the bone contact data shows slightly lower levels of direct bone contact compared to the commercial benchmark. High-scoring topographies strongly outperform the nonpatterned implants, which is commonly applied in dental and artificial joint replacement implants, in both the pull-out test as well as the percentage of the surface that is in direct contact to the new bone formed at the defect site. At the same time, the results of the low-scoring topography featuring implants show the importance of selecting the right topography, or the clinical outcome can be opposite to what is desired.

In conclusion, our uniquely designed topographies allow for 2 times faster load bearing and 3-5x stronger fixation of orthopedic and dental implants into bone and significantly improve implant performance.