Rate and strength of osseointegration of oxidized and machined, turned titanium implants in rabbit bone for 3 and 6 weeks

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Purpose: The study presented was an investigation of rate and strength of integration of oxidized and turned implants at early healing times. Bonding failure analysis of the bone to implant interface was performed.

Materials and Methods: Screw-shaped titanium implants were prepared and divided into two groups, magnesium ion incorporated, oxidized implants (Mg implants, n = 10) and machined, turned implants (Controls, n = 10). Mg implants were prepared using Micro Arc Oxidation (MAO) methods.[1] Surface oxide properties of implants such as surface chemistry, oxide thickness, morphology/pore characteristics, crystal structures and roughness were characterized with various surface analytic techniques. Implants were inserted in the tibiae of ten New Zealand white rabbits. After follow-up periods of 3 and 6 weeks, integration strength of implants, i.e. removal torque (RTQ) and rate of osseointegration (Δ RTQ/Δ healing time) were measured. The term of rate of osseointegration in the present study was defined as follows: Rate of osseointegration = Δ RTQ/Δ healing time, where Δ RTQ indicates a change of RTQ values and Δ healing time represents an interval of the healing time of implants in bone. For the statistical analysis, comparisons of rate and strength of osseointegration between the groups were performed using Wilcoxon Signed Rank Test. Differences were considered statistically significant at $p < 0.05$, highly significant at $p < 0.01$ and not significant at $p > 0.05$.

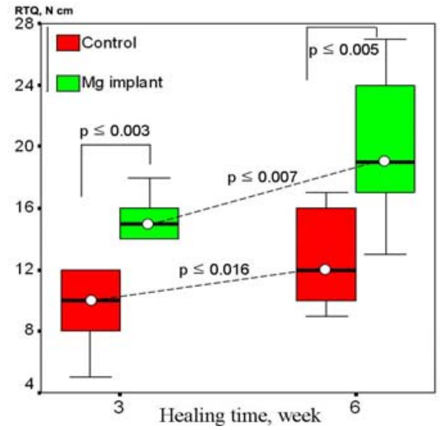
Results / Discussion: Surface oxide properties of implants are summarized in Table 1.

Property	Turned implant	Oxidized Mg implant
composition	Mainly TiO_2.	Mainly TiO_2 ,Mg ≈ 9%.
Morphology	nonporous	porous
Porosity	None	23.7 % (± 0.1)
Oxide thickness	17 ± 6 nm	3400 ± 600 nm
Crystalliny	Amorphous	Anatase + rutilw
Roughnesss	Sa 0.55 µm, Sdr 10.6%	Sa 0.68 µm, Sdr 26.3 %

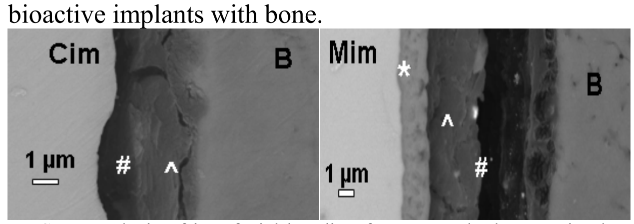
Osseointegration strength in RTQ values are presented in Table 2.

	Three weeks		Six weeks	
Implant	Control	Mg implant	Control	Mg implant
Mean,Ncm	9.4	15.3	12.7	20.1
Sd	2.6	3.5	3	4.4
Max	12	22	17	27
Min	5	9	9	13

Rate of osseointegration (Δ RTQ/Δ healing time, Ncm/week) of test and control implants was respectively 4.2 Ncm/week and 3.1 Ncm/week at a healing time of 3 weeks, and 3.4 Ncm/week and 2.6 Ncm/week at a healing time of 6 weeks. Rate of osseointegration of Mg implants between the healing period of three and six weeks (the dashed lines in the Figure below) is more rapid than that of machined, turned implants: 2.5 Ncm/week vs. 2.0 Ncm/week.



Rate and strength of osseointegration of Mg implants were significantly more rapid and stronger than for turned implants at follow-up periods of 3 and 6 weeks. Bonding failure for Mg implants dominantly occurred within the bone tissue, whereas bonding failure for turned implants mainly occurred at the interface between implant and bone. FE-SEM analysis of interfacial bonding failure showed that interfacial fracture lines for the machined, turned implant were more often observed between the surface oxide of the implant and the soft tissue/immature bone while for the Mg implant it occurred more often between immature and mature bone and sometimes within the immature amorphous bone. The present results support our previous results[2-3] reporting potential biochemical bonding of electrochemically oxidized, bioactive implants with bone.



FE-SEM analysis of interfacial bonding fracture at the bone to implant interface. Cim = control implant, Mim = Mg implant, B = bone, * = oxide layer, # = fractured space during mechanical loads/RTQ testing, ^ = amorphous immature bone layer.

Conclusions: Oxidized, bioactive implants are rapidly and strongly integrated in bone. The present results indicate that the rapid and strong integration of oxidized, bioactive Mg implants to bone may encompass immediate/early loading of clinical implants.

References: 1. Sul et al, Med Eng Phys 2001;23: 329-346. 2. Sul YT. Biomaterials 2003: 24; 3893-3907.
3. Sul et al, Biomaterials 2005: 26; 6720-6730.

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