What surface properties determine significant differences of bone response to oxidized Mg-incorporated, TiUnite and Osseotite implants?

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Purpose: The purpose of the present study was to investigate which surface properties enhance bone response to implants and thereby assess validity of a biochemical bonding theory proposed previously.[1-2] The present study compared rate and strength of osseointegration and osteoconductivity of different types of bone implants

Materials and Methods: Screw-shaped titanium implants were divided into three groups: one custom-made experimental Mg implant (Mg implant) of 3.75mm diameter, and 7 mm length and two commercially available clinical implants, TiUnite® (3.75 × 7 mm, Nobel Biocare, Göteborg, Sweden) and Osseotite® (3.75 × 8.5 mm, Implant Innovation, FL, USA). Sixty screw-shaped titanium implants, twenty implants from each group, were inserted through one cortical layer in the tibiae of ten New Zealand white rabbits, three implants in each tibia for 3 and 6 weeks. Mg implants were prepared using Micro Arc Oxidation (MAO) methods.[3] 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. After a follow-up period of 3 and 6 weeks, integration strength of implants, i.e. removal torque (RTQ) and osseointegration speed (Δ RTQ/Δ healing time) were measured. After RTQ testing, these samples were prepared for undecalcified cut and ground sections and devided into two parts by using the Exakt system. Osteoconductivity of implant surfaces was evaluated by quantifying newly formed bone surrounding implants on the both sides. Statistical analyses were performed by using two-way analysis of variance (ANOVA) and the Tukey test for RTQ values and newly formed bone and the Wilcoxon Signed Rank test for rate of osseointegration. Differences were considered highly significant at p values ≤ 0.01, significant at p values ≤ 0.05 and not significant at $p \geq 0.05$.

Results / Discussion: Surface oxide properties of implants are summarized in Table 1, whereas Osseointegration strength in RTQ values and newly formed bone are presented in Table 2.

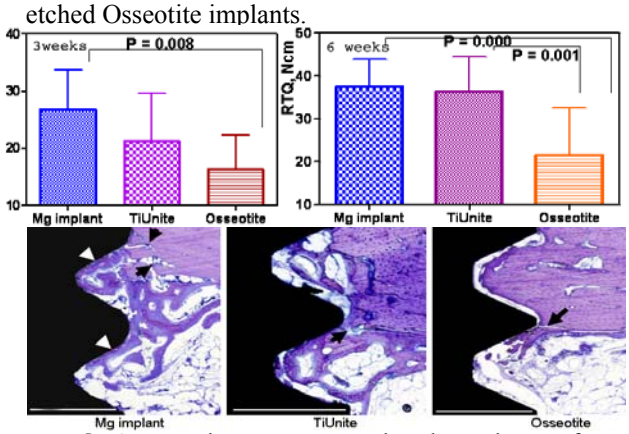
Table 1

Oxide characteristics	Mg implant	TiUnite	Osseotite
Chemical composition	TiO2, Mg ≤ 9.3 at%,	TiO2, P ≤ 10.9 at%.	TiO2. Na ≤ 18 at%,
Morphology	Duplex oxide	Duplex oxide	Micro-pits
Pore/pit size	≤ 2 μm	≤ 4 μm	≤ 2 μm
Oxide thickness	3.4 μm	0.9 -11 μm	3-5 nm[5]
Crystal structure	Anatase + rutile	Anatase + rutile[4]	Amorphous[5]
Roughness,Sa,μm	0.69	1.35	0.72

Table 2. Removal torque measurement, Ncm

	Three weeks			Six weeks		
	Mg implants	Tiunite	Osseotite	Mg implants	Tiunite	Osseotite
Mean	27.1	21.3	15.4	37.5	36.5	21.5
SD	6.6	7.8	6.4	6.5	8	11
Newly formed bone, %						
Mean	29	18	13	39	31.1	25.7
SD	17	16	12	9.6	9.2	16.2

Mg implants demonstrated significantly greater RTQ values (p=0.008 and p=0.0001) and larger new bone formation (p=0.031 and p=0.030) than Osseotite and also showed tendency of higher RTQ and new bone formation than TiUnite at 3 and 6 weeks respectively ($p<0.05$) (Figure1 and 2). TiUnite showed significantly stronger osseointegration than Osseotite surfaces at 6 weeks (p=0.001). Rate of osseointegration (Δ RTQ/ Δ weeks) between 3 and 6 weeks of healing time was significantly more rapid for oxidized Mg (p = 0.011) and TiUnite (p = 0.001) implants, but was not significant for dual acid-etched Osseotite implants.



Conclusions: The present study showed *significantly higher RTQ values* for Mg implants at early healing period of 3 weeks despite their *significantly lower roughness values* than TiUnite (27 Ncm vs. 15 Ncm, $p \leq 0.0001$). The present findings indicate that surface chemistry of oxidized, bioactive Mg implants facilitated more rapid and stronger osseointegration. Potentially bioactive Mg implants may have advantages of reducing implant failure rates in the early stage and increase success when inserted in compromised bone.

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