Testing the mechanical fixation of dental implants

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INTRODUCTION: Sufficient mechanical fixation of dental implants is an essential factor to the success of implant systems [1]. A positive correlation has been found between removal torque and the degree of bone-implant contact [2], which may suggest that removal torque to insertion ratio (RIR) could be used to assess the mechanical fixation. On the other hand, in Kim's study, bone-implant stiffness (BIS) strongly correlated to insertion torque and resonance frequency analysis, also reflecting the mechanical fixation of implants [3]. However, in their study, the crosshead displacement was used to determine the BIS. Here, bone and implant motion (BIM) was directly measured from the implant, and mechanical fixation of the implant was investigated for two different surface finishes.

METHODS: Solid rigid polyurethane foam blocks (40 × 40 × 8 mm, density 0.32 g/cm3, Sawbones, WA, USA) with a pilot hole (Ø2.4/2.8 × 12.5 mm length) were prepared. Twenty-six titanium NobelActive® NP implants (Ø 3.5 × 13mm, Nobel Biocare, Sweden) with two different surfaces (TiUnite® or machined, n=13 each) were manually inserted into bone surrogates to 11.5mm depth. Ten implants were immediately removed after insertion; and, ten implants were removed 2 days after insertion. Insertion and removal torques were recorded with a digital torque wrench (DID-4A, Electromatic Equipment Co, NY, USA).
Mechanical testing (Electroforce 5500, TA instruments, MN, USA) was performed on six implants 2 days after insertion (Fig.1(a)). Five cycles of preconditioning (-4 to -6 N) was applied to a hemisphere loading cup on the implant. Twenty cycles of axial compressive loading were applied with 35 N mean and 15 N amplitude with a frequency of 0.5 Hz. A custom-made disc was attached to the implant and BIM was measured from the disc using a deflectometer (Model: 3540-001M-ST, Epsilon Technology Crop, WY, USA). BIS was determined from the slope of the load-displacement data during unloading.
ANOVA was used to test if RIR was affected by implant surface, waiting time between implant insertion and removal, or mechanical loading. A two-tailed t-test was used to compare the BIM and BIS between implant surfaces. Analyses were performed using IBM SPSS Statistics (IBM Corporation, USA) with significance at $\alpha = 0.05$.

RESULTS: When implants were immediately removed, RIRs were 0.76 (±0.08) and 0.73 (±0.04) for implants with TiUnite and machined surfaces, respectively. After 2 days waiting time, the RIRs significantly dropped to 0.68 (±0.03) and 0.61 (± 0.06) (Fig. 1(b), $p = 0.002$). Surface finish, however, was not a significant factor ($p = 0.12$), even if TiUnite samples had a 5-10% higher RIR mean. There was also no significant difference in BIM or BIS due to surface finish (Table 1).

DISCUSSION:
RIR was affected by waiting time between implant insertion and removal. Due to sample size, type 2 error may have prevented detection of surface finish effects on RIR, BIM and BIS. Bone surrogate compliance was not removed from the deflection measurements, therefore the BIM and BIS are over- and under-estimated, respectively.

SIGNIFICANCE/CLINICAL RELEVANCE: Rigid polyurethane foam is a common material used to mimic trabecular bone in preclinical studies. The study presented here shows that relaxation of the foam after the implantation has a great effect on the testing results and an appropriate waiting time improves repeatability and accuracy of the tests to assess the implant fixation.

REFERENCES:
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2. Johansson et al, Clin Oral Implants Res, **2** :24-29,1991
3. Kim et al., Clin Implant Dent Relat Res **18**:332-41, 2016.

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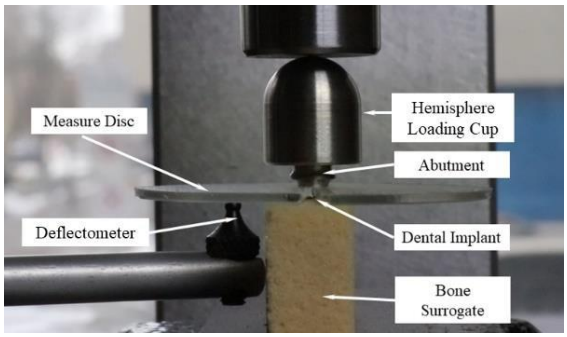
IMAGES AND TABLES:

(a)



(b)

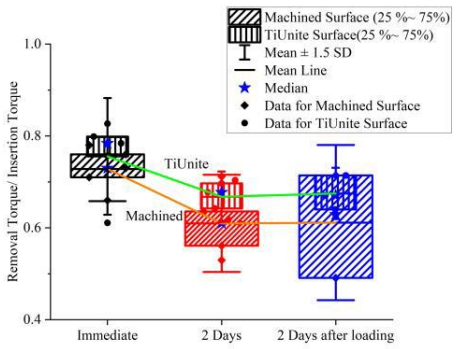


Figure 1(a) Experimental setup (b)Removal to insertion torque ratio (RIR).

Table 1 BIM and BIS for bone-implant system.

Surface Finish	Machined	TiUnite
BIM (μm)	16.8 (± 3.63)	11.5 (±2.62)
BIS (KN/mm)	3.18 (±0.822)	4.78 (±0.767)