PRIMARY FIXATION OF DENTAL IMPLANTS IN BONE SURROGATE IN RELATION TO INSERTION TORQUE - BIOMECHANICAL EVALUATION

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Introduction

Primary fixation of dental implants, mechanical engagement between implant and bone, can be quantified by implant motion (IM) in preclinical assessment under external load to understand implant biomechanics [1]. A high insertion torque (IT) is believed to suggest firm anchorage. However, the relationship between the IT and primary fixation is not trivial. Therefore, the objective of this preclinical study was to investigate the primary fixation and its relationship to IT in rigid polyurethane (PU) foam for two implant designs.

Method

Two implant designs in two sizes [parallel-walled: Brånemark MkIII TiUnite NP 3.5×13 (P1) and WP 5.0×13 (P2), and tapered implants: NobelActive® NP 3.5×13 (T1) and RP 4.0×13 (T2), all from Nobel Biocare] were inserted into PU foam blocks (40×40×8 mm^3, 20 PCF, Sawbones) with a pilot hole (Ø 2.4/2.8 mm for P1 and T1 or Ø 3.2/3.6 mm for P2 and T2) with a constant insertion speed (12 rpm, MACH-1 V500CST, Biomomentum), in dry conditions and room temperature.

The fixation tests were conducted 2 days after insertion with 2 configurations: axial and 30° off-axis loading (Electroforce 5500, TA instruments) with 5 repeats (40 tests, Fig.1). Stepped-cyclic loading was applied: 5 cycles of preconditioning (-4~-6 N), followed by a 3-stepped cyclic loading of 35 N (mean) ±15 N (amplitude), 70±30 N, and 105±45 N (0.5 Hz and 20 cycles per step). For axial loading, IM was measured as vertical displacement (v) (deflectometer, 3540-001M-ST, Epsilon Technology Corp.). For 30° off-axis loading, IM was measured as implant rotation angle (θ) analysed using 2D tracking (Canon EOS Rebel SL2 DSLR, EF-S 18-55mm Lens, Canon. Inc., spatial resolution 22.6-34.5 pixel/mm at 60 fps, Digital Image Correlation Engine version 2.0 [2]).

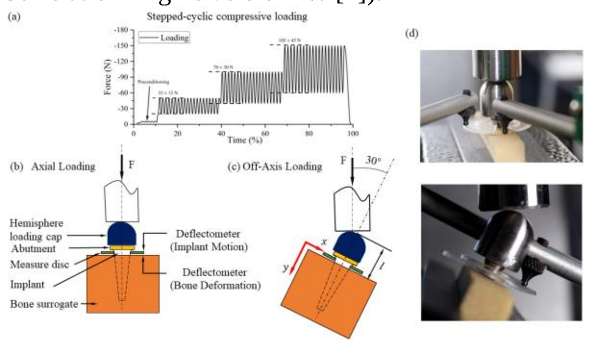

Figure 1: (a) Stepped-sinusoidal loading. (b) Axial loading (c) 30° Off-Axis loading. (d) IM measurements for axial (top) and off-axis loading (bottom).

Results

P1 group had the lowest IT values, while T2 had the highest. Under axial loading, a moderate correlation between maximum v and IT was found (R^2 = 0.59-0.69, Fig 2.) and no failures of the bone surrogate were observed. For 30° off-axis loading, similar coefficient of determinations were found between the maximum θ at the step 1 and IT, and the step 2 and IT (R^2 = 0.59 and 0.66, respectively); in contrast to step 3 (R^2 = 0.092, Fig.2). A few failures of the bone surrogate were observed during the last loading step.

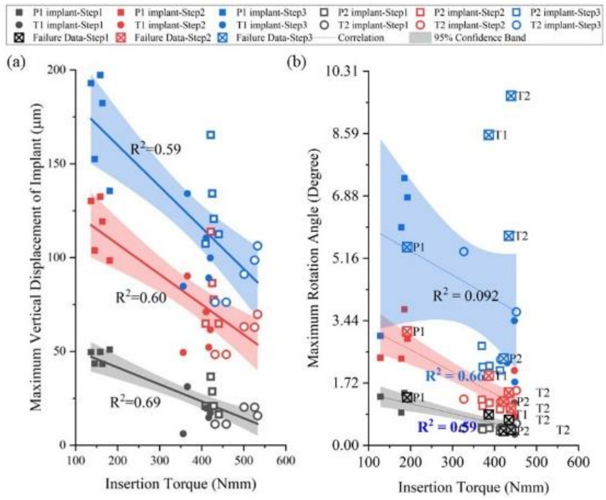

Figure 2: Relationship between the IM and IT for (a) axial loading and (b) 30° off-axis loading.

Discussion

This preclinical study shows the complex relationship between implant IT and primary fixation. While low IT can result in more IM under loading, high IT does not necessarily guarantee better fixation, especially under high and/or complex loads as with off-axis loading. The moderate correlation for the non-failure cases suggested IT may predict primary fixation for stable interfaces over time; however, further studies are required to comprehensively understand interface biomechanics.

References

1. Haiat G et al., Annu Rev Biomed Eng, 16:187-213, 2014.
2. Turner D et al., Sandia National Laboratories, 2015.

Acknowledgements

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