Re-osseointegration as an adaptive response to mechanical overload

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INTRODUCTION: Successful long-term osseointegration of metal implants depends on a direct, structural, and functional connection between bone and implant [1]. Despite high clinical success rates, implant failures still occur. Following disruption of the bone-implant interface caused by mechanical stimuli, successful re-osseointegration has been demonstrated [2,3]. However, the underlying biological and biomechanical responses governing re-osseointegration remain poorly defined. This study used our newly established preclinical model [3] to investigate the temporal biomechanical, tissue, and cellular patterns that contribute to the re-osseointegration process.

METHODS: One screw-shaped titanium implant with an alkali modified surface was inserted per tibia into the tibiae of female Sprague Dawley rats (*n=64*). After 28 days of unloaded healing, mechanical overload was induced by surgically exposing the implant head and snap-rotating selected implants 90° counterclockwise, immediately followed by 90° clockwise rotation. Control implants were exposed but not rotated. Animals were sacrificed immediately or at 3-, 7-, or 28-days post-disruption. Implant stability was assessed by removal torque testing (RTQ), while peri-implant tissues were analysed by X-ray micro-computed tomography, histomorphometry, histology, and electron microscopy.

RESULTS: Biomechanical stability was significantly decreased following disruption ($p < 0.05$, Fig. 1A), due to substantial loss of bone-implant contact and damage to peri-implant bone. By 28 days post-disruption, stability was fully restored and even increased compared to the disruption point control. Following mechanical overload, a staged regenerative response was observed. At 3 days post-disruption, a provisional connective tissue matrix and a strong pro-osteogenic response were present; by 7 days, extensive new bone formation was found in the peri-implant space; and by 28 days, peri-implant bone had remodelled with no evidence of disruption sequelae (Fig. 1C). Moreover, higher bone formation was observed at 28 days post-disruption compared to time-point control (Fig. 1B).

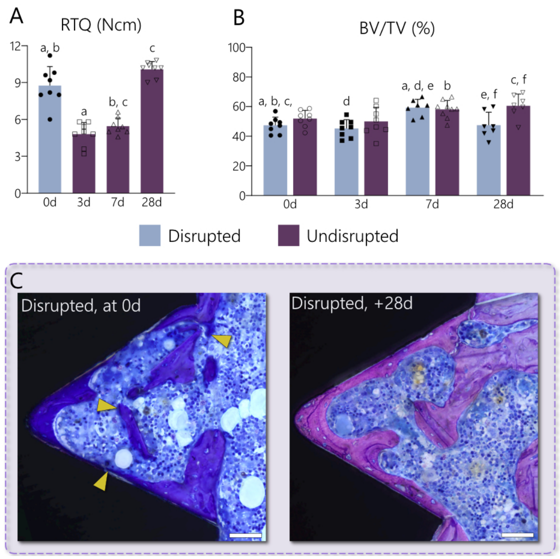

Fig. 1 A) Biomechanical stability measured with RTQ. B) Bone volume within total volume of implant threads (BV/TV). C) Representative undecalcified, basic fuchsin-toluidine blue micrographs showing damage to peri-implant bone following disruption (left) and complete re-osseointegration by 28 days post-disruption (right). Yellow arrowheads point to disruption damage in peri-implant bone. Data are presented as mean ± standard deviation. The same letters indicate statistical difference ($p < 0.05$). Scale bars = 50 µm.

DISCUSSION & CONCLUSIONS: These findings demonstrate that re-osseointegration of mechanically disrupted titanium implants can occur in vivo under non-pathological conditions. Rather than inducing fibrotic failure, mechanical overload in healthy bone triggered a regenerative cascade that repaired peri-implant bone and restored bone-implant contact and biomechanical stability. Enhanced bone formation following disruption indicates that this response was not merely reparative but adaptive to mechanical trauma. Collectively, these data suggest that re-osseointegration is a dynamic, biologically driven process with the potential to increase implant longevity and improve clinical outcomes.

REFERENCES: [1]F.A. Shah et al (2018) *Acta Biomater*, **84**:1-15. [2]C-J. Ivanoff et al (1997) *Int J Oral Maxillofac Implants,* **26**(4):310-5. [3]M. Jolic et al (2025) *Biomater Sci*, PMID: 41111326.