Micro-Computed Tomographic Analysis of Endosseous Titanium Implant Integration: a Novel Approach for Assessing the Anchorage of Titanium Implants in Bone

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Uncemented endosseous titanium implants constitute the standard of care in restorative dentistry and orthopaedic surgery. However, the mechanisms involved in this unique biological interaction with a foreign substance are poorly understood, mainly due to the absence of robust animal models and tools to analyze the implant-bone system. Here, we report a novel method to quantitatively evaluate endosseous implant anchorage by micro-computed tomography (μCT). A 5 mm long, 1 mm diameter titanium screw was inserted horizontally into the proximal tibial metaphysis of 4 months old male rats. The implantation site was examined 2-8 weeks thereafter by a desktop μCT system at 15 μm resolution. To better penetrate the highly radio-opaque titanium and improve the signal-to-noise ratio the system was operated at 70 KeV (energy) and 350 ms integration time, vs. the standard 50 KeV and 100 ms, respectively. The titanium and mineralized tissue were individually segmented by a multi-level thresholding procedure using Image Processing Language and topological operators developed with software devised specifically for this purpose. Unlike the traditional assessment of implant anchorage which is limited to the determination of the implant surface fraction in direct contact with bone (percent osseointegration, %OI) in a few histological sections, the present method analyses the %OI as well as the peri-implant trabecular bone (PIB) volume (BV/TV) and connectivity (Conn.D) densities directly in three-dimensional μCT images. After the μCT analysis the same specimens were subjected to biomechanical testing by a pullout test. All the μCT parameters showed high correlations with the ultimate force and toughness revealed by the implant pullout test. Surprisingly, the correlation coefficients between the biomechanical and PIB parameters were higher than those with the %OI, thus highlighting the critical role of PIB in connecting the implant to the surrounding cortex. The presently developed μCT operational definitions and software for analyzing the implant-bone system comprise an efficient, automatic, non-destructive and highly robust tool proposed as the “gold standard” for the experimental evaluation of endosseous implantation.