Can implants move in bone? A longitudinal in-vivo micro CT analysis of implants under constant forces in rat vertebrae

Kathrin Becker1,2,* Frank Schwarz2, Nicole Rauch3, Silava Khalaph1, Ilja Mihatovic3, Dieter Drescher1
1 Department for Orthodontics, Universitätsklinikum Düsseldorf, Germany
2 Department for Oral Surgery and Implantology, Göthe University, Frankfurt, Germany
3 Department for Oral Surgery, Universitätsklinikum Düsseldorf, Germany

* Presenter of the poster

Objective(s):
Stationary stability of implants has been postulated. Despite, clinical observations suggested that constant loading may induce implant migration1,2. Interestingly, displaced implants did not become loose. If this phenomenon really exists remains puzzling.

In-vivo microcomputed tomography (μCT) allows to scan small animals at different time points at very high resolution. Hence, this method allows to quantify implant displacement over time and to assess the associated bone remodelling.

The aims of the present investigation were to assess (i) if implants can move in bone while remaining osseointegrated, and (ii) to assess the association between positional changes and the magnitude of applied force.

Materials & Methods:
Surgery: Two customized machined implants (0.8 x 3.0 mm, Ra=0.8) were placed in the dorsal portion of caudal vertebrae of n=61 rats. The implants were exposed to constant forces (low force: 0.5 Newton, medium force: 1.0 N, high force: 1.5 N, original as-signment: 16 animals/group) applied through a flat nickel titanium tension spring, or no forces (control/passive spring).

Scanning: In-vivo μCT scans were performed at 0, 1, 2, (all animals) and at 4, 6, and 8 weeks (31 animals). Threshold based segmentation was performed, and forthcoming scans were registered with previous scans based on the segmented bone tissue (Amira software). Implant migration was measured as the linear distance between corresponding implant tips.

Statistics: Linear mixed effects models were calculated to assess the relationship between implant displacement, applied force and time point. Error plots were created for descriptive purposes.

Results:
The post-operative healing was considered as generally uneventful. No complications such as allergic reactions, abscesses or infections were noted except for one animal, that repeatedly manipulated the wound. Metal and motion artifacts affected scans from eight animals, so missing values were interpolated. For all other scan, image registration was performed successfully. Repetition of distance measurements at the anterior implant after one months revealed high reliability (ICC: 0.982).

Discussion:
The present study confirmed that implants can move in bone as a consequence to constant forces.
• Higher forces of 1.0 to 1.5 N induced distinct movements, accompanied by new bone formation.
• In the lower forces (0.5 N) groups implant movement decreased over time.
• Minor implant movements in the initial healing phase seemed to be associated with a regular healing process (control group).
• Implant displacement was in general accompanied by new bone formation. New bone formation at the former implant position may result from a callus distraction like process and a prolonged granulation phase.

The customized nickel-titanium springs enabled constant loading of immediate versus delayed loading protocols.
• The animal model has been sparsely used in dentistry. It was introduced by Renaud et al.3,4. It provides easy operative access, and the impact of surface roughness, and also the impact of distance measurements at the anterior implant after one month revealed high reliability (ICC: 0.982).

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Literature cited: