High Resolution Synchrotron µCT Analysis of *de novo* Bone

Neldam, C.A.[1], Lauridsen, T.[1,2], Lefolii, T.T.[1], Feidenhans'l, R.K.[2], Pinholt, E.M.[1]

[1] Department of Oral and Maxillofacial Surgery, Institute of Odontology, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark
[2] Nano Science Center, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

Background

Osseointegration of dental implants are traditionally evaluated by classic histomorphometry. The evaluation is based on a two dimensional (2D) cross-section of a bone sample using light- or electron microscopy histology.
This method has one major disadvantage; it only gives information of the bone-implant distribution along a single slice through the sample.
Accurate 3D data are necessary for proper comparison between species, bones, different types of bone, and tissues.

Objectives

We present a novel method of 3D evaluation of peri-implant hard tissue microstructure.
Synchrotron µCT consists of a parallel beam and a high photon flux density which makes it possible to evaluate the peri-implant bone volume down to the micrometer scale and reproduce it as a 3D tomography.

Materials and Methods

AstraTech OsseoSpeed dental implants, with a length of 8 mm and 3.5 mm in diameter were installed in a critical size defect in a goat mandible, with the micro threads above bone level surrounded by bone graft (fig. 1).

Figure 1: Critical size defects in a goat mandible.

The bone samples were evaluated at ID19 beam line, at the European Synchrotron Radiation Facility in Grenoble, France.

The beam line specializes in microtomography due to high flux and coherence, and a small beam size which creates high resolution tomography (fig. 2a, b).

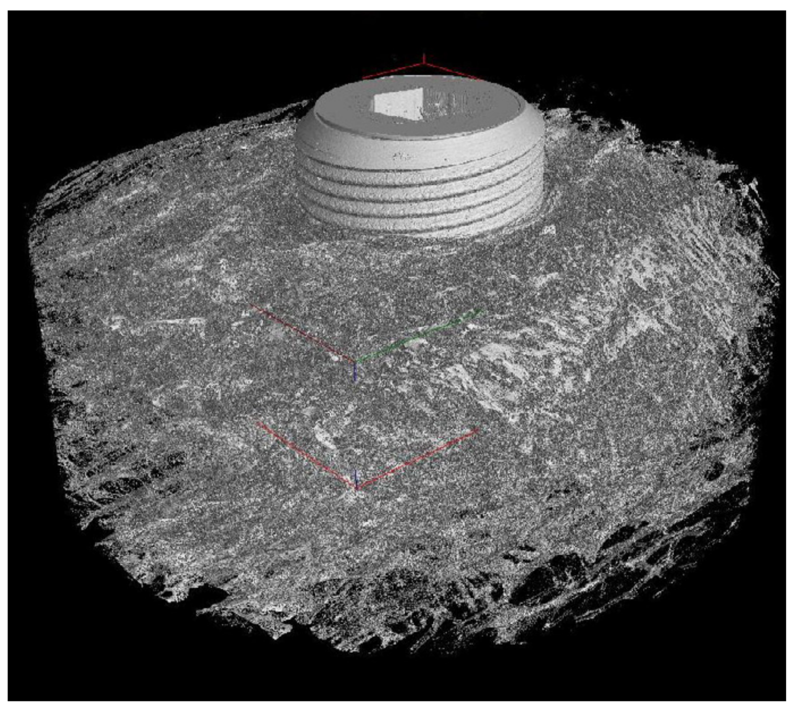

Figure 2a: Synchrotron scan of dental implant surrounded by autologous bone. Resolution: 5 µm.

A high energy, monochromatic beam was used due to the necessity of scanning through the titanium implant.
The pixel size was 5 µm. The region of interest was defined as the part of the sample which representing *de novo* bone and micro threads.

The bone volume surrounding the entire implant surface was evaluated, in conjunction with the level of mineralization, bone to implant contact, and the absorption coefficient of the entire 3D sample and compared to 2D histomorphometry (fig. 3).

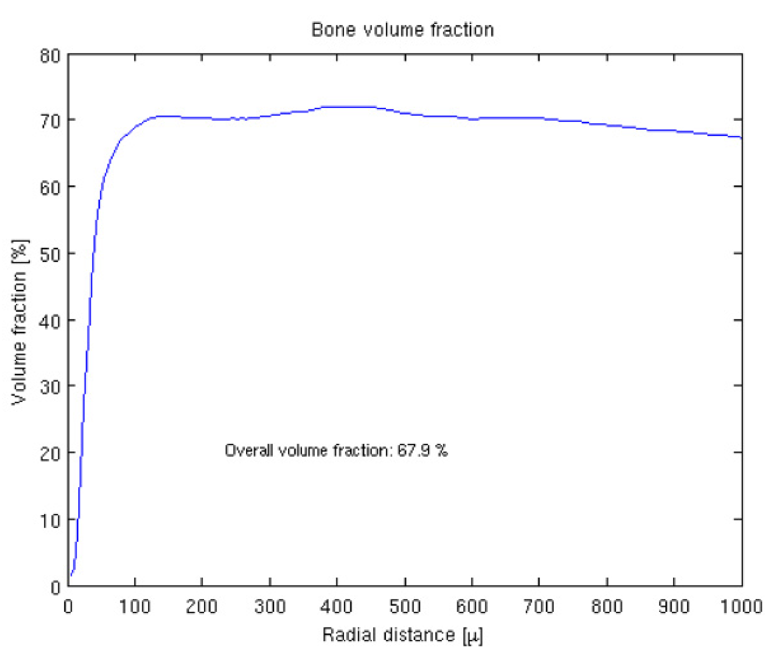

Figure 3: Bone volume and bone-to-implant contact evaluated by SRµCT.

After scanning of the samples the tissue specimens were cut into 7-10 µm thick histologic sections and evaluated by classic histomorphometry.

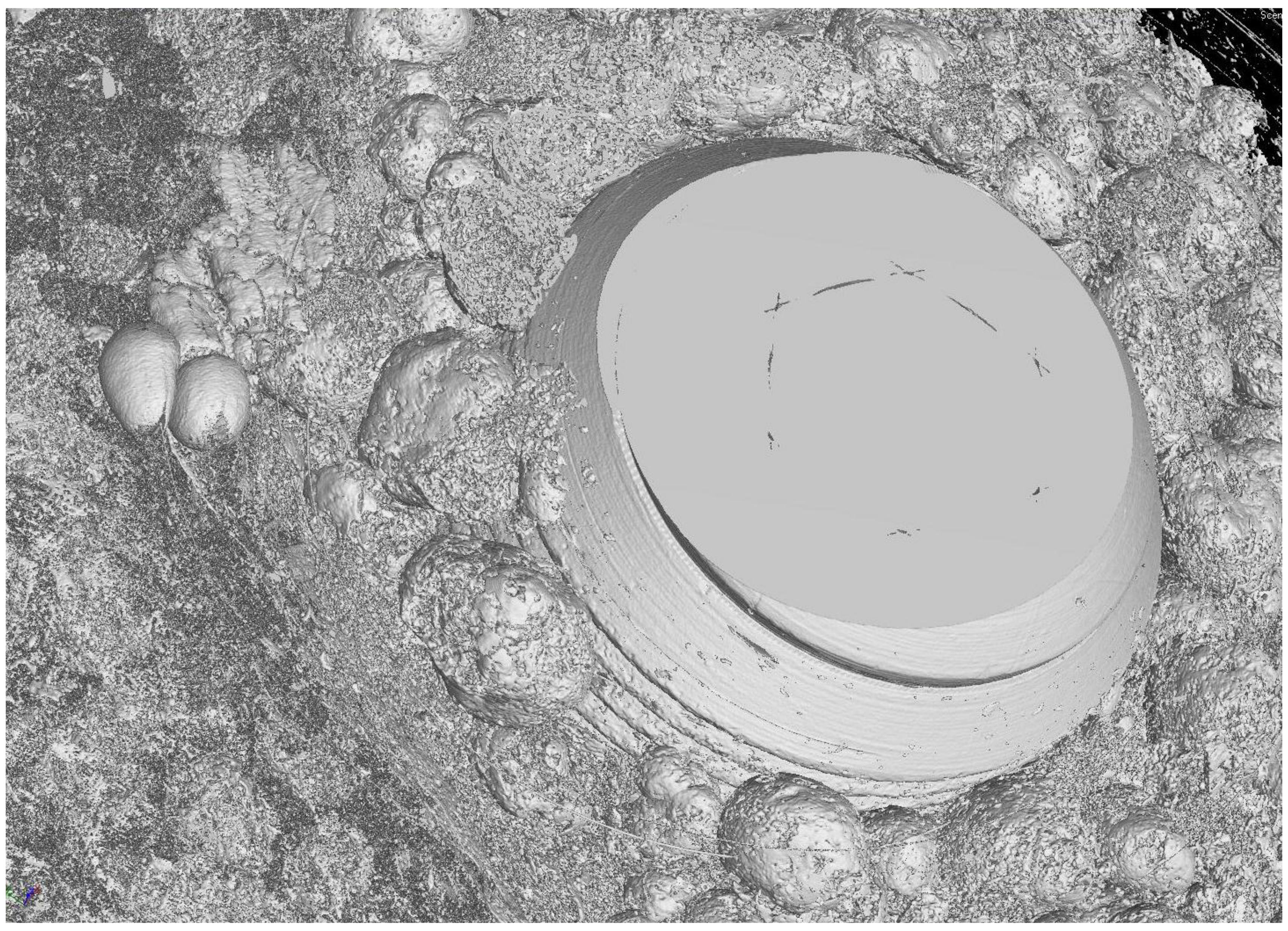

Figure 2b: Synchrotron scan of a bone sample with biphasic grafting material. Resolution: 5 µm.

Results

The high flux x-rays of synchrotron µCT (SR µCT) were able to penetrate the titanium dental implant.
Based on the 3D data, it was possible to evaluate the difference in bone volume fraction, density and porosity of the peri-implant hard tissues.

Comparison with histomorphometry
The 3D SRµCT analysis was compared with 2D analysis (e.g. histological sections) (fig. 4), showing that 3D tomogram evaluation is significantly more certain as evaluations by 2D methods (fig. 3, 5).

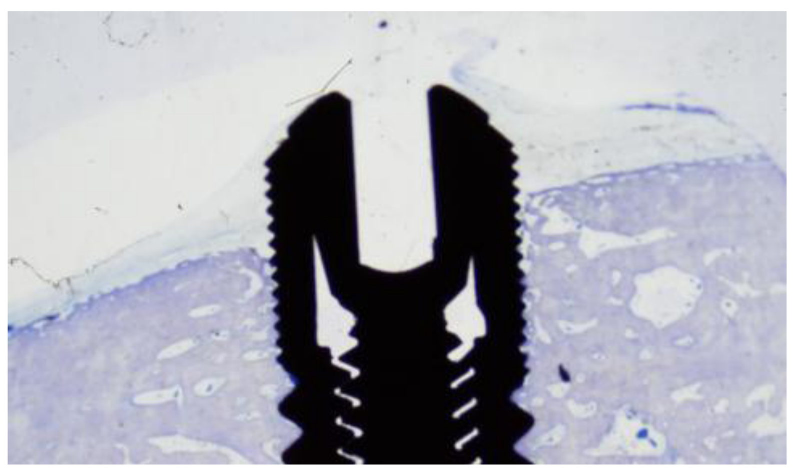

Figure 4: Histologic section of the same sample as in fig. 2a, fig. 3, and fig. 5.

The results from the 3D SRµCT scans showed a low percentage of bone in proximity to the implant when using the 5 µm resolution (fig. 3).

The bone volume within the first 70 µm where approximately 50 %. This was in accordance to the results from the histomorphometry (fig. 3, 5). When comparing SRµCT with histomorphometry a significant deviation in bone to implant contact was found.

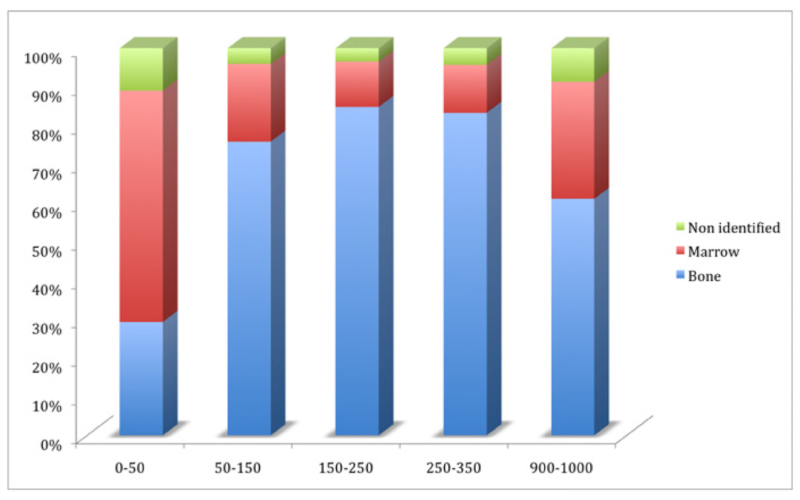

Figure 5: Shows the distribution of bone, marrow, and Non identified tissue evaluated in zones by histomorphometry.

Conclusion

Using synchrotron µCT for evaluating peri-implant bone has been successful in depicting the bone and cavities in three dimensions thereby enabling us to give a much more precise answer to the area of the bone-to-implant contact compared to previous methods.

The next step will be to further develop our method into an even more accurate picture of the bone fraction in the very near proximity (0-100 µm) of the dental implant.