

# Trabeculae in the epiphysis are more adapted to mechanical load than trabeculae in the metaphysis during growth

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# TRABECULAE IN THE EPIPHYSIS ARE MORE ADAPTED TO MECHANICAL LOAD THAN TRABECULAE IN THE METAPHYSIS DURING GROWTH.

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## Introduction

During growth, the 3D trabecular bone architecture in the metaphysis is gradually renewed due to the development of new trabeculae from the growth plate, whereas trabeculae in the epiphysis are formed from the secondary growth center early in the development. Hence, trabeculae in the epiphysis are relatively older than those in the metaphysis. Previously, it was shown that trabeculae align to the orientation of the dominant forces gradually with age [1], which takes some time. Hence, it is likely that, during growth, the relatively older trabecular architecture in the epiphysis is more adapted to the mechanical load than the younger architecture in the metaphysis. In this study, this hypothesis was tested by comparing the 3D morphology of the trabecular structure in metaphysis and epiphysis in growing pigs.

## Methods

We used tibiae of five female pigs at 23 weeks of age. Institutional approval was obtained for the experiments. Bone cylinders of 8.5 mm in diameter were drilled from the proximal tibiae (epiphysis and metaphysis) of the animals. The bone cylinders were scanned in a micro-CT ( $\mu$ CT 20, Scanco Medical AG., Zürich, Switzerland) with a spatial resolution of 28  $\mu$ m [2]. A 4x4x4mm<sup>3</sup> volume of interest was segmented and represented in 22x22x22  $\mu$ m<sup>3</sup> voxels. An individually optimized density threshold value for every sample was used.

From the 3-D reconstructions, we determined the bone volume fractions, degrees of anisotropy ( $MIL_{max}/MIL_{min}$ ), trabecular numbers, trabecular thicknesses, trabecular spacings, connectivity densities [3], and structural model indexes (SMI) [4]. The SMI varies between zero and three, whereby an SMI of zero represents an infinite plate structure and an SMI of three an infinite circular cylinder. The data was statistically analyzed using Student's t-tests for paired analyses. Standard deviations were compared using the F-test.

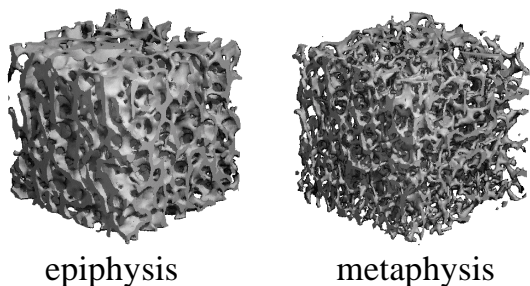


Figure 1: 3D reconstruction of trabecular bone specimens of the epiphysis and metaphysis from porcine proximal tibiae.

## Results

The 3D reconstruction showed a difference in trabecular structure between epiphysis and metaphysis (Fig 1). The bone volume fraction was significantly higher in the epiphysis compared to the metaphysis (Fig. 2A). In addition, the average trabecular thickness in the epiphysis was higher than in the metaphysis;  $107 \pm 6 \mu$ m versus  $91 \pm 5 \mu$ m, respectively ( $p < 0.05$ ). Although the degree of anisotropy was not significantly different between epiphysis and metaphysis (1.46 versus 1.40) their standard deviations (SD) were very significantly different (Fig 2B). The SD of anisotropy was higher in the metaphysis than in the epiphysis ( $p < 0.05$ , Fig 2B). No significant differences were found between trabecular number, trabecular spacing and connectivity density. The structural model index was significantly lower for the epiphysis as compared to the metaphysis (Fig. 2C).

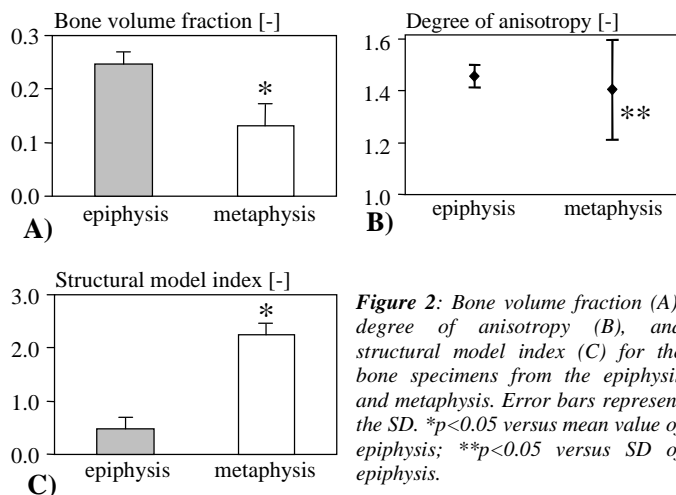


Figure 2: Bone volume fraction (A), degree of anisotropy (B), and structural model index (C) for the bone specimens from the epiphysis and metaphysis. Error bars represent the SD. \* $p < 0.05$  versus mean value of epiphysis; \*\* $p < 0.05$  versus SD of epiphysis.

## Discussion

This study showed remarkable differences in the 3D morphological parameters of epiphyseal and metaphyseal trabecular bone. The structural model index for the trabecular architecture in the epiphysis showed that its structure is plate-like, whereas the structure in the metaphysis is more rod-like. The low variety of the anisotropy in the epiphysis suggests that the structure is better organized compared to the structure in the metaphysis, for which the degree of anisotropy was much more variable. This corresponds with our hypothesis that the relatively older trabeculae in the epiphysis are more adapted to the mechanical load than the trabeculae in the metaphysis during growth.

The higher bone volume fraction in the epiphysis compared to the metaphysis was also found in rats [5] and suggests that the epiphysis bears higher loads than the metaphysis, as higher loads result in increased bone mass. In a previous study using 3D strain-mapping techniques in rats, higher shear strains were measured in the metaphysis than in the epiphysis [6]. This suggests that the metaphysis is less adapted to shear strains than the epiphysis.

In conclusion, this study supports the hypothesis that the relatively older trabeculae in the epiphysis are more adapted to the mechanical load than the trabeculae in the metaphysis during growth. At later stages of development the metaphysis will probably catch up with the epiphysis as an adapted structure to mechanical loads is expected at maturity, after the growth plate is closed.

## References

- [1] Tanck et al., 46th annual meeting ORS, 148, 2000; [2] Rüdgesegger et al., Calc Tissue Int, 58:24-29, 1996; [3] Odgaard and Gundersen, Bone, 14:173-182, 1993; [4] Hildebrand and Rüdgesegger, Comp Meth Biomech Biomed Eng, 1:15-23, 1997; [5] Westerlind et al., Proc Natl Acad Sci 94:4199-4204, 1997; [6] Bay, //www.mrsc.ucsf.edu/bigsur/abstracts/bay.html, 2000.

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