# Ex-vivo MR imaging of trabecular bone structure at 1.5T and 3T.

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## Introduction:

The difference between measurements of trabecular bone architecture obtained with magnetic resonance (MR) imaging with different field strengths and sequences is the object of intensive research. Trabecular bone has a complex structure and explains biomechanical properties of bones. Optimized sequences improve image quality and acquisition time, both important for clinical applications, e.g. assessment of bone quality. In this work, we compared 1.5T and 3T MRI imaging and Fiesta-C and FGRE sequences to investigate the trabecular structure measurements in calcaneus specimens and compared these with Computed Tomography (CT).

## Methods:

Eleven calcaneal specimens were obtained from human donors (4 male, 4 female, mean age 77 years). MR imaging was performed at a 1.5T and a 3T Signa GE scanner (GE Medical Systems, Milwaukee, WI, USA), both equipped with 44mT/m gradients. High-resolution Fiesta-C (TE=2.6 ms, TR= 11.9, FOV=10cm, time(t)=11min) and FGRE (TE=6.2 ms, TR= 22.2, t=13min) MR images were acquired at 1.5T, and Fiesta-C (TE=5.0 ms, TR= 12.9, FOV=10cm, t=11min) and FGRE (TE=4.0 ms, TR= 16.1, t=13min), all with a FOV of 10cm and a resolution of 0.156×0.156×0.50 $mm^3$. The high-resolution CT images (voxel size= 0.27×0.27×0.30 $mm^3$) were acquired on a 16-row spiral Philips Mx8000 IDT scanner.

The binarization of the MR images was based on the dual reference model and assuming a biphasic histogram previously described by Majumdar et al. (1), whereas for CT images, a threshold equal CT-value of the bone equivalent insert of a simultaneously scanned reference phantom. In the central sagittal slices of all MR and CT images, a circular region of interest (ROI) was manually placed posteriorly because of its sensitivity to osteoporotic changes (2). ROIs were carefully chosen to include trabecular bone and marrow and to avoid cortical bone and any air artifacts present. Structural parameters equivalent to 2D bone histomorphometry (histo) (3) and by using the model-assumption-free 3D distance transformation method (dt3d) were calculated for the chosen ROIs. They included bone volume/total volume (BV/TV), trabecular (Tb) number (Tb.N), Tb thickness (Tb.Th), and Tb separation (Tb.Sp). We used Pearson's correlation coefficient r and two-tailed t-test to compare MR and CT derived parameters. Further, we computed the relative differences.

## Results:

The correlation of the calculated MR parameters with the corresponding CT parameters are presented in Table 1. For the 1.5T MR scanner, no histomorphetric parameter correlated with the CT-derived parameters. However, significant correlations were found for most of the dt3d parameters if obtained with the FGRE sequence. At 3T, apparent Tb.N and Tb.Sp showed high correlations between r=0.76 and r=0.92 (all $p<0.01$) for both structure parameter techniques. A moderate correlation r=0.61 ($p<0.05$) was observed for apparent BV/TV for FGRE and dt3d Tb.Th. was negatively associated with the CT results for Fiesta-C (r=-0.67, $p<0.05$). On average, the absolute MR-derived BV/TV and Tb.N. parameters are different from the corresponding CT values ($p<0.05$). For BV/TV and Tb.N, MR imaging overestimates the the structure parameters (see Table 1), whereas Tb.Sp and Tb.Th are mostly underestimated, except for Tb.Th of 3T Fiesta-C, which is on average 7% and 14% larger.

**Table 1:** Correlations and relative differences of the calculated MR parameters with the corresponding CT parameters.

| | Correlations r with CT | | | | | | | | Relative difference (MR-CT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BV/TV | | TbN | | TbS | | TbTh | | BV/TV | | Tb.N | | Tb.Sp | | Tb.Th | |
| | histo | dt3d | histo | dt3d | histo | dt3d | histo | dt3d | histo | dt3d | histo | dt3d | histo | dt3d | histo | dt3d |
| 1.5 T Fiesta C | ns | ns | ns | ns | ns | ns | ns | ns | 68% | 58% | 55% | 50% | -58% | -46% | -17% | -11% |
| 1.5 T FGRE | ns | 0.81** | ns | 0.84** | ns | 0.84** | ns | ns | 48% | 28% | 126% | 40% | -49% | -40% | -20% | -11% |
| 3T Fiesta C | ns | ns | 0.83** | 0.80** | 0.92** | 0.79** | ns | -0.67* | 60% | 36% | 40% | 16% | -38% | -23% | 7% | 14% |
| 3T FGRE | 0.61* | ns | 0.84** | 0.76** | 0.93** | 0.77** | ns | ns | 68% | 56% | 113% | 43% | -56% | -42% | -10% | -3% |
| ** p<0.01, * p<0.05, ns: not significant | | | | | | | | | p<0.05 | | | | | | | |

## Discussion:

In general, we observed that MR structure parameters obtained from 3T scanners are more closely related to CT parameters than those from the 1.5T scanner. While the relative differences are quite similar, the 3T MR parameters correlate better. Because FGRE also showed higher relative differences, the 3T Fiesta-C acquisition demonstrated the best overall performance. The drawback of this sequence is the artificial amplification trabeculae (blooming effect) that, although also present to some extent in CT images, leads to thicker trabeculae.

Concerning the histomorphometry parameters, BV/TV and Tb.N are the two truly independent parameters. Therefore, in order to compare MR and CT imaging, Tb.N emerges as the best structure value because it is more closely related to the CT results. Further, although designed for isotropic voxels, dt3d structure parameters proved to be a useful tool for MR-CT comparison despite their anisotropic voxel sizes. Future projects will include comparison with in vivo MicroCT, as well as sophisticated registration techniques.

## References:

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