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How is bone mineral density related to ultra-short echo time MRI-derived bone porosity index in the Thoroughbred metacarpal condyle?

Introduction

- **Lateral condylar fractures** of the third metacarpal bone (McIII) are the most common reason for **euthanasia** on UK racecourses [1].
- **Early identification** of features leading to catastrophic injury would have contribute to **animal welfare** and be of **financial interest** for the racing industry.
- **Microscopy:** accumulation of microcracks in the McIII subchondral bone is a precursor for fatigue fractures [2]
- **Clinical CT and MRI:** no differences in microcrack formation in fractured vs non-fractured limbs detected [3, 4]
- **Bone porosity, lateral condylar fractures and CT**: physiological remodelling processes in bone subjected to stress include temporary increase in porosity, during rest phases. This adaptation process is hindered during continuous high intensity training in racehorses, leading to a decrease in porosity in the subchondral bone, associated with an increase in bone volume fraction as seen on high resolution peripheral quantitative computed tomography (HR-pQCT) [5].
- **Bone porosity and MRI:** Traditionally, using MRI to evaluate cortical bone has been challenging due to the limited signal generated by tightly bound protons. More recently, ultrashort echo time MRI (UTE MRI) has been used in human patients for imaging cortical bone and determining its porosity using a dual-echo approach. This revealed a strong inverse correlation between bone stiffness and CT-derived bone mineral density [6]. Whether this similarly applies to the equine patient is yet to be determined.

Aims

- Use UTE sequences to measure porosity index in the distal McIII/MtIII of racehorses in training
- Use HR-pQCT CT to validate the porosity measurements derived from UTE-MRI
- Potentially establishing an early indicator of disease, thereby potentially preventing serious injury and promoting animal welfare

Methodology

- Five post-mortem equine Mc/MtIII (McIII; n=1/MtIII; n=4)
- HR-pQCT in a 64-slice CT scanner (Siemens, Somatom Definition AS)
- 3T MRI in a clinical scanner (MAGNETOM Skyra 3T, Siemens Healthcare, Erlangen, Germany)
- BMD and PI were calculated and corresponding images generated.
- Coregistration of BMD and PI images in Elastix using a mutual information metric and a B-spline transform
- Manual definition of the volume of the distal condyle (=3D ROI) in an open-source 3D imaging software (Slicer [7])
- Scatter plot of BMD and PI values for each pixel in the 3D ROI

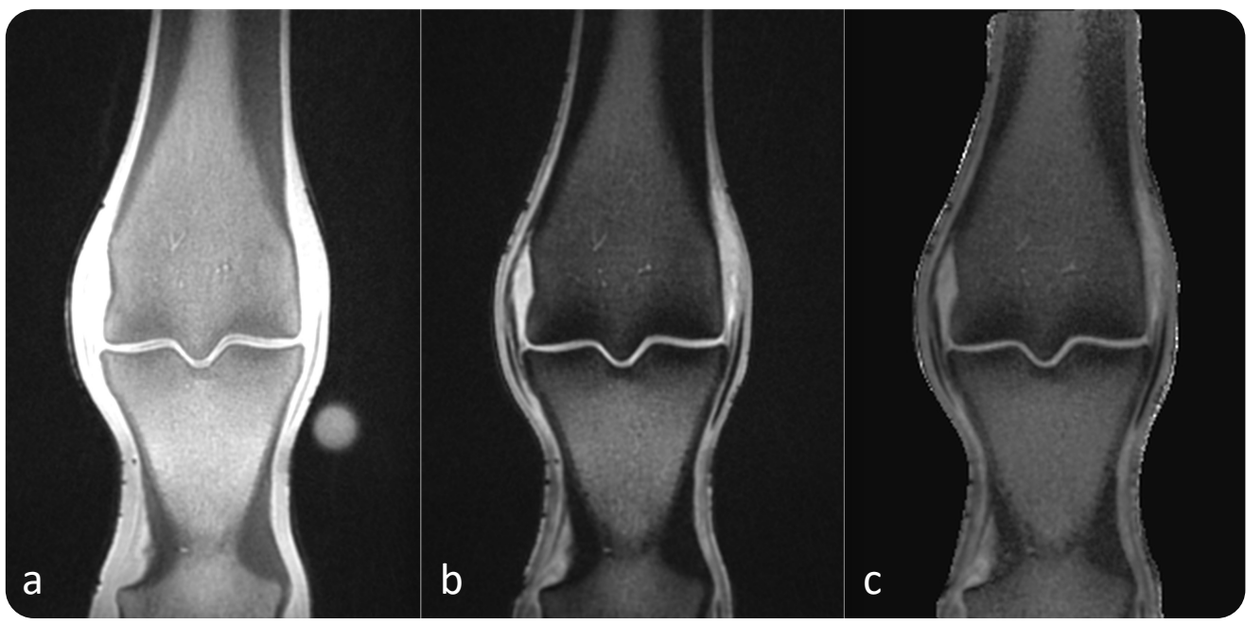

*Fig.1: **Example MR images**. UTE images were acquired using dual-echo UTE sequences. Image a was acquired with a short echo time of 0.04ms (echo 1). Image b was was acquired with a longer echo time of 2.68ms (echo 2) Porosity index was calculated by dividing echo intensity 2 by echo intensity 1. The result was multiplied by 100%. The resulting image is shown in panel c.*

Results - Pilot Study

BMD and PI of the equine distal Mc/MtIII are inversely correlated with an average slope of -62.5 in the scatterplot and an average correlation coefficient of 0.31.

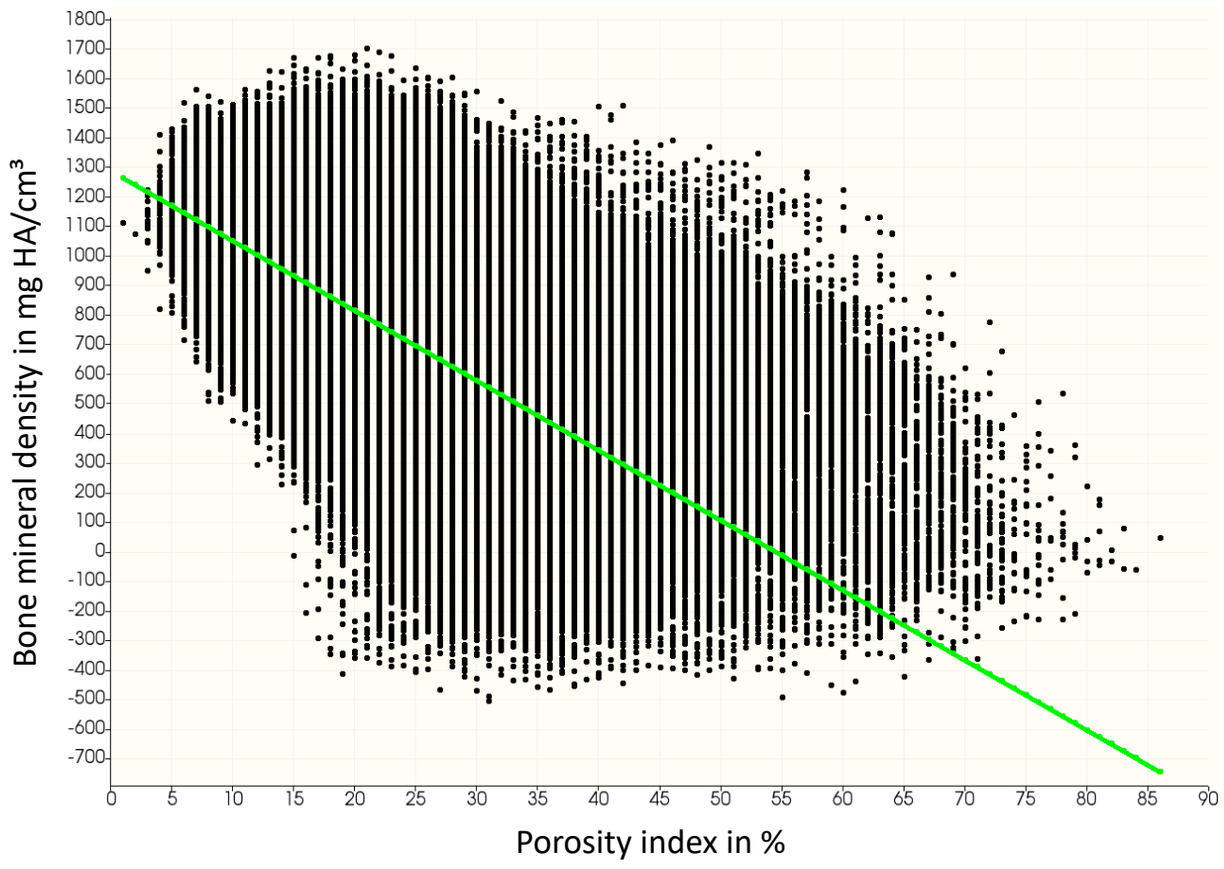

*Fig.2: **Scatterplot example of one specimen**. The 3D-ROI was defined manually based on a 3D MPR reconstruction of CT images. The whole metacarpal/ metatarsal condyle was included in the 3D-ROI. Care was taken to not include soft tissues surrounding the osseous structures. The same ROI was used in co-registered MR images. BMD values derived from CT images and PI images derived from MR images were plotted against each other for each pixel. The negative slope indicates a inverse correlation between the two values.*

Conclusion

BMD and PI are inversely correlated in the equine distal Mc/MtIII. Further work is needed to assess how correlation patterns behave in different areas of the bone and to evaluate PI in the presence of microcracks in horses with and without clinically relevant stress fractures of the parasagittal groove.

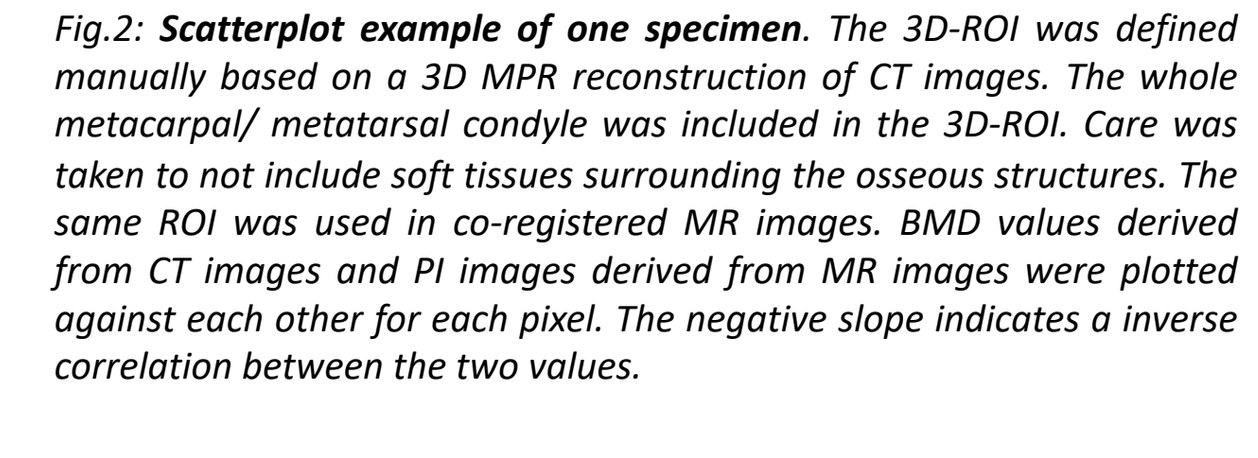

*Fig.3: **Image processing**. Images a) and b) show the coregistered MR and CT images with the 3D ROI in green. Image c) is an example of a HR-pQCT images which was used to calculate bone mineral density in relation to a standard osteodensitometry phantom containing calcium hydroxyapatite and demineralised water (asterisk).*

Further plans – Main study

- Increase sample size
- Correlation of UTE imaging and high-resolution peripheral quantitative computed tomography CT with
  - MicroCT
  - Finite element model / mechanical testing

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