Density and Strength Distribution of the Subchondral Bone Plate of the Canine Talus

A. Todorović[1], W. Dingemanse[2], M. Lazarević Macanović[1], M. Müller-Gerbl[3], M. Mitrović[1], I. Jonkers[4], J. Vander Sloten[5], H. van Bree[6], I. Gielen[1,7]

[1] Faculty of Veterinary Medicine, University of Belgrade, Serbia; [2] Kennel and Paddock, Veterinary Rehabilitation and Hydrotherapy, UK; [3] Institute of Anatomy, Basel University, Switzerland [4] Human Movement Biomechanics Research Group, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Belgium; [5] Biomechanics Section, Faculty of Engineering Science, KU Leuven, Belgium; [6] VetMedImage, Belgium ; [7] Faculty of Veterinary Medicine, Ghent University, Belgium

Introduction

The main function of loadbearing bones is the transduction of compressive forces during locomotion. These forces give rise to local strains and stresses at the level of the subchondral bone plate and induce bone modelling and remodelling (Madry et al., 2010). Based on Wolf's law, changes in density lead to an optimal bone structure, i.e. the higher the forces, the stronger the bone needs to be and the higher the density will become (Müller-Gerbl et al., 1990; Müller-Gerbl et al., 1992).

The aim of the present study is to evaluate the penetration strength of the subchondral bone plate of the canine talus and to compare the results to the mineral density distribution, evaluated by computer tomographic osteoabsorptiometry (CTOAM).

Methods

Twenty paired canine cadaver tali were included in this study. The bones originated from different large breed dogs (all > 25 kg). Depending on the size of the specimen, 3 or 4 rows of test points were drawn onto the articular surface. Test points were located on the medial and lateral trochlear ridge, and in the trochlea tali. In some cases, an additional fourth row was added on the sloped medial surface of the lateral trochlear ridge.

The device measured the resistant force of the indentation needle at a constant speed of 1 mm/s. Using a ball joint and custom made frame, all test points were positioned perpendicular to the indentation needle. After testing, CT scans were made to provide the exact location of the test point and to ensure full penetration of the subchondral bone plate. Using a previously described technique to map the subchondral bone densities (CTOAM), the density at each test point was measured. With a calibrated density phantom, these density measurements were expressed in mg hydroxyapatite/cm3.

Image data was acquired using a 16-slice CT scanner (Somatom Sensation, Siemens, Erlangen, Germany). Scans were performed before and after indentation testing, to check full penetration of the subchondral bone plate and to register the exact points of indentation to compare with the CTOAM images.

For each test point (on average 16 test points for each talus), the density was measured and the force necessary to penetrate the subchondral bone plate was registered. After that the correlation coefficients were calculated.

Results

In all specimens, a high correlation was found between the subchondral bone density and the mechanical strength. The coefficient of determination (r^2) ranged from 0.78 to 0.96 with a mean of 0.89 and was statistically significant ($p < 0.01$). The location of the density maxima matched the location of maximal mechanical strength. There was no significant difference in the location of the density maxima and the strength maxima (p-value = 0.512).

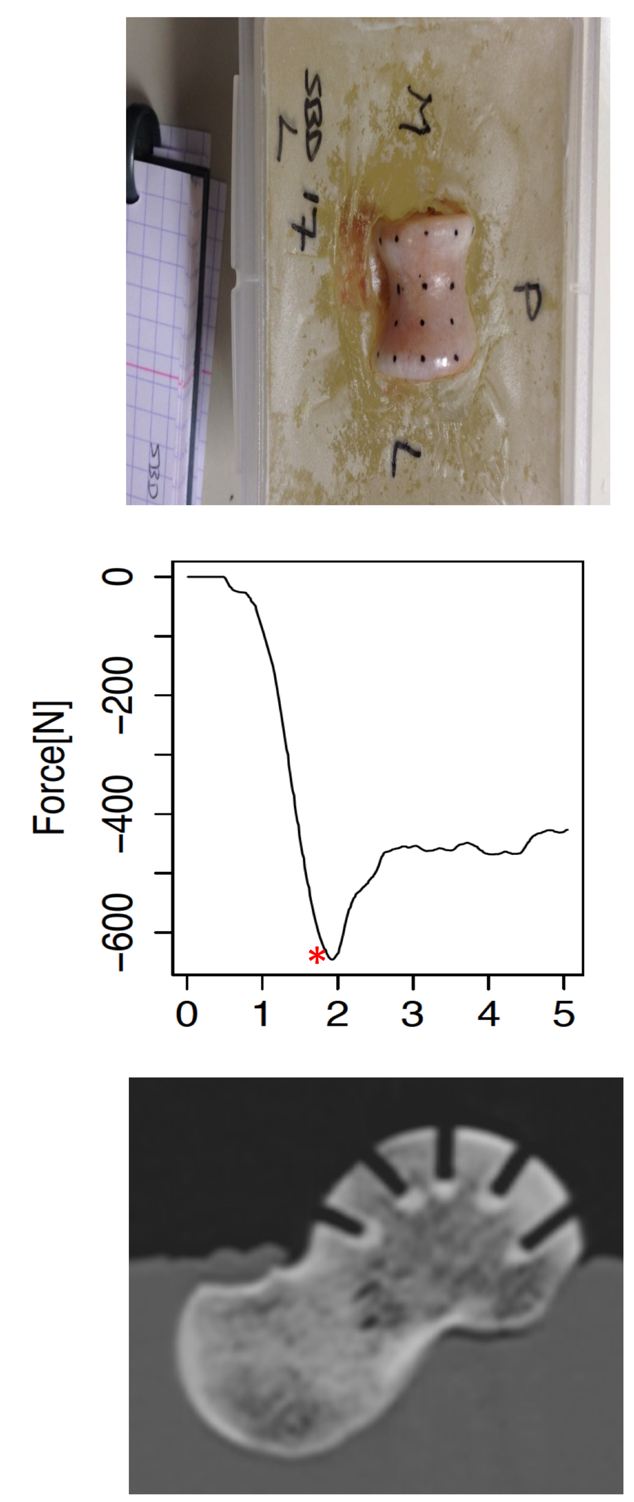

Figure 1. Top: Test-points indicated on the surface of the talus prior to testing. **Middle:** The indentation testing results in a force-time curve. The force-time curve has a steep downhill slope during penetration of the subchondral bone plate, and is marked by the maximum force (*). The force at this point was registred and correlated with the subchondral bone density of the test point. **Bottom:** Sagittal reformatted CT image of a talus after testing, showing the perpendicular direction of the needle hole and full penetration of the subchondral bone plate.

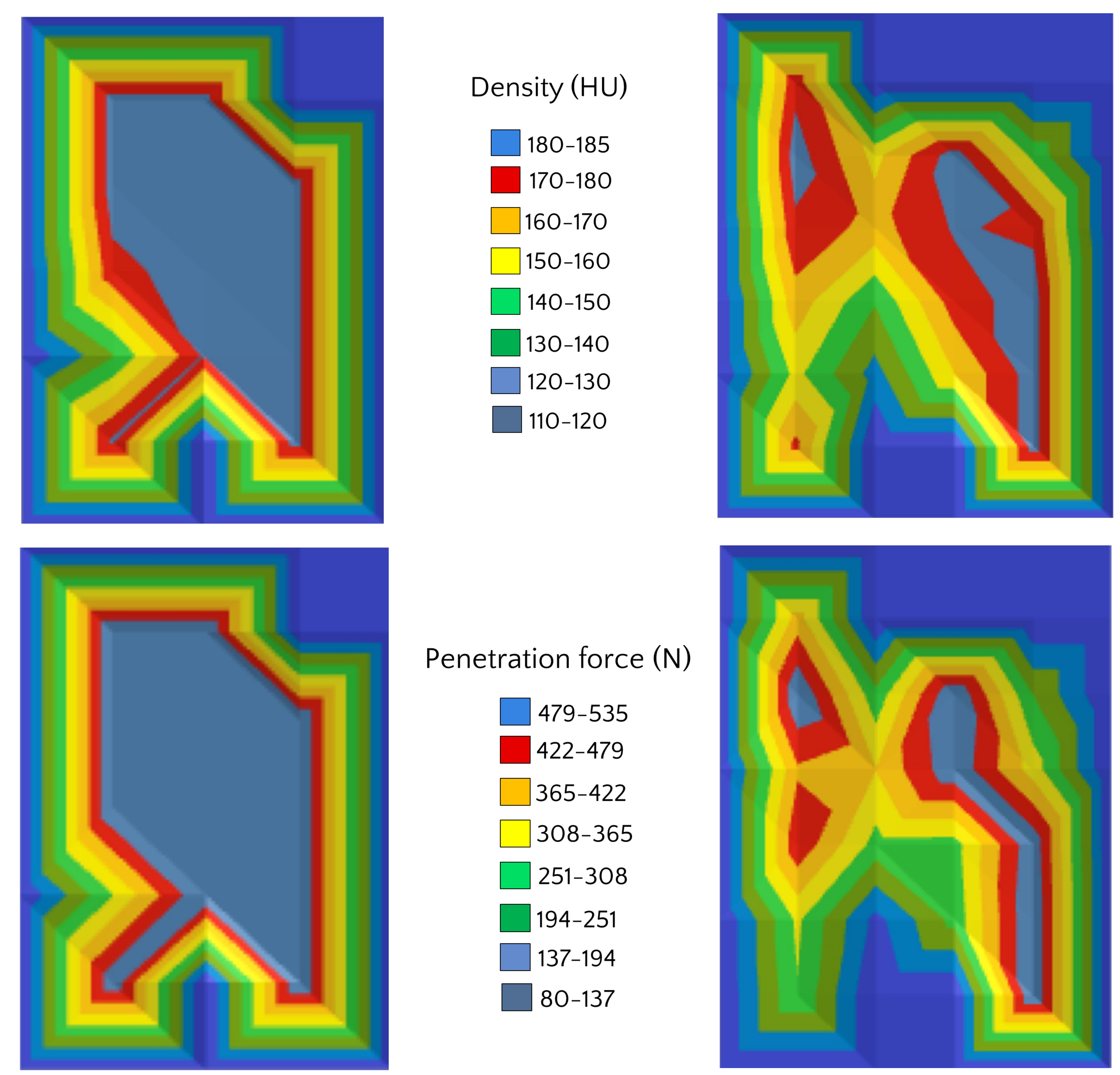

Figure 2. Visual comparison of subchondral bone density **(top)** and penetration force **(bottom)**.

Conclusion

This study shows that the use of non invasive techniques like CT, combined with CTOAM can not only be used to evaluate subchondral bone density, but that it can also be related to actual subchondral bone strength.

The strength of CTOAM in biomechanical research is its ability to show the morphological effects of long-term load distribution (Müller-Gerbl et al., 1992). Actual joint loading is very difficult to determine in vivo. Because CT is a non-invasive technique, this method can be applied in a clinical setting to study both healthy joints and joint pathology.

References

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