Session 37

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Assessment of structural and mechanical properties of equine cortical bone with several techniques

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Soundness of bone tissue is one of the major concerns for the sport horse industry

The horse skeleton its subjected to considerable loading and strengths

IMPORTANT

To understand the structure, the architecture and the mechanical properties of the equine bone tissue

AIM – to evaluate the mechanical and structural properties of equine third metacarpal bone in the Lusitano horse

Mechanical properties:

✓uniaxial compression tests

(Indirect evaluation: measurements of speed of sound (SOS) ⇨ quantitative ultrasonography (QUS))

Structural properties:

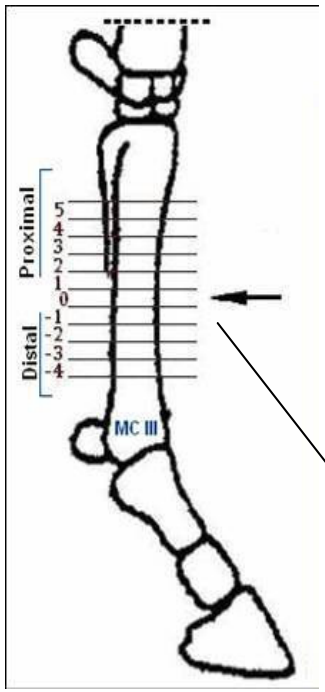
✓ scanning electron microscopy (SEM) ⇨ 2D structural analysis

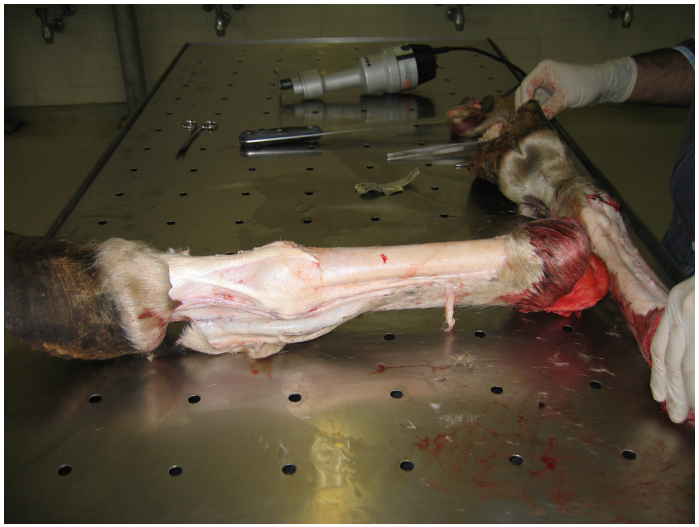
(SEM is coupled with an energy dispersive x-ray spectroscopy (EDS) ⇨ chemical analysis)

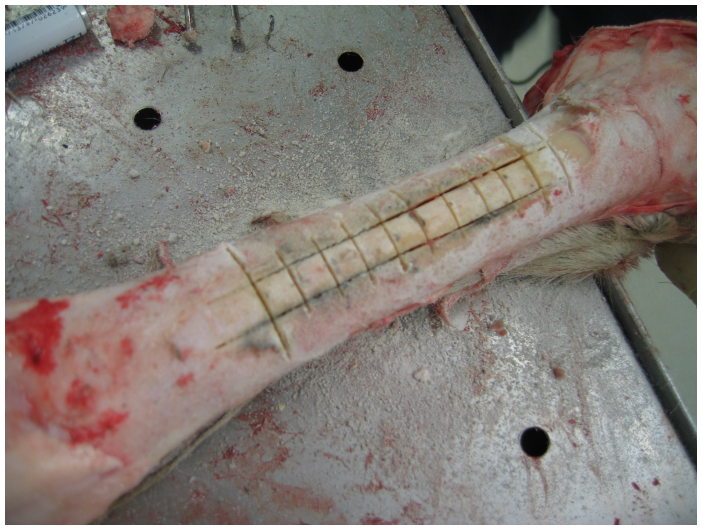
✓ Micro Computorized Tomography (micro-CT) ⇨ 3D structural analysis

Samples

- taken *post mortem* from the third metacarpal bone (MC III), of *Lusitano* horses
- on the dorsal and lateral regions of the bone
- cubic specimens were cut, wrapped in gauze soaked in physiologic saline solution and stored.
- samples used in SEM were mounted in a resin, polished and coated with gold.

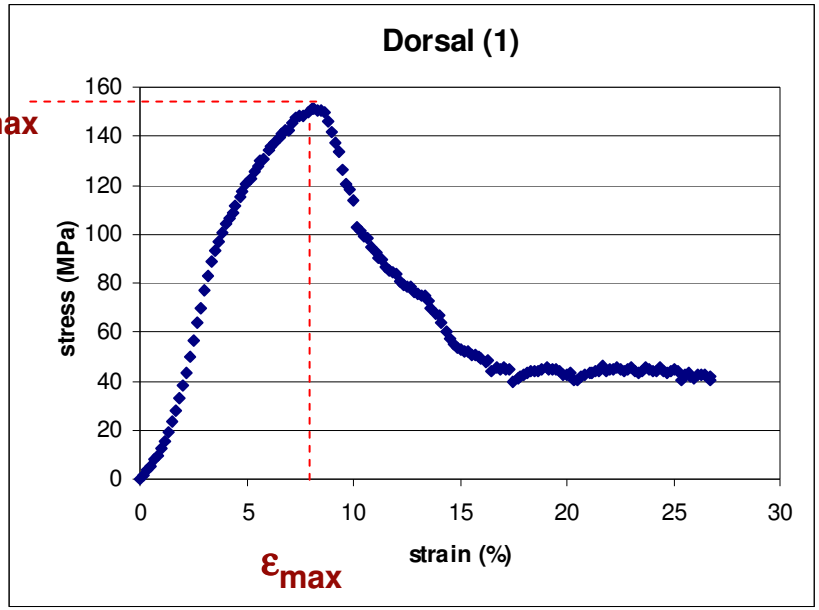






The mechanical compressive tests were performed in an Instron 8502 machine

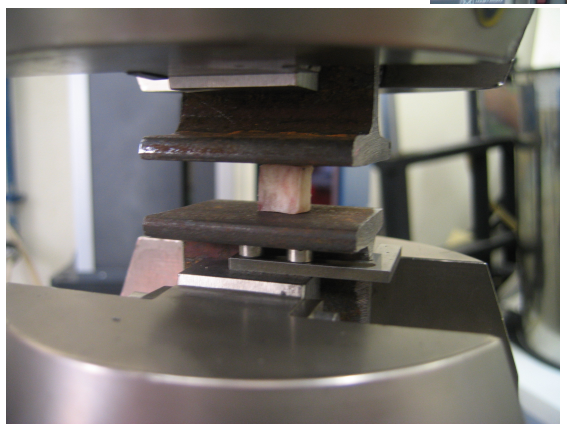
stress σ (MPa) - strain ε (%) curves



Load cell – 250 kN

v=2mm/min

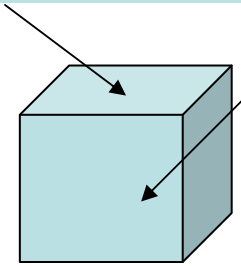
$$\sigma = \frac{F}{A_0} \qquad \varepsilon = \frac{\Delta l}{l_0}$$



- slope, E
- maximum stress, σ_{max}
- maximum strain, ε_{max}

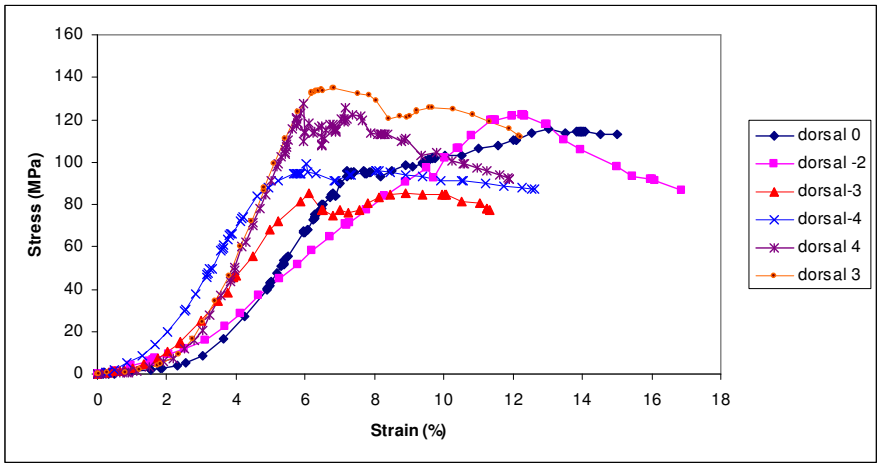
Field emission scanning electron microscope JEOL, JSM-7001F
coupled with an energy dispersive x-ray spectroscopy (EDS) detector Oxford

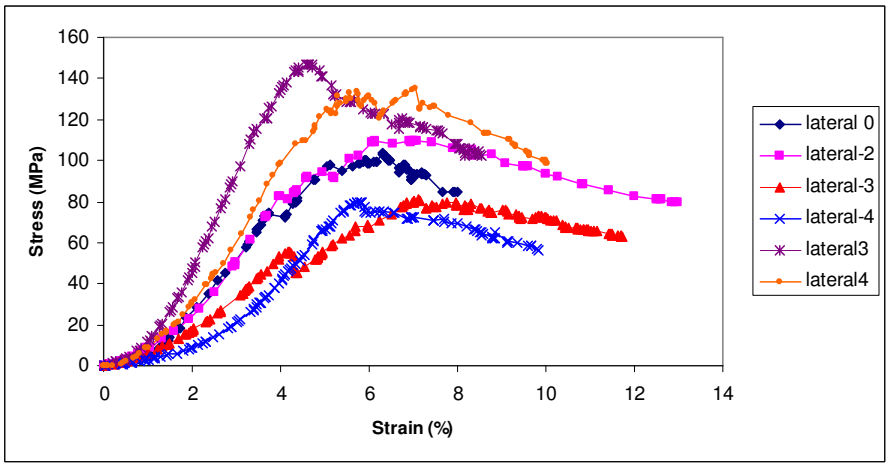
- Dorsal and lateral
- transversal and longitudinal sections



Micro computed tomography (micro-CT) analysis was undertaken with a Skyscan 1172

Results from mechanical compression tests





Dorsal

E= 23.5±6 (GPa)

σ_{max} =113.2 ±17.9 (MPa)

ε_{max} = 8.3 ± 3.4 (%)

Lateral

E= 26.8±4 (GPa)

σ_{max} =108.9 ±27.4 (MPa)

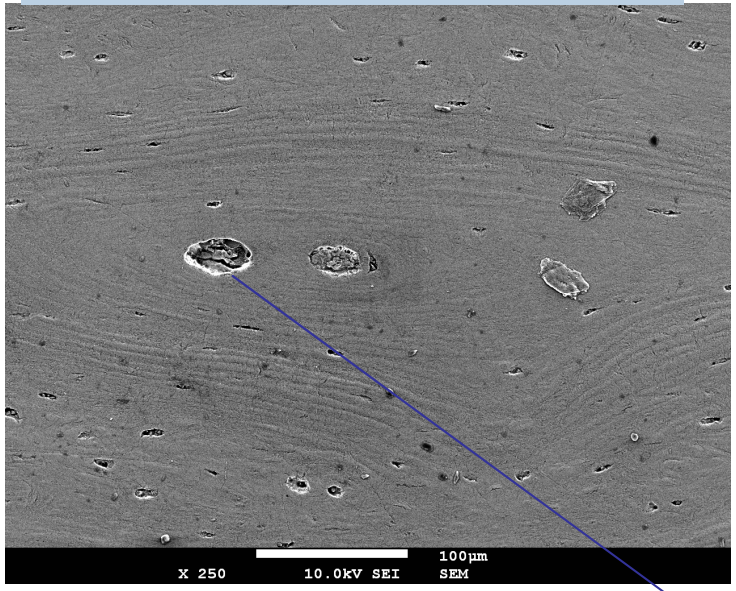
ε_{max} = 6.2 ± 0.7 (%)

Literature:
E= 14 - 25 (GPa)
σ_{max} =100 - 140 (MPa)
ε_{max} = 7 - 10 (%)

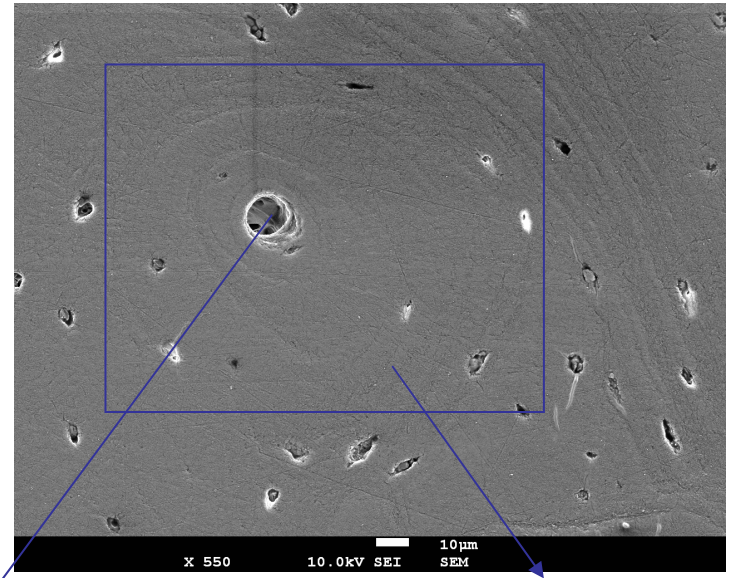
Heterogenity between stress-strain curves could be ascribed to a diverse bone architecture and structure along the shaft

SEM results

Lateral- transversal section 250x



Dorsal – transversal section 550x



Haversian canals

osteon

Porosity - Areas were measured using commercial image analysis software (SigmaScan Pro 5)

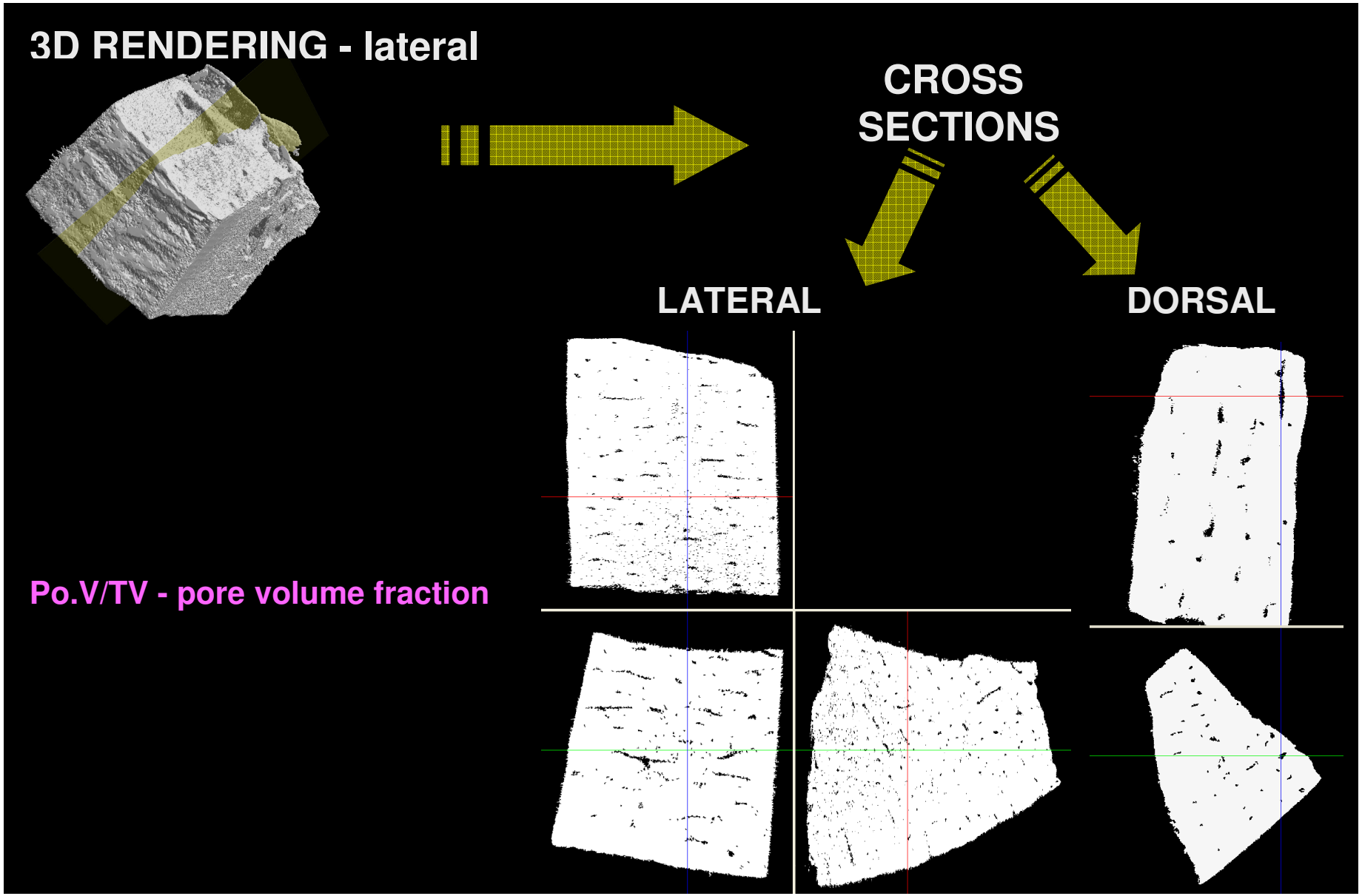
Results : Dorsal – Transversal – 2.03±0.52 %; Dorsal – Longitudinal – 2.66±0.84 %;

Lateral – Transversal – 2.36±0.59 %; Lateral – Longitudinal – 2.11±0.95 %;

Literature – porosity – 1-30%

EDS results: Ca = 34.4 ±3.9; P=16.3 ±2.2; O=35.4 ±2.5; C=14 ±3.6 (weight %)

Micro – CT- **complete internal 3D structure at hight resolution**



Conclusions

- **Preliminary results were shown**
- **The techniques used were found to be adequate to fulfil the objectives of the work**
- **Further tests will contribute for the establishment of the relationship between structure and mechanical properties.**

Quantitative ultrasonography (QUS) ⇨ assessment of superficial cortical bone properties

Speed of Sound (SOS) - related to the mechanical properties of the medium by:

$$SOS_{Dorsal/Lateral}(m/s) = \sqrt{\frac{E}{\rho_{bone}}}$$

E – Young's modulus (or elasticity modulus)

ρ - density

(Carstangen *et al.*, 2002)

QUS provides an indication of both the elasticity and bone mineral density of the superficial cortical bone.

Thank you!