Mapping Articular Cartilage Biomechanical Properties of Normal & Osteoarthritic Mice Using Indentation

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CHU Sainte-Justine Research Center
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Disclosure

E. Quenneville and M. Garon are the owners of Biomomentum Inc.

J-F. Lavoie works for Biomomentum Inc.

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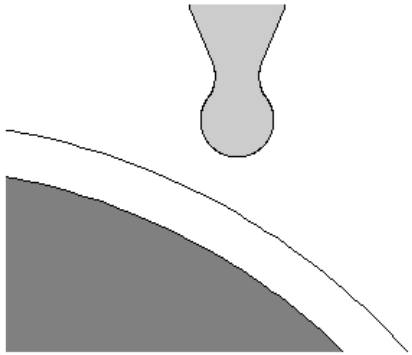
Introduction

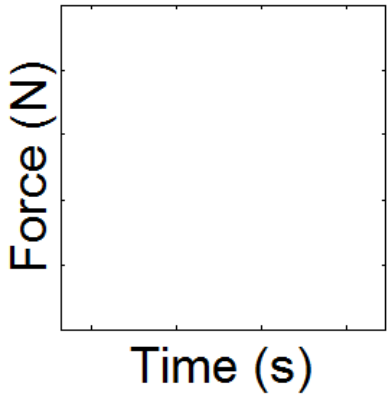
- Mouse models have unique advantages to study articular diseases (ex. transgenic).
- The size of their articular surfaces pose significant challenges to map mechanical properties (ex. knee).
- We have previously developed and validated on human, sheep and rat knee joints a novel automated indentation technique (Sim et al. *Trans ICRS2013 &* Sim et al. *Trans ORS2014*).
- First objective of this study was to scale this indentation technique to map the mechanical properties of the articular surfaces in murine knees.
- Second objective is to identify early alterations of the articular cartilage of a mouse strain (STR/ort) that spontaneously develops osteoarthritis (OA) on the medial side of their knees.

Automated indentation technique

→ Perpendicular Indentation at each position

Measures the contact coordinates of the predefined position





- **3-axis mechanical tester** (Mach-1 v500css from Biomomentum)
- **Multiaxial load cell** (force resolution: F_z = 3.5 mN and $F_x = F_y$ = 2.5 mN)
- **Spherical indenter** (r = 0.175 mm)

Contact coordinates (x,y,z) of predefined positions and 4 surrounding positions

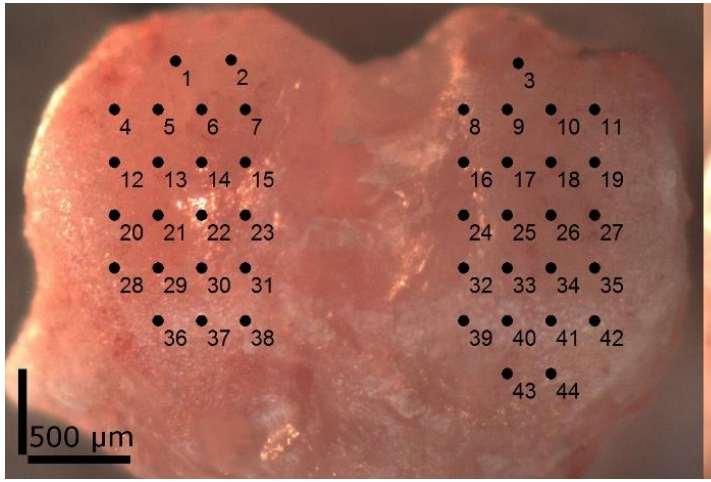
Surface orientation (θ_z)

Normal force/displacement vs time

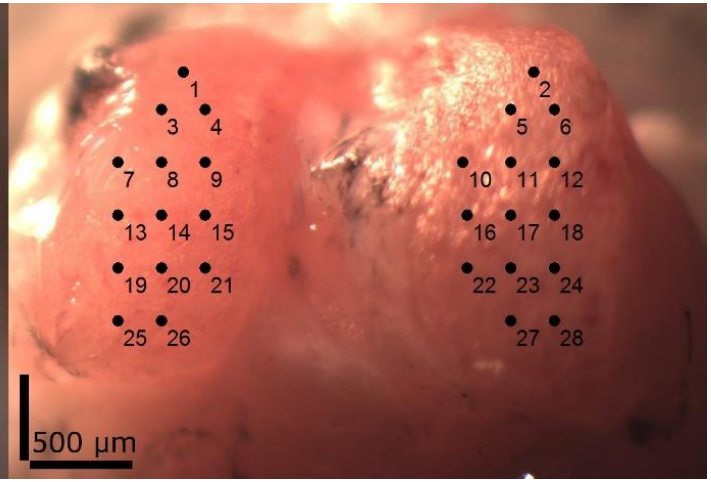
Male Balb/c – Healthy control
12 weeks old: N = 3
15 weeks old: N = 2

Male STR/ort – OA mouse
12 weeks old: N = 3
15 weeks old: N = 2
Spontaneously develop OA in the medial compartment of their knee (Walton, M., *J. Pathol*. 1977)

Left Tibial Plateau



Left Femoral Condyles

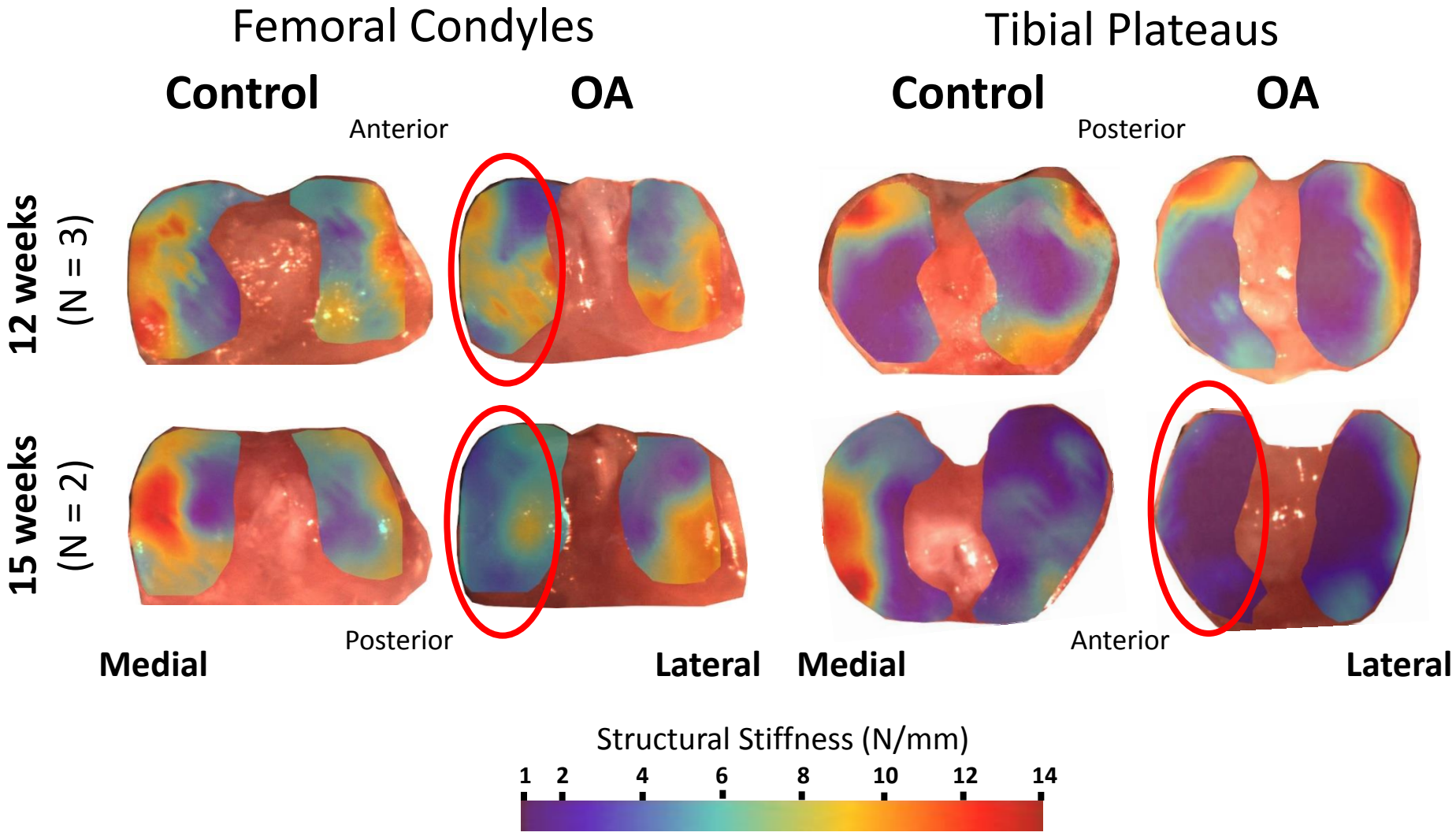


Indentation velocity: 30 µm/s

Reported is the structural stiffness (N/mm):

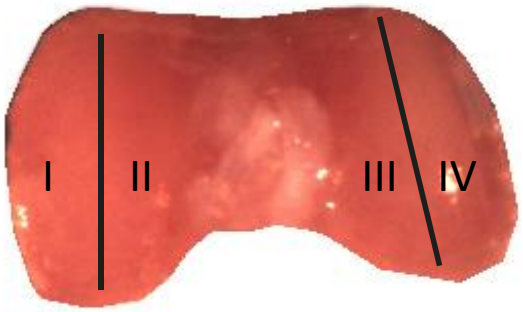
$$\frac{\text{Load (N) @ 0.010 mm}}{\text{0.010 (mm)}}$$

Mapping of average structural stiffness on control and OA mouse cartilage surfaces from the left knee



Reduced structural stiffness is measured on medial side of OA mice joint

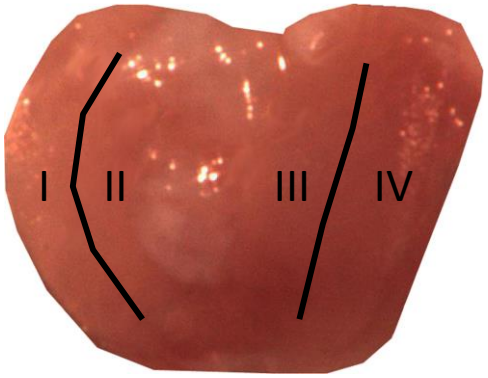
Femoral Condyles



Medial Lateral

Zones

Tibial Plateau

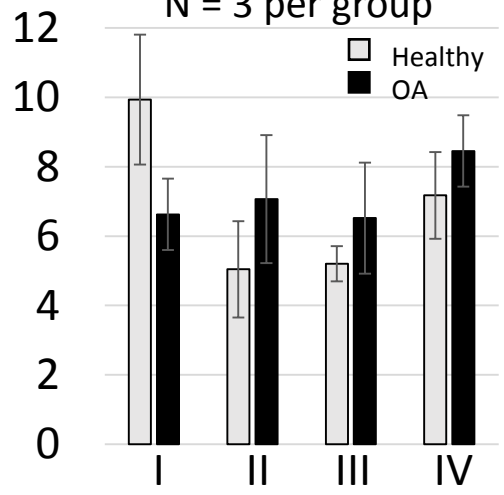


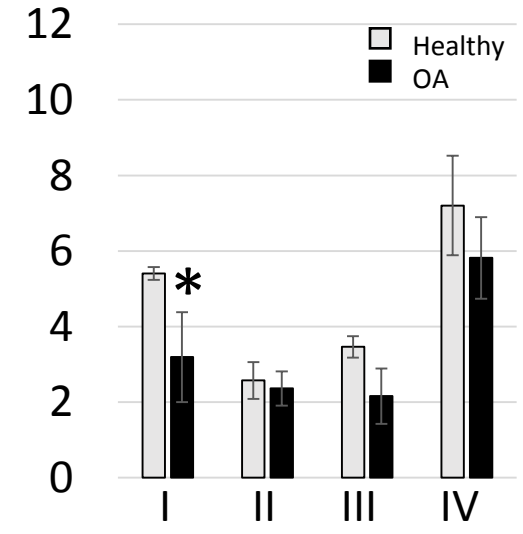
Medial Lateral

Zones

14 weeks

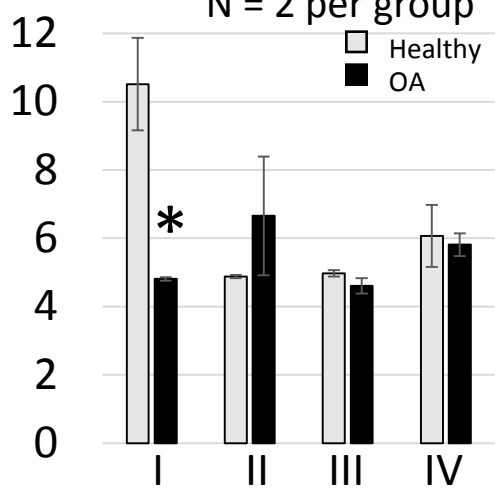
N = 3 per group

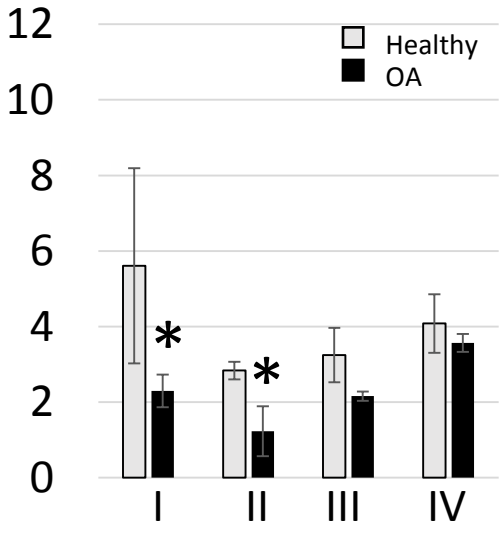




15 weeks

N = 2 per group





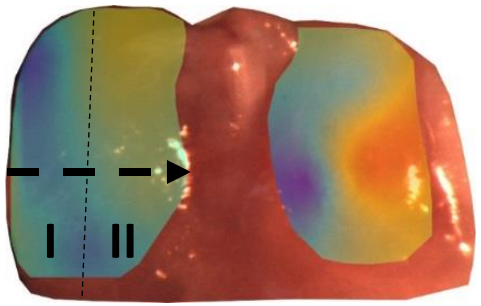
Error bar = SE

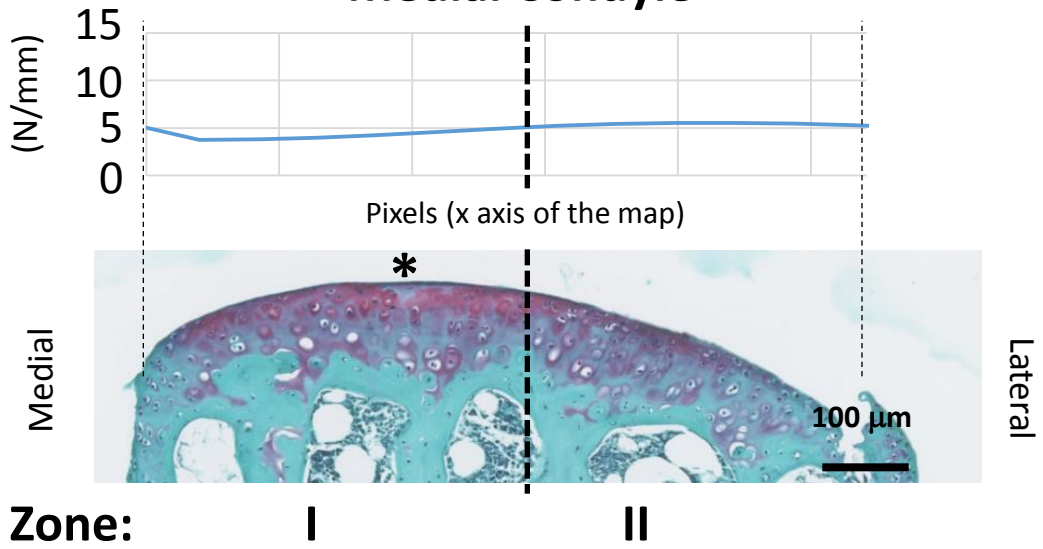
Interpretation of the Structural Stiffness using histology

Structural stiffness map

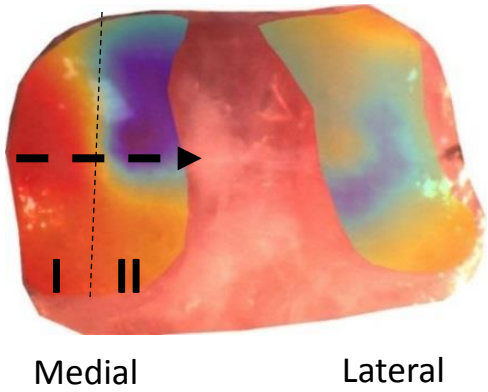
Medial Condyle

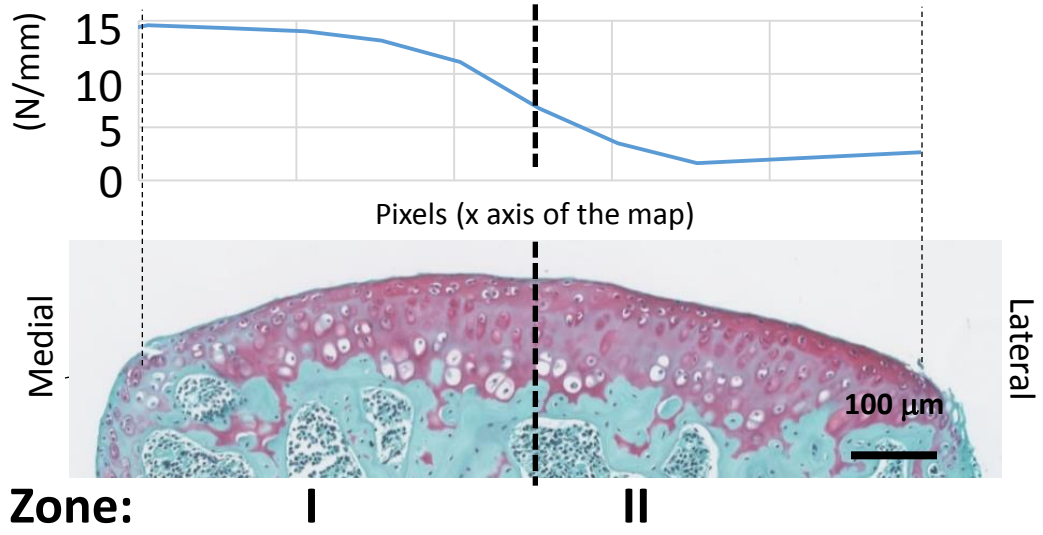
OA
(15 weeks)





Healthy
(15 weeks)





Conclusions

- Mechanical properties can be mapped on entire articular surfaces of tiny mouse joints.
- Mappings show similar distribution patterns to those previously observed for the stifle joints of larger species, with stiffer cartilage in the region covered by the meniscus (Sim et al. Trans *ORS2013)*
- Decrease of the average structural stiffness for the medial compartment of the OA-developing mouse is in agreement with the literature (Walton M. *J. Pathol*. 1977)

Significance:

- This non-destructive technique can reveal itself useful in mice studies on the effect of age, gene modifications (transgenic-models) and disease (OA models).

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