EXPERIMENTAL ASSESSMENT OF MECHANICAL CHANGES IN HUMAN OSTEOARTHRITIC CARTILAGE

Alice Berardo (1,2), Chiara Giulia Fontanella (3), Ilaria Toniolo (1), Gianluca Mazzucco (1), Elisa Belluzzi (4), Assunta Pozzuoli (4), Pietro Ruggieri (4), Emanuele Luigi Carniel (3)

1. Department of Civil, Environmental and Architectural Engineering, University of Padova, Italy
2. Department of Biomedical Sciences, University of Padova, Italy
3. Department of Industrial Engineering, University of Padova, Italy
4. Orthopedics and Orthopedic Oncology, DiSCOG, University of Padova, Italy

Introduction

Articular Cartilage (AC) is a complex connective tissue and plays a key role during load bearing, shock absorption, and lubrication in joints. However, traumatic events, aging and degenerative pathologies may affect its structural integrity, causing pain and long-term disability. Among these causes, osteoarthritis (OA) represents a health issue, which concerns 1 out of 4 people in Europe [1]. Moreover, it has been observed that OA affects also the mechanical behaviour of AC, with direct effects on both tribological and bearing activities [2], [3].
Within this scenario, this study aimed at quantifying the effects of OA on the viscoelastic properties of human cartilage through indentation and unconfined compression tests. Results may be exploited to Finite Element models, for a complete evaluation of the mechanical effects of OA on knee joints.

Methods

OA tibial plateaus were collected from six human subjects (M: 2 F: 4; 79±4 y/o) that underwent total knee replacement (at the Orthopedics and Orthopedic Oncology Unit, University Hospital of Padova CESC Code: AOP2649). Normal indentation (Fig. 1a) and unconfined compression tests (Fig. 1b) were carried out with Mach-1 Mechanical Tester (©Biomomentum Inc.), to obtain instantaneous and equilibrium mechanical behaviour of AC. Normal indentation consisted in multiple measure points on the tibial surface, adopting a 0.3 mm of indentation amplitude with a velocity of 0.05 mm/s. Consequently, with a needle penetration procedure, the thickness of the cartilage layer was extracted. Stress-relaxation tests were realized in unconfined compression on cartilage disks (5 mm diameter). Four ramps (5% strain, 20% s^{-1} strain rate) were imposed, the first with a relaxation time t of 600 s (preconditioning), while t =1500 s for the others.

Figure 1: Experimental setup for normal indentation (a) and unconfined compression tests (b).

The Equilibrium Modulus and permeability were fitted with the Fibril-Network Reinforced Biphasic Model [5].

Results

The distributions of the Instantaneous Modulus (*IM*) (Fig. 2a) and the AC thickness (Fig. 2b) were obtained for the entire portion of the samples covered by AC [4]. Viscoelastic behaviour was analysed from stress-relaxation tests in unconfined compression (Fig. 2c-d).

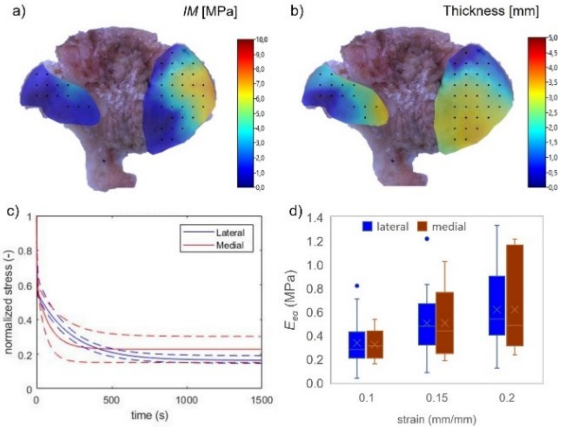

Figure 2: a) IM and b) thickness variations on the tested samples. c) Normalized stress-relaxation curves. d) Variation of E_{eq} by increasing the applied strain for lateral and medial tibial plateaus.

Discussion

Significant variations have been observed even within the same sample for both instantaneous and long-term mechanical parameters, which can be directly correlated to local damage due to OA.

References

[1] Global Bouden of Disease, “Global Bouden of Disease Study 2019 (GBD 2019) Results. Osteoarthritis - Level 3 Cause.” 2020.
[2] R. U. Kleeman *et al.*, *Osteoarthr. Cartil.*, 13, 958–963, 05 2005.
[3] M. Ihnatouski *et al.*, *Materials (Basel).*, 13, 20 2020.
[4] W. C. Hayes *et al.*, *J. Appl. Physiol.*, 31, 562–568, 71 1971.
[5] J. Soulhat *et al.*, *J. Biomech. Eng.*, 121, 340–347, 99 1999.

Acknowledgements

This work was supported by MIUR, FISR 2019, Project n° FISR2019_03221, titled CECOMES. A special thanks to the master students who had contributed to the research: Carlotta Agressi and Marta Zanini.