



HAL
open science

What is the influence of strain rate on human cortical bone propagation mechanisms

Rémy Gauthier, Hélène Follet, Max Langer, Evelyne Gineyts, Cécile Olivier, Pierre-Jean Gouttenoire, Lukas Helfen, Sylvain Meille, Jérôme Chevalier, Frédéric Rongieras, et al.

► To cite this version:

Rémy Gauthier, Hélène Follet, Max Langer, Evelyne Gineyts, Cécile Olivier, et al.. What is the influence of strain rate on human cortical bone propagation mechanisms. 8th World Congress of Biomechanics (WCB 2018), Jul 2018, Dublin, Ireland. hal-01868513

HAL Id: hal-01868513

<https://hal.science/hal-01868513>

Submitted on 5 Sep 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

What is the influence of strain rate on human cortical bone crack propagation mechanisms?

Rémy Gauthier¹, Hélène Follet², Max Langer^{3,4}, Evelyne Gineyts², Cécile Olivier^{3,4}, Pierre-Jean Gouttenoire^{3,4}, Lukas Helfen⁴, Sylvain Meille⁶, Jérôme Chevalier⁶, Frédéric Rongiéras^{1,5}, Françoise Peyrin^{3,4} and David Mitton¹

¹ Univ Lyon, Université Claude Bernard Lyon 1, IFSTTAR, LBMC UMR_T9406, F69622, Lyon, France;

² Univ Lyon, Université Claude Bernard Lyon 1, INSERM, LYOS UMR1033, F69008, Lyon, France ;

³ Univ Lyon, CNRS UMR 5220, Inserm U1206, INSA Lyon, Université Claude Bernard Lyon 1, Creatis, F69621 Villeurbanne, France;

⁴ ESRF, 38, Grenoble France;

⁵ Service Chirurgie Orthopédique et Traumatologie - Hôpital Desgenettes, 69003, Lyon, France;

⁶ Univ Lyon, INSA-LYON, MATEIS, UMR CNRS 5510, F69621, Villeurbanne, France ;

Introduction

Osteoporosis remains today a major health problem. Cortical bone fracture mechanisms are well documented under quasi-static loading condition. However the influence of strain rate on fracture needs to be better understood as bone fractures mainly occur after a fall from a standing height. The fracture process in human cortical bone is complex, and involves the overall organization of the tissue. Previous results showed that the whole porosity network, from the Haversian system to the lacunar network, as well as the collagen cross-links maturation, might be involved in the crack propagation mechanisms in cortical bone. Thus, the aim of the current study is to collect biomechanical, morphometric and biochemical parameters to make an overall characterization of human cortical bone crack propagation mechanisms considering two different loading conditions.

Materials and methods

In that objective, paired human femoral diaphysis, femoral neck and radial diaphysis were extracted from 8 female donors (70 ± 14 y.o., min: 50 y.o., max: 91 y.o.). Toughness experiments were performed on cortical bone samples. Two loading rates were considered for each bone: a quasi-static standard condition, and a condition representative of a fall. The mechanically tested specimen were then used to perform synchrotron radiation micro-computed tomography imaging (voxel = [0.7 μm]³) in order quantify the Haversian and lacunar systems, and to evaluate the formation of micro-cracks during crack propagation. Adjacent cortical bone specimens were finally used to measure the concentration of immature and mature enzymatic cross-links by a high performance liquid chromatography. The CX ratio (CX = [Immature] / [Mature]) was analyzed as it gives information on the collagen cross-links maturation.

Results and discussion

Results showed that if collagen cross-links are involved in the elastic contribution of the fracture process, the plastic one is mainly governed by the porosity network associated with micro-cracking or crack deflection toughening mechanisms under a quasi-static loading. Under a fall-like condition, the cortical porosity is less involved in crack propagation mechanisms. Crack propagation barriers seem less efficient in this critical loading condition. This study provides new information on human cortical bone crack propagation mechanisms under quasi-static and fall-like loading condition, on different paired anatomical locations.

Acknowledgment

This work was done in the framework of LabEx PRIMES (ANR-11-LABX-0063). This study was partly funded by the Région Rhône-Alpes and by the ANR project MULTIPS (ANR-13-BS09-0006). The authors also want to thank the Fédération INGE'LYSE for its financial support.

References

Ritchie et al., Strain, 2006

Gauthier et al., JMBBDM 2017

Ural & Vashishth, Int. Mater. Rev., 2014

Seeman & Delmas, N. Eng. J. Med., 2006