PhD-Thesis proposal in Sciences and Technologies at FEMTO-ST Institute, Univ. Bourgogne Franche-Comté (UBFC)

Soft tissue biomechanics: Human skin.

Domain : Biomechanics, Mechanics and Materials science

The thesis subject is driven by the department of applied mechanics at FEMTO-ST institute. The project follows on from earlier multidisciplinary collaboration with the LMB (Laboratoire de Mathématiques de Besançon), the university hospital center (Clinical Investigation Center CHRU in Besançon) and the University of Luxembourg (computational mechanics team).

Context :

The numerical methods and compute power available today enable precise simulation of the behavior of biological tissues, including the ability to predict their biomechanical properties. However, these simulations are only relevant if they are based on sufficient and representative input data concerning a specific tissue. The accurate simulation of biological living tissues remains both a scientific and a practical challenge to this day for several reasons: the scarcity of in vivo data, the inaccessibility of certain information, the heterogeneity (i.e. complexity) of biological tissues, to name a few. This project will focus on the biomechanical behaviour of human skin, including substitutive materials, via state of the art numeral modelling and validation against experimental data obtained on proof samples. The mechanical stress field within human skin is supposed to be responsible for such pathologies as keloids. This is evidenced by pro-keloid anatomical sites which have the characteristics of mechanically stressed environments [1]. Collaboration with doctors and biologists will facilitate a better understanding of the mechanisms responsible for the evolution of these pathologies.

Objectives :

In the context that keloids pose as a highly relevant medical issue, the aim is to define the specification of a device for the prevention of keloid development (e.g. as part of a post-sternotomy therapeutic support). This will be achieved by gaining the necessary understanding of the development of a keloid from a mechanical point of view, e.g. as influenced by the stress field in the vicinity of a keloid. The project will mainly concern the mechanical causes. Although genetic and biological origins of this pathology exist, these will not be the focus of the research.

Methodology :

A direct mechanical analysis of a patient-specific case-study to determine the patient-specific stress field around a keloid is difficult due to various uncertainties in a computational model, including material parameters, model boundary conditions. Above all, the validity of a chosen material model can not be established a priori [1]. Therefore, it is useful to adopt a surrogate physical model of the skin that is simpler in order to validate a given computational model. To this end, skin “phantoms” with mechanical properties close to human skin [2] are easy to carry out mechanical tests thereby reducing the level of uncertainty. The phantoms will be produced and tested in order to build experimental benchmark data [3] and reduce the influence of uncertainties due to inter-individual variability. The tests will make possible the choice of a material behavior model, the identification of the materials parameters and the validation of a numerical prediction of the physical model response to mechanical solicitation. Other trials similar to those that can be performed in vivo (Ultrasound, suction, uniaxial and biaxial extension…) [4] will be conducted on the physical model. The comparison between the calculation and experimental data and a sensitivity analysis will provide the minor-error estimation of parameters and the identification of the best measuring site to reduce the influence of uncertainties. The results analysis will highlight the need for complementary tools able to provide field measurements (eg. stereo–digital image correlation) and obtain a well-posed problem.

The objective of the project deals with the non-linear elastic properties, the viscosity and anisotropy of the tissue. Dynamic vibro-acoustic tests (Doppler 3D-laser) are considered in addition to quasi-static ones. Experiments on artificial materials that mimic skin can link the results obtained by vibration and quasi-static extension.

The activities will include:

- The experimental mechanical characterization of an artificial material with similar singularities as skin (anisotropy, heterogeneity, nolinearity) and artificial bi-material structure similar to skin-keloid domain
- A set of in vivo trials to expand an existing database [5]. Each test will enrich the database and the knowledge of the problem [3].
- The data processing and numerical model updating in order to provide the prediction of stress fields components in the domain.

The project will benefit from existing links with the hospital (surgery Unit and Clinical Research Center (CIC-CHRU)) for the in vivo clinical trials protocol design and the recruitment of panel subjects. Collaborations with Biomedical engineering student (UBFC) will be set up about the regulatory framework.

BIBLIOGRAPHY

[1] R. Ogawa, K. Okai, F. Tokumura, K. Mori, Y. Ohmori, C. Huang, H. Hyakusoku, S. Akaishi, The relationship between skin stretching/contraction and pathologic scarring: the important role of mechanical forces in keloid generation. *Wound Repair and Regener*ation, 2012, 20(2):149-157.

[2] A.K. Dabrovska, G.-M. Rotaru, S. Derler, F. Spano, M. Camenzind, S. Annaheim, R. Stampfli, M. Schmid and R.M. Rossi, Materials used to simulate physical properties of human skin Skin Research and Technology, 2016, 22:3-14.

[3] J. Hale, P. Farrell, S. Bordas. A Bayesian inversion approach to recovering material parameters in hyperelastic solids using dolfinadjoint, in: FEniCS ’15 Workshop, Imperial College, London, 2015.

[4] E. Jacquet, S. Joly, J. Chambert, K. Rekik, P. Sandoz. Ultra-light extensometer for the assessment of the mechanical properties of the human skin in vivo. Skin Research and Technology, 2017, 23:531–538.

[5] E. Jacquet, J. Chambert, J. Pauchot, P. Sandoz. Intra- and inter-individual variability in the mechanical properties of the human skin from in vivo measurements on 20 volunteers. Skin Research and Technology, 2017, 23:491–499.

Background	*master degree or equivalent degree in biomechanics, mechanical engineering or computational mechanics.*
Skills	*Mechanical testing, Numerical simulation in Mechanics. A strong motivation and interest in living tissue biomechanics is favoured.*
Place	*FEMTO-ST Institute – Department of Applied Mechanics, Besançon (25) France*
Period	*Automn 2018 – Automn 2021*
Language	*English, French (level required B2-C1).*
supervisor	*Mrs Emmanuelle JACQUET, PhD. Dr. Ing., Associate Professor, FEMTO-ST Institute, Department of Applied Mechanics,* *Adress : 24 rue de l'Epitaphe, 25000 Besançon, FRANCE* *e-mail : emmanuelle.jacquet@univ-fcomte.fr*, phone : +(33) 3 81 66 60 19
Working conditions	*Doctoral contract at UBFC : CDD 36 months* *Annual gross salary : 23 700 €*

In order to apply :

Send by email to project coordinator Emmanuelle Jacquet (emmanuelle.jacquet@univ-fcomte.fr). Applications should be submitted electronically before the 14th may 2018.