From experimental data to a numerical model of Keloid-Skin Composite structure

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As keloids are a consequence of abnormal wound healing process, the fibroblast proliferate excessively in dermis (Ogawa & Orgill, Mechanobiology of Cutaneous Wound Healing and Scarring, in Bioengineering Research of Chronic Wounds, 2009) and develop an unsightly and uncomfortable tumor that replaces the healthy skin. The structure and the properties of keloids highly differe from healthy skin, in particular the mechanical properties. Several anatomic sites are known as pro-keloid sites. Others don't develop any keloid (Ogawa & Orgill, Mechanobiology of Cutaneous Wound Healing and Scarring, in Bioengineering Research of Chronic Wounds, 2009). In addition to genetic and biological causes, the mechanical solicitation of the in vivo skin induces the growth of keloid. Furthermore, this is highly related to the site and the range of body motion. This assumption is well documented by (Ogawa, et al., 2012). The design of a medical device should improve the prevention of the pathology but the mechanical components of the stress fields have to be determine in order to explain the mechanical process of keloid growth.

The corresponding technical specificities suppose that mechanical identification of the stress fields is based on a minimal error approach. The present paper deals with a model which is both numerical and experimental. We make a mold of the keloid with a silicone in order to build a 3D geometric numerical model of it. The mechanical properties of both two materials keloid and healthy skin are determined thanks to an original characterization device that allow an uniaxial test such as the area around the measuring zone can be neglected (Jacquet, Joly, Chambert, Rekik, & Sandoz, 2017). So the test seems to be a traction test on the skin surface. Displacement and force sensors are able to control one of them and measure the other and vice versa. A speckle pattern is laid on the zone of interest and the displacement field is identified by a digital image correlation method during the mechanical test. The 3D model is analyzed by finite element method with hyperelastic material models and the resulting stress field all around the keloid is compared to the experimental data.

The objective consists in controlling the uncertainties regarding to the high variability of mechanical properties of human skin , unknown boundary conditions, heterogeneity of biological tissues and unknown initial skin tension. The paper will focuse on the numerical framework we designed to identify the stress field around the keloid.

The 3D numerical model allow to reproduce the real keloid in an artificial sample that mimics skin in vivo and emphasizes some singularities of skin. All mechanical properties of the skin are not supposed to be reproducted by the artificial sample. Well-known materials integrated into a physical model of keloid, can lessen some uncertainties about the behavior and boundary conditions.

An original method has been developed from numerical methods and in vitro and in vivo experiments. The next step consists in investigating the nature of the stress field around the keloid in order to help to design a specific device able to contain the growth of the keloid. And further, the expected improvement is a better localization and an improved protocole for in vivo experiments relevant respectively to the medical purpose.

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