Biaxial extensometer for measuring of the human skin anisotropy in vivo

L. Capek, Z. Lochman., L. Dzan and E. Jacquet

Abstract—Knowing biomechanical properties of human skin is important for clinical decision making as well as clinical intervention. Measuring these properties in vivo is critical. However, existing devices don’t respect the fact, that human skin is an anisotropic material. Nowadays devices investigate mostly the human anisotropy in the way of uniaxial testing. It leads to distorted information. In this paper we proposed a new biaxial device for testing the human skin in vivo. This device can be used to obtain the true anisotropy of human skin.

I. INTRODUCTION

Research into the biomechanics of the human skin has attracted a lot of dermatologists’ interest. Skin performs a wide variety of functions resulting from chemical and physical reactions inside these components. The major function of skin is to act as a barrier to the exterior environment. From the mechanical point of view human skin is a heterogeneous material composed of collagen and elastin fibres in a proteoglycan matrix [1]. Acting together, these components are responsible for the complex mechanical behaviour of skin as manifested in stress, strain curves. These curves are characterized by a low-stiffness region at small strains followed by a dramatic increase in stiffness as the strain becomes large [2,3]. Moreover, its behaviour depends on direction.

Wijn et al. provided uniaxial experiments on the leg in parallel and perpendicular directions to Langer’s lines and founded that the Young’s moduli is 3.8 times greater in parallel direction [4]. Khatyr et al. showed that the anisotropy ratio on the forearm is equal to 5 [5]. Manschot et al. showed that on a leg 76 % of elastic fibres are oriented along Langer’s lines and only 51 % are oriented perpendicularly [6].

There are several non-invasive and invasive techniques for evaluation of mechanical properties of human skin. The most commonly used methods are based on the measurement of suction, torsion and traction [3,7,8,9,10]. Other experimental methods can be used to measure the skin mechanical behavior like elastic wave propagation or indentation [11]. However, the data obtained with these methods are mainly descriptive and often very different, depending on the experimental conditions. The most common test is a uniaxial one. It works by applying displacements to the skin using two extensible pads that are attached to the skin. The force needed for deformation is measured by a load cell as the skin deforms.

The aim of this study was to construct a prototype of a biaxial extensometer allowing measuring the directionally dependence of biomechanical properties of human skin in vivo.

II. MATERIAL AND METHODS

In spite of the fact that there are lot of uniaxial in vivo extensometers, there is no device, to our knowledge, enabling to load the human skin in two directions simultaneously in vivo. The design of the extensometer was done in the CAD software Pro/Engineer (PTC software ltd., Czech Republic).

The device consists of two miniature load cells, four actuators, fours pads and a movable frame, fig. 1.

The input parameters: low mass, high stiffness, variability and cost. For optimizing of these parameters an finite element analyses was performed. The movement of two opposite actuators is tied with maximal speed 600 steps/second and maximal displacement 26 mm. The movement from the actuators to pads is transfer by a lever system. The pads are joined to the skin surface by doubled
sided adhesive tape. The distance between two opposite pads is flexible, but the minimal distance is 30 mm. The final design of the real biaxial extensometer can be seen on the figure 2. All components were fabricated from duralumin, which maintains the low mass with high resistance.

We have provided three main tests for validating our new biaxial extensometer. All of them were provided at the region of forearm on the man:

- The first one was done in axis x (parallel to Langer’s lines),
- the second one in y axis (perpendicular to Langer’s lines)
- the last one in x and y axis together.

III. RESULTS

All gained stress and time curves exhibit the initial, low-stiffness region, where the collagen fibres align themselves parallel to the maximum stretch direction while either the elastin and/or the proteoglycan matrix provides resistance to deformation. Once the collagen fibres are aligned, further extension of the skin requires extension of the collagen fibres, resulting in a significant increase in skin stiffness until failure.

The typical curves are presented below. In the first test carried out in x direction the maximal force was recorded to 2.45 N, fig. 3. In the second test carried out in y direction the maximal force was recorded to 6.5 N, fig. 4. In the last test the maximal forces recorded in x direction was 6.6 N and in perpendicular direction 7.5 N, fig. 5.

IV. CONCLUSION
We assume that the tensile tests are, from a mechanical point of view, one of the best possible load application for identifying skin’s anisotropy. Human skin exhibits a nonlinear anisotropic properties. For identifying of human skin’s anisotropy biaxial tests must be provided. Nowadays the most common tests used for identifying of human skin anisotropy are uniaxial tests done separately in different directions. From the mechanical point of view it doesn’t give us the whole information about human skin’s anisotropy. According to literature, there is no biaxial device providing tensile tests on human skin in vivo.

The proposed biaxial device is the first prototype of this type. All gained stress and time curves exhibit the nonlinear behaviour with values close known from the literature [2,3]. The most new information can be seen from the figure 6, where two stress strain curves were gained in the same time. The human skin’s anisotropy is proved, but is not so significant as can be seen in literature, where uniaxial tests are done separately.

It should be noted, that only preliminary tests were done and results are no valid from the statistical point of view. In the future the results will be confronted by a correlation system Dantec Q-400 (Dantec Dynamics Ltd., Germany) and the statistical results must be gained. The aim of this paper was to present our new biaxial system constructed for measuring of human skin in vivo.

ACKNOWLEDGMENT

We would like to thank you to Dr. Aleš Lufinka for technical helps during this project.

REFERENCES