EVALUATION OF BIOMECHANICAL PROPERTIES OF SOFT TISSUES MIMICKING PHANTOMS BY IMPACT ANALYSES.

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Introduction

In oncology, the development of most pathological processes is accompanied by an alteration of the mechanical properties of the tissue and a change in its biomechanical properties [1]. Similarly, in dermatology, several skin diseases such as scleroderma or keloids scars alter the biomechanical characteristics of the skin [2]. Thus, the assessment of soft tissue properties is of great relevance for clinical diagnosis. The physicians often employ empirical techniques to assess the soft tissue stiffness and detect potential abnormalities.

The objective of this work is to investigate the feasibility of using impact analysis to assess the biomechanical properties of soft tissue. This new approach is non-invasive, provides real-time information and is relatively inexpensive and ease-of-use compared to existing medical devices such as the Fibroscan® or the Cutometer®.

Methods

The experimental device consists of a 5 grams hammer equipped with a force sensor (8204, BK Connect, Brüel and Kjaer, Naerum, Denmark) that impacts a cylindrical beam in contact with the upper surface of the sample to be characterised. The assembly is integrated into a support that guides the punch and holds the sample during the measurement and ensures the reproducibility of the measurements (see Fig.1a).

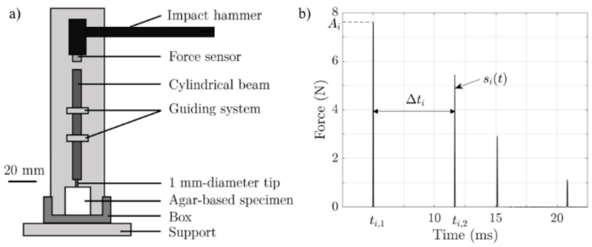

Figure 1: Schematic description of the experimental device (a). Example of signal $s_i(t)$ corresponding to the variation of the impact force in function of the time (b).

A signal processing technique deriving from [3] was applied to the signal $s_i(t)$ corresponding to the variation of the force as a function of time during an impact of the hammer on the beam (Fig.1b). Thus, a time indicator, Δt, was obtained from the average of the difference, Δt_i, between the time of the first, $t_{i,1}$, and the second local maxima, $t_{i,2}$, of four signals $s_i(t)$.

$$\Delta t = \frac{1}{4}\sum_{i=1}^{4} \Delta t_i, \quad \Delta t_i = t_{i,2} - t_{i,1} \qquad (1)$$

As a first step, the tests were carried out using agar-based phantoms which have been extensively employed to mimic biological soft tissues [4], with an agar concentration varying between 1g to 5g per 100 mL of deionized water. For specimens with different agar concentrations c, the indicator Δt and its standard deviation, $\sigma_{\Delta t}$, were derived from the impact force signals $s_i(t)$.

Results

The time indicator Δt decreases as a function of the agar concentration c (Fig.2). According to an ANOVA analysis, for each agar concentration c, the values of Δt are significantly different (p-value=4.10^{-10}).

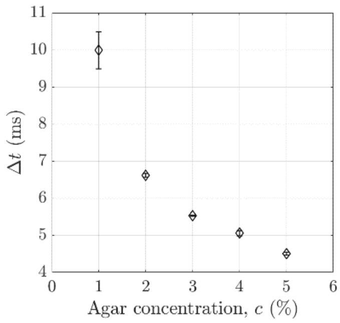

Figure 2: Evolution of the time indicator Δt in function of the agar concentration c for one specimen.

Discussion

The method can be used to distinguish the elastic properties of agar phantoms and has the advantage of being easy to use and inexpensive. Moreover, the behaviour of our indicator is consistent with others studies [5] and the sensitivity of the impact method is of the same order of magnitude as elastography or dynamic mechanical analysis.

References

1. Skovoroda et al, Biophysics, 6(40):1359-1364, 1995.
2. Gennisson et al, IEEE Trans Ultrason, Ferroelect, Freq Contr, 51(8):980-989, 2004.
3. Tijou et al, J Mech Behav Biomed Mater, 88:102-108, 2018.
4. Ebenstein et al, J Biomed Mater Res, 69A(2):222-232, 2004.
5. Hall et al, IEEE Trans Ultrason, Ferroelect, Freq Contr, 44(6):1355-1365, 1997.

Acknowledgements

This project has received funding from the European Research Council (ERC) under Horizon 2020 (grant agreement No 682001, project ERC Consolidator Grant 2015 BoneImplant), from the project OrthAncil (ANR-21-CE19-0035-03) and from the project OrthoMat (ANR-21-CE17-0004).