Quantitation of collagen structure and remodeling in the cervix during pregnancy using polarization-resolved SHG microscopy

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Collagen plays a key role in the cervix mechanics. During pregnancy, the collagen fibers reorganize leading to cervical softening to ensure an efficient delivery [1]. Understanding this remodeling is crucial for many applications, such as the early detection of preterm birth. The techniques used so far had many limitations in their resolution and specificity to collagen. In this work, we use polarization-resolved Second Harmonic Generation microscopy (p-SHG), which is very efficient for monitoring collagen reorganization during gestation as shown in a recent preliminary study [2]. Sections from different depths in the cervix and from mice at different stages of gestation are prepared. Mosaicking is performed by acquiring a series of p-SHG images (tiles) using a motorized stage to extend the field of view and acquire the whole section of the cervix (2 x 2 mm^2). The intensity and orientation maps of the collagen fibers are then obtained for each tile and stitched together to reconstruct maps of the section. The pipeline for mosaicking acquisition and reconstruction is fully automated. After that, metrics are developed to quantify the collagen content, the porosity between fibers and the collagen organization.

Our pSHG data show that the ecto-cervix (bottom) is richer in collagen that the endo-cervix (upper cervix), confirming previous histological studies with a technique more specific to collagen [3]. The density and size of pores also show differences between the different depths and stages of pregnancy, which match what we would expect from collagen remodeling. The orientation maps show a high organization over all depths at the beginning and a high disorganization at the end of pregnancy (fig. 1). Between these limits, a remodeling range is observed with an increase of disorganization from the endo to the ecto-cervix. Hence, p-SHG provides a quantitative analysis of the fibers structure at the micrometer scale, showing interesting differences between different parts of the cervix. Structural and organizational changes are observed during pregnancy, with an identification of the remodeling range. These results can give us insight about cervical mechanics.

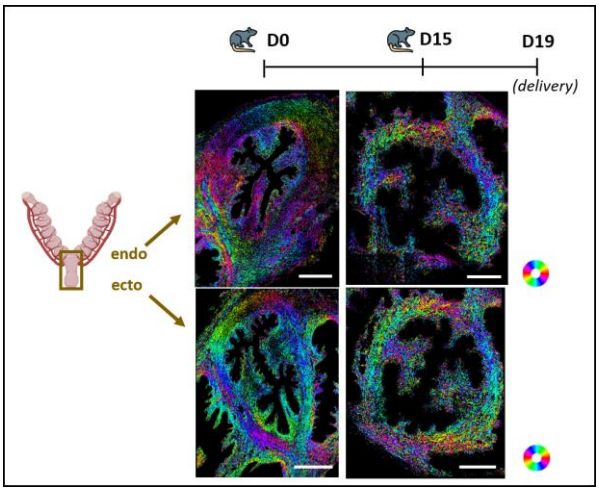

Fig 1: Example of p-SHG orientation maps. Scale bar: 400 µm. Orientation shown by the color wheel.

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