IN-SITU 4D MICROFOCUS X-RAY COMPUTED TOMOGRAPHY: APPLICATION TO VASCULAR SYNTHETIC GRAFTS

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Introduction

Atherosclerosis is the most common form of cardiovascular diseases (CVDs) and is affecting mostly the larger arteries. It is the major worldwide cause of death [1]. The accumulation of lipidic plaques within the arterial lumen induces its narrowing and the inflammatory process activation, thus causing blood flow disturbances [2]. Although atherosclerosis is not a direct cause of death, it leads to other CVDs that can be lethal, such as heart attacks, stroke or even other vascular diseases [3]. A possible treatment for atherosclerosis consists of replacing or bypassing the diseased artery by a synthetic vascular graft. These grafts must mimic the human vascular tissue properties to avoid complications. However, many of the current clinically available synthetic grafts show an important mismatch in mechanical properties compared to the native tissue, and thus further optimization of the graft design is still required.

Materials and methods

In this study, we used 4D X-ray microfocus computed tomography (4D-microCT) for the mechanical characterization of three different synthetic vascular grafts (Dacron®, Vectra®, and Gore-Tex®). 4D-microCT is a combination of microCT imaging and in-situ mechanical loading. It allows the "dynamic" assessment of structural changes during graft deformation, and this in full 3D and at the microscale. 4D-microCT was used in combination with digital volume correlation (DVC) to better understand the local mechanical behavior of the grafts. The three grafts were tested in the longitudinal and circumferential direction.

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Results and conclusions

Dacron®, Vectra® and Gore-Tex® present a very different microstructure, even though their main purpose of use is the same. With this observation, we could already hypothesize that their mechanical behavior would be different. After subjecting them to uniaxial in-situ tensile loading, we observed that, at the same deformation state (200 µm of overall stretching in the longitudinal direction of the graft), the strain-field distribution within each graft was distinct and dependent on their microstructure (Figure 1). In the circumferential direction, we observed a mechanical anisotropy for the three grafts (not shown in the present abstract).

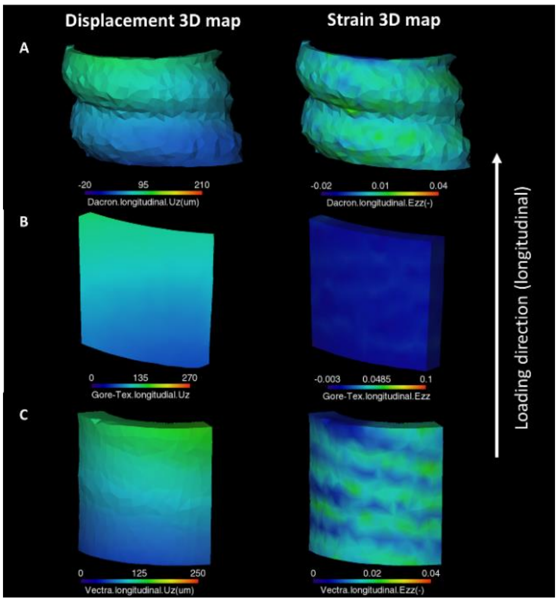

Figure 1: 3D rendering of strain-field distribution within synthetic grafts (A)Dacron, (B) Gore-Tex and (C) Vectra. This figure shows the results for 200µm of stretching in the longitudinal direction (white arrow).

For future work, the goal will be to test vascular samples using 4D contrast-enhanced microCT (4D-CECT) and directly compare results between native tissues and their synthetic homologs in the physiological range of deformation or even with more complex loading than uniaxial mode.

In conclusion, 4D-microCT is a technique capable of detecting structural changes inside samples undergoing mechanical loading at the microscale with the assistance of DVC. By combining in-situ mechanical tests with microCT system, it allows to directly link heterogeneities in the strain mapping to the microstructure itself, or possible defects that are not detectable with ex-situ mechanical testing.

References

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