# Anisotropic properties of heart valves can be measured with spherical indentation

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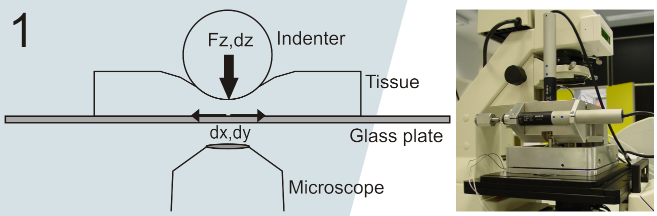
## Introduction

- Annually 6000 heart valve replacements in newborns in Europe.
- Unlike current treatments, Tissue engineering (TE) results in a living heart valve, with the ability to grow, repair and remodel.
- In vitro mechanical conditioning is critical for developing strong TE heart valves. It also stimulates development of an anisotropic and inhomogeneous collagen fiber network, which is typical for native heart valves.
- Current mechanical characterization methods do not capture the complex mechanical properties of this fiber network.

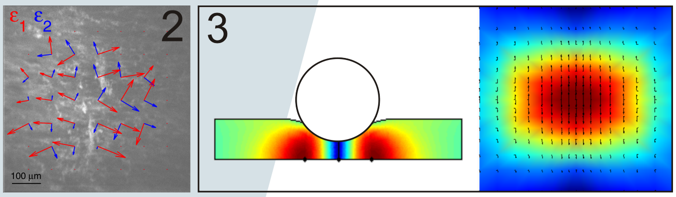
**Objective: development, validation and application of a method for the non-destructive, local mechanical characterization of TE heart valves, including anisotropy.**

## Methods

1. A spherical indentation test is performed on top of an inverted confocal microscope. Indentation force and confocal images of the bottom plane of the sample are recorded during the test.

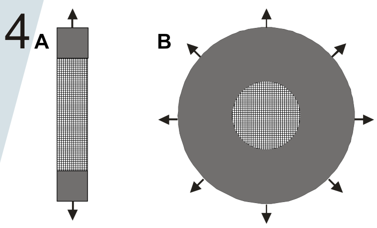



2. Digital Image Correlation (DIC) is applied to the images obtained in step 1 to quantify local first ($\epsilon_1$) and second ($\epsilon_2$) principal strain magnitude and direction.




3. A numerical model is coupled to the indentation force and principal strains for parameter estimation. Resulting parameters describe fiber distribution and fiber tensile behavior.

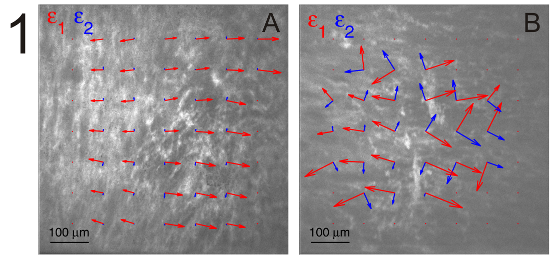
4. Static constraining during culture induces fiber orientation along the constrained direction. Tissues were cultured using uniaxial (A) or equibiaxial (i.e. in all in-plane directions) constraining (B).



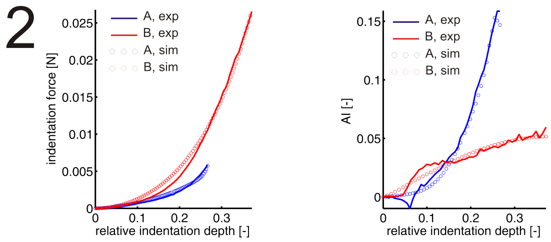

**Hypothesis:** Uniaxial culture constraints will result in anisotropic mechanical properties. Therefore the indentation test will reveal a narrow (uniaxial) fiber distribution for A and a broad (uniform) distribution for B.

## Results

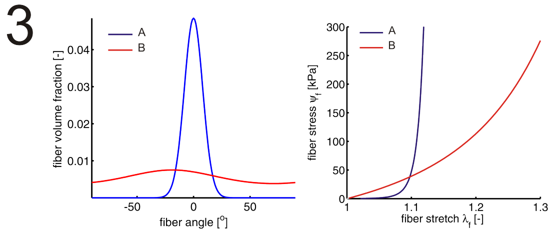
1. The uniaxially constrained sample (A) demonstrates a clear preferred principal strain direction, while the equibiaxially loaded sample (B) demonstrates a more isotropic deformation pattern.




2. For both samples a good quantitative fit was obtained between experimental results and the numerical model for the indentation force (left) and the anisotropic index (AI, right).




3. As hypothesized, a uniaxial fiber distribution was found for sample A and a uniform fiber distribution for B (left). Furthermore, the fiber tensile behavior of A was much more nonlinear (right).




## Conclusions

- Method validated for TE constructs using static culture constraints.
- Good quantitative fit between experiment and model.
- Anisotropic constraints result in anisotropic properties.
- Static constraining during culture can be used to tune fiber distribution and mechanical properties.