Predicting springback in NiTi annuloplasty rings with phase-specific stress scaling


# Book of Abstracts

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# PREDICTING SPRINGBACK IN NITI ANNULOPLASTY RINGS WITH PHASE-SPECIFIC STRESS SCALING

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## Introduction

Functional tricuspid insufficiency, commonly associated with mitral valve disease, is generally treated using prosthetic annuloplasty rings (ARs). These devices are manufactured from nickel-titanium (NiTi) tubes through a shape-setting process, which involves heat treatment of the tube while it is inserted into a circular mold, to define the final shape of the AR. However, residual stresses left in the NiTi after the heat treatment cause springback of the AR upon removal from the mold, resulting in deviations from the intended geometry. In this context, the present study proposes a computational procedure based on finite element (FE) analysis for the prediction of springback of NiTi ARs.

## Methods

Four NiTi tubes, two laser-cut and two non-laser-cut, each available in two different sizes (i.e., sizes 1 and 2), underwent a shape-setting process to achieve a circular shape. The process consisted of two main steps: (1) insertion of the NiTi tube into a circular mold and (2) heat treatment in a high-temperature salt bath, followed by removal from the mold. This procedure was repeated three times for each of the four NiTi tubes. After shape-setting, their geometries were reconstructed using the optical measurement machine Smart-Scope ZIP250 (OGP Hommel srl). FE models of the NiTi tubes were developed using hexahedral elements and a super-elastic constitutive material model for NiTi. The FE analysis replicating the experimental procedure was performed in Abaqus Standard (Dassault Systemes Simulia Corp.) and comprised two main steps: (1) insertion of the NiTi tube into the mold, modelled with rigid surfaces (Fig. 1a); (2) heat treatment and extraction of the NiTi tube from the mold (Fig. 1b). The heat treatment process was modelled by scaling the stresses with constant relaxation coefficients. Specifically, relaxation coefficients $r_p$ and $r_a$ were applied to stresses exceeding the upper plateau stress of NiTi (i.e., when the material is in the transition phase between austenite and martensite) and to stresses below the upper plateau stress (i.e., when the material is in the austenitic phase), respectively. First, the relaxation coefficients were calibrated by fitting the FE model to the experimental data of the laser-cut tube with size 1, minimizing the difference at four points along the NiTi tube (Fig. 1c). Thereafter, the procedure was validated by comparing the geometries predicted by the calibrated FE model with those obtained experimentally for the laser-cut tube with size 2 and the non-laser-cut tubes with sizes 1 and 2 (Fig. 1d).

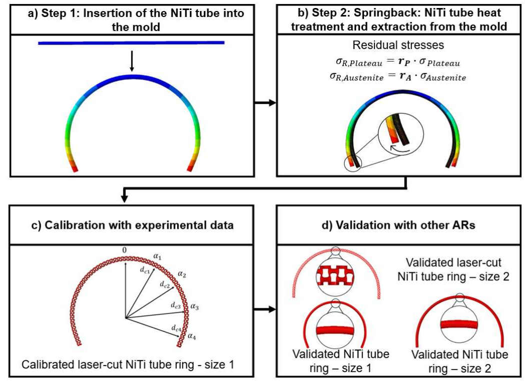


*Fig. 1: Main steps of the computational procedure for the springback prediction in NiTi annuloplasty rings.*

## Results

Relaxation coefficients $r_p$ = 2% and $r_a$ = 27% were determined by the calibration procedure for the laser-cut NiTi tube with size 1. This resulted in a maximum percentage error of 0.84% (at point $\alpha_4$) in the distance between the geometry predicted by the FE analysis and that measured experimentally (Fig. 2a). Moreover, the computational procedure was successfully validated for the other NiTi tubes, as illustrated in Fig. 2b.

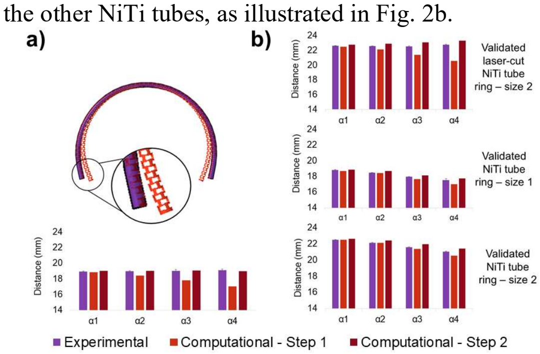


*Fig. 2: a) Calibration and b) validation of the computational procedure for the springback prediction.*

## Discussion

The computational procedure enabled the springback prediction across various NiTi tubes, highlighting the role of phase-dependent residual stresses in springback. To conclude, the computational procedure provides a valuable tool for improving the design and manufacturing of NiTi ARs, reducing the need for trial-and-error adjustments during the design phase.

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