

TOWARDS THE PREDICTION OF SPRINGBACK IN SHAPE SETTING FOR NITI ANNULOPLASTY RINGS

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Introduction

Functional tricuspid insufficiency (TI) primarily occurs in patients with mitral valve disease, leading to pulmonary hypertension and right ventricular volume overload [1]. TI is typically corrected via tricuspid valve repair using prosthetic annuloplasty rings [2]. These devices may be realized in nichel-titanium (NiTi), a shape memory alloy widely used in the medical field for its biocompatibility and superelasticity. Heat treatment is applied to shape annuloplasty rings into a circular configuration. However, residual stresses remain in NiTi after heat treatment, leading to springback and, consequently, deviation of the device geometry from the desired one. Trial-and-error springback compensation during the device design process is costly and time-consuming. In this context, this study combines experimental tests and finite element (FE) analysis to quantify springback following the shape setting of a NiTi annuloplasty ring. The ultimate goal is the development of a computational approach for predicting springback effects, providing valuable guidance for the design process and improving the reliability and performance of NiTi annuloplasty rings.

Methods

The shape setting of the annuloplasty ring involves two main steps: (1) fitting of a straight NiTi tube in a mold to achieve a circular configuration (Fig. 1A); (2) heat treatment of the tube in a high-temperature salt bath and release from the mold (Fig. 1B). The procedure was experimentally conducted three times using NiTi tube samples of the same size. The geometry of the device following Step 2 was reconstructed using the optical measurement machine Smart-Scope ZIP250 (OGP Hommel srl). Subsequently, a FE model was implemented in Abaqus Standard (Dassault Systemes Simulia Corp.) to replicate Step 1 of the shape setting procedure, aiming to obtain the geometry of the annuloplasty ring within the mold without accounting for springback. Therefore, to quantify the extent of springback, the geometry measured experimentally (Fig. 2A, in purple) and by FE analysis (Fig. 2A, in red) were compared. Specifically, the distance d pre-springback and post-springback was computed for four points equally distributed throughout the tube length (Fig. 2A).

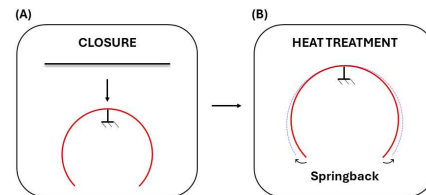


Figure 1: Scheme of shape setting of the annuloplasty ring. (A) Step 1: closure of the tube around the mold; (B) Step 2: heat treatment and release from the mold

Results

Figure 2B shows the mean and standard deviations of the distance d between pre and post-springback configurations. The curve reveals an increase in distance as the angle progresses, reaching a maximum of 0.69 ± 0.01 mm at the free ends of the tube.

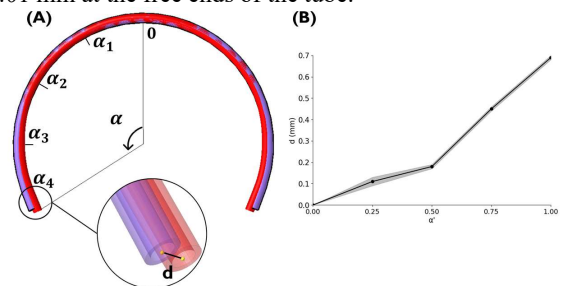


Figure 2: (A) annuloplasty ring pre- (red) and post-springback (purple); (B) distance d as a function of the normalized angle $\alpha' = \alpha/a_4$.

Discussion

This study evidences the occurrence of springback in the manufactured annuloplasty ring and provides a quantitative analysis of this phenomenon, attributed to insufficient NiTi stress relaxation following heat treatment. Subsequent work will involve utilizing FE analysis to simulate the springback phase, allowing the tube to return to its post-springback configuration after stress reduction, replicating the heat treatment process (Step 2, Fig. 1B).

References

1. Ren, W.J. et al, Journal of Cardiothoracic Surgery, 2015
2. Tang, G.H.L. et al, Circulation, 114(SUPPL. 1), 2006

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