Structural properties of natural porcine aortic valves

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Introduction

Currently, tissue engineered (TE) heart valves are not sufficiently strong to function as aortic valves. The future design of TE aortic valves will be based on the native human aortic valve, with regard to mechanical properties, structural and biochemical composition of collagen in the valve. In this study porcine valves are used to develop standardized methods to assess these specific features.

Materials and Methods

Biochemical assays

The homogeneity of collagen distribution throughout a porcine aortic leaflet was analyzed on a local scale. In an HPLC analysis, collagen was represented by the amount of hydroxyproline (Hyp), collagen cross-links were measured with hydroxypyridinium (HP).

Fibril thickness

Former studies [1] have suggested that tissue subject to high stresses result in thinner collagen fibrils and higher fibril density. This theory is analyzed using i) a numerical model [2], which predicts stresses in the aortic leaflet (fig. 1) and ii) transmission electron microscopy (TEM) photos of high and low stress areas in the leaflet. Ellipses were fitted on the fibrils in the photos to estimate the diameter.

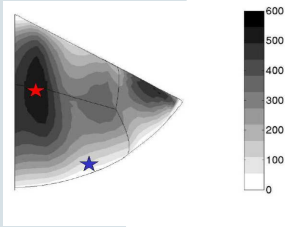

Fig. 1 *Cauchy stress map of an aortic leaflet. Samples for TEM are taken from a high stress (red) and from a low stress area (blue).*

Results and Discussion

Biochemical assays

Fig. 2 shows a colormap of the collagen content in the three porcine leaflets.

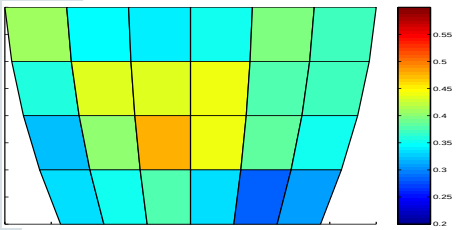

Fig. 2 *Collagen content (mg/mg dry weight) in a porcine aortic valve, averaged over three leaflets. Color indicates amount of collagen per segment.*

The average collagen content in porcine valves is about 80% of human collagen values from literature [3]. Student t-tests (α=0.05) show significantly higher collagen contents in the mid region (inner 8 segments) of the leaflet compared to the outer region (outer segments)(fig. 3).

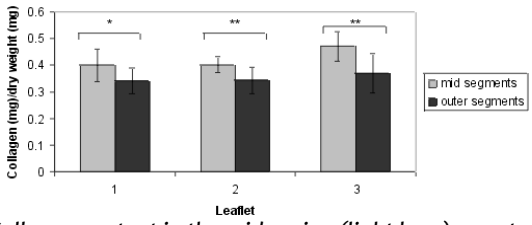

Fig. 3 *Collagen content in the mid region (light bars) vs outer region (dark bars). * p ‹ 0.05, ** p ‹ 0.01, error bar = standard deviation.*

The HP cross-link concentration was significantly higher in the mid region. The increased values of HP and Hyp in the 'high stress' mid region, are in accordance with theories from literature [4].

Fibril thickness

Fig. 4 shows the collagen fibrils in the high and low stress areas of the leaflet.

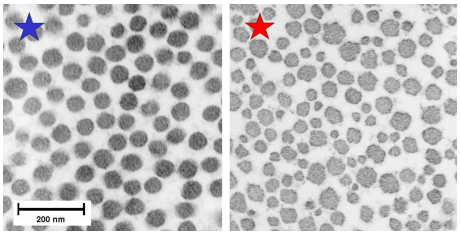

Fig. 4 *Collagen fibrils in high stress area (left) and in low stress area(right).*

	Fibril diameter (nm)	Fibril density (fibrils/μm^2)
High stress area	29.1 $\pm$ 5.5	314.6 $\pm$ 55.4
Low stress area	32.3 $\pm$ 4.2	278.6 $\pm$ 32.1

Table 1 *Fibril diameter and fibril density for high (n = 6) and low stress areas (n = 4) in the leaflet.*

A slightly larger fibril diameter seems to be present in low stress areas compared to high stress areas. This corresponds with former studies [1]. However, this is not statistically proven and more experiments are needed to draw meaningful conclusions.

Future Research

The proposed methods and mechanical testing will be used for tissue engineered and native human valves on a larger scale to provide more information. Furthermore, the effect of age on the features will also be examined.

References:

[1] *Liao J., Vesely I., J. Biomech., 2003;36:1125-1133*

[2] *Driessen N.J.B. et al., J. Biomech. Eng, submitted 2004*

[3] *Bashey R.I. et al., J. Gerontol. 1967; 22(2):203-208*

[4] *de Souza R.R., Biogerontol. 2002;3:325-335*