Introduction

Including the smooth muscle cell (SMC) behavior in constitutive models of blood vessels is relevant, as the SMCs may change tone when subjected to an altered mechanical loading and can initiate arterial remodeling. The aim of this study is therefore, to model the circumferential stretch-active SMC stress \( (\lambda \theta - \tau_S) \) relation of the arterial wall and derive specific SMC parameters.

Methods

Fresh porcine coronary ring segments \((n=12)\) were mounted in a set-up that allows control of the internal circumference of the segment while measuring the circumferential force (fig. 2). For each segment the \( \lambda \theta - \sigma_{\theta \theta} \) relation at maximal constriction and relaxation was measured and the active SMC stress contribution was determined (constricted minus passive relation). A relation for the total active SMC stress was derived:

\[
\tau_S = \frac{1}{2} G_S \lambda \theta \left( \tanh(\lambda \theta - 1) + 1 \right) e^{-\alpha_1 (\lambda \theta - \lambda_{\text{mid}})^6},
\]

with \( G_S \) and \( \alpha_1 \) two SMC fit parameters and \( \lambda_{\text{mid}} \) the middle of the \( \lambda \theta \) range within which SMC stress is still generated. The experimentally derived \( \lambda \theta - \tau_S \) relation was fitted with (1). Next, \( \tau_S \) was added to a fiber-reinforced Neo-Hookean material model of the passive coronary artery to predict the \( P - \lambda \theta \) relation of a maximally constricted coronary artery with passive material parameters of a generic and a less stiff artery (van den Broek et al., 2010).

Results

The \( \lambda \theta - \sigma_{\theta \theta} \) relation of the active SMCs shows a typical Hill-like shape (Dobrin, 1978, fig. 3a) and the active SMC stress relation (1) was well able to fit the experiment (fig. 3b).

Conclusion

The proposed new active stress relation for the SMCs has shown to provide a good description of the active tension generated in coronary ring segments at varying \( \lambda \theta \). Opposed to other models, this model does not need additional boundary conditions, which avoids material instabilities. The model was successfully added to an existing passive artery model to simulate the \( P - \lambda \theta \) relation of a constricted coronary artery.

References