MECHANICAL PROPERTIES OF URETHRAL TISSUE

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Introduction

The rather simple, purely mechanically driven, commercially available implant for patients suffering from persistent urinary incontinence, i.e. the urinary control system AMS 800™ (American Medical Systems, Minnetonka, Minnesota, USA), has serious restrictions that often result in atrophy and erosion after the period of a few years although the implantation procedures have been constantly improved [Mourtzinos, 2005]. The development of better implant designs requires the determination of the necessary forces and the related tissue strains as the function of the level of activity. The necessary forces to close the urethra in vitro have recently been derived as the function of bladder pressure and the sphincter geometry [Marti, 2006]. For the development of the artificial sphincter one needs, however, also the related strains reflecting the mechanical properties of the urethral tissue.

Methods

As rather simple approach, explanted sow urethras were prepared and held in special devices developed to measure the stress-strain relation using the conventional tensile testing machine. Because the compression might be the better approach, the specifically designed set-up taking advantage of laser beams and loading the explanted urethra in a similar way as described in [Marti, 2006]. In order to bridge the gap to in vivo experiments, the aspiration device [Nava, 2004] is applied in vitro and in vivo for animal and human urethras. Subsequently, the Young's modulus could be determined by means of inverse finite element modelling.

Results

As expected for soft human tissue, the slope of the stress-strain curve is not constant. Higher strain values give rise to steeper curves related to a strain-dependent Young's modulus (see Figure 1). Furthermore, one observes the well-known hysteresis for cyclic loading and unloading characterizing the energy dissipation within the tissue. In order to estimate the Young's modulus for selected uniaxial strain values one may just consider the endpoints within the stress-strain curve. For 15% uniaxial strain the Young's modulus corresponded to only (5±2) kPa. For 35% strain it raised to (11±3) kPa. 45% strain resulted in a value for the Young's modulus of (21±4) kPa. The compression experiment applying inside the urethra the pressure of 41 cmH_2O led to the Young's modulus of (19±5) kPa. The aspiration technique, relying on tensile strains, together with the inverse FEM has provided the Young's modulus of (17±5) kPa.

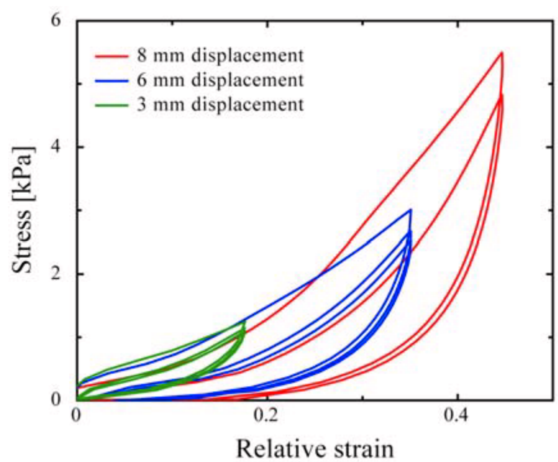

Figure 1: Stress-strain curves for an explanted sow urethra.

Discussion

The three kinds of stress-strain measurements applied have consistently yielded clinically relevant data of the Young's modulus of the urethra. The estimate corresponds to values between 10 and 20 kPa. This value reasonably compares to the value of the kidney that was determined to (18±5) kPa [Snedeker, 2005]. Preliminary results indicate that the in vivo experiments on patients could be replaced by in vitro tests using freshly explanted sow urethras, which show a similar behaviour than explanted human urethras.

References

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