Simulation Systems for Stress Incontinence

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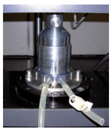
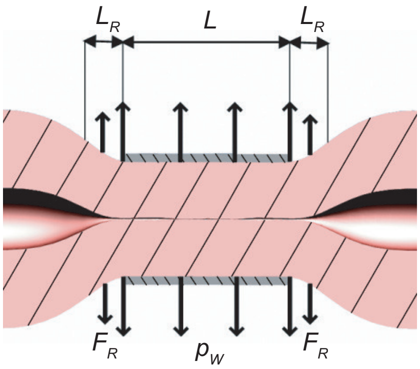
INTRODUCTION



The currently used implant for severe incontinence is the urinary control system AMS 800™ with one or two cuffs as the artificial sphincter. The system is often revised because of urethral atrophy. We have realized an in vitro testing system to study the efficacy of the implant under steady state and dynamic conditions to optimize the cuff geometry. The experiments are based on explanted human and animal (sow) urethras. The behaviour of explanted urethras may differ from the in vivo situation, because blood flow and pressure are suppressed. To determine the influence of the aging on the mechanical properties, the experiments have been repeated for several times. The influence of the aging process was much smaller than the difference from one urethra to another.

COMPRESSION MODEL

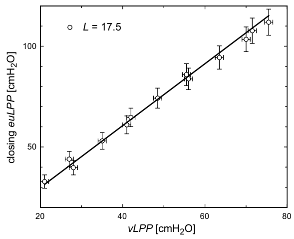
The urinary bladder generates the pressure acting on the urethral sphincter termed the vesical pressure. The vesical leak point pressure (*vLPP*) is defined as the lowest vesical pressure necessary for leakage. For constant vesical pressure, the sphincter pressure when the urethra opens is termed the external urethral leak point pressure (*euLPP*).

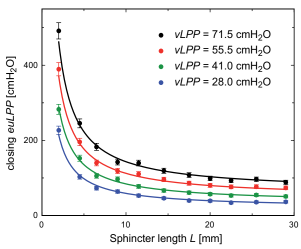


The compression model [F. Marti et al. Phys. Med. Biol. 51 (2006) 1361] provides the relationship between *vLPP* and *euLPP*:

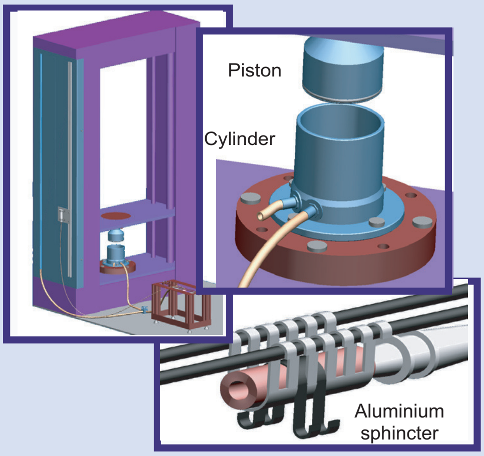
$$euLPP = (vLPP + p_W)\left(1 + 2\frac{L_R}{L}\right) + \frac{F_R}{RL}$$

This equation shows the experimentally proven linear dependence of *vLPP* and *euLPP* and the observed decrease of *euLPP* versus sphincter length *L*.

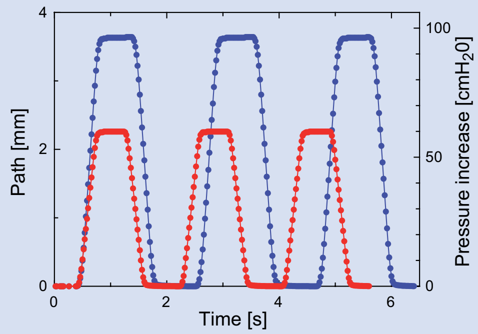




COUGH SIMULATION

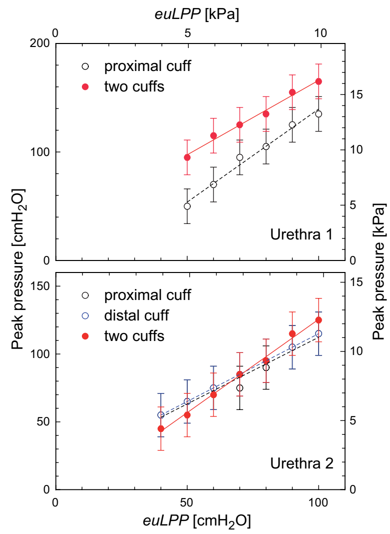


To simulate the changes of the bladder pressure during stress situations such as cough, the mechanical testing machine Zwick 1456 (Zwick GmbH Ulm, Germany) drives a piston, which generates a well-defined pressure impulse. The pressure pulse transferred by tubes to the urethra acts on the urethral sphincter and simulates the stress situation.

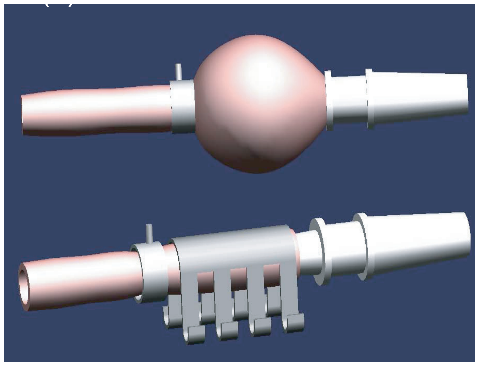


The experimental path-time curves for the pressure rise of 60 and 100 cmH_2O, generated by the experimental set-up developed, exemplarily demonstrate that the simulated changes of the bladder pressure correspond to common in vivo stress situations [K.-J. Kim et al., Mechanism of female urinary continence under stress: frequency spectrum analysis, J. Biomech. 34 (2001) 687]. Consequently, an in vitro system is realized to validate and optimize the efficacy of urethral sphincters not only under steady state conditions but also for the more relevant situation of stress incontinence.

RESULTS



Comparing peak pressure versus euLPP for one or two cuffs and different human urethras, the experimental data show that the distal cuff was advantageous for Urethra 1, but did not result in a difference for Urethra 2.



Urethra 1 was soft enough to inflate during pressure impulse. For Urethra 2 inflation was suppressed, corresponding to the behaviour of a stiff urethra. Hence the second cuff is only advantageous if

- the (soft) urethra reduces the efficacy of the proximal cuff due to shape changes or
- the urethras are inhomogeneous,

verified also by measurements with sow urethras.

CONCLUSION AND ACKNOWLEDGEMENT

If the urethra is soft, it inflates, and the proximal cuff, which helps the distal cuff to remain its shape, opens. Thus, the implantation of a second cuff is recommended. In case of radical prostatectomy, scar tissue formation often prevents the ability of the urethra to inflate. Since the urethra is inhomogeneous, the second cuff might be better positioned and therefore useful. The two cuffs should be placed without gap as quantitatively derived from the compression model. The supply of the AMS 800 by F. Bönzli, Promedics and the support of the Institute for Veterinary Pathology, University of Zürich is gratefully acknowledged.