170 DEVELOPMENT OF DISPLACEMENT-CONTROLLED MULTIAXIAL STRETCHING DEVICE FOR CHARACTERISING MECHANICAL PROPERTIES OF FEMALE PELVIC FLOOR TISSUE

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Introduction

Up to 20-30% of women over the age of 20 may suffer from pelvic floor disorders and up to 50% of women over the age of 50[1]. Furthermore, injuries to the pelvic floor muscles as a result of childbirth can lead to varying types of incontinence, pelvic organ prolapse (POP), and avulsions[2 3]. Better understanding of the mechanical properties of the muscles is thus required to improve risk assessment for child birth induced injury. As pelvic floor muscle is anisotropic and can be subjected to large multiaxial deformations during childbirth, mechanical characterisation requires multi-axial testing. Pelvic floor tissue sample sizes are typically small (<20mm) and expected forces are low (<15N). Modern commercially available machines are big and expensive, designed to apply large load to structural materials. The aim of this project is to develop a displacement-controlled multiaxial stretching device for characterising viscoelastic properties of female pelvic floor tissue.

Method

A low cost, desktop radial stretching device was developed, based on an open source design by Schausberger et al[5], with adaptations to make it suitable for soft tissue testing. Specific adaptations include modifying grips for smaller soft-tissue samples, digital image correlation (DIC), and an environmental chamber for biological tissue testing. Samples can be clamped onto 18 arms to create a radial stretch during testing (Figure 1).

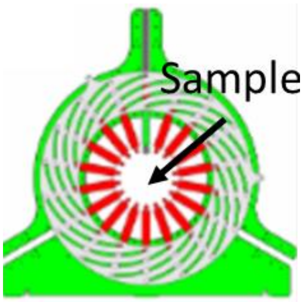

Figure 1 – Radial Stretch Tester

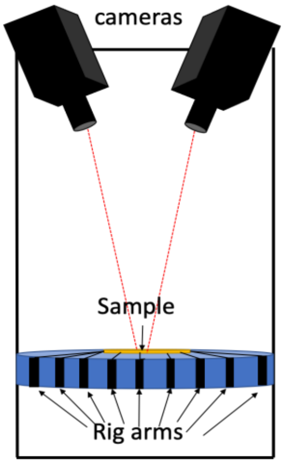

Figure 2 – Radial Stretch Tester with DIC

Table 1: DIC set up

Speckle size	50 pixels (approx.)
Subset	125
Step size	20
Measurement points	2000 (approx.)
Camera	10 bit 5472 x 3648
Field of view	20 mm diameter (approx.)
Focal length	450 mm (approx.)
Correlation method	Standard
Smoothing method	Gaussian filter, 15

The radial stretch tester has been fitted with a 20N load cell (FSJ03829, Futek Inc., USA) to obtain load data and modified to incorporate smaller samples sizes and DIC to obtain strain data (Figure 2). Tests have been carried out using a sample of Versaflex™ CL2000X (Polyone Corporation). A displacement rate of 12mm/min was used for all tests. Uniaxial tests were carried out on a Lloyds instruments uniaxial tester with 50N load cell and repeated in the radial stretch tester in both uniaxial and radial mode. Grip-to-grip displacement was used to calculate strain in the Lloyd test. DIC was carried out to record strain for the radial stretcher tests (Table 1) and Vic3D (Correlated Solutions Inc., USA) was used to analyse the data. The speckle was applied by hand with permanent ink. Further tests have been carried out comparing clamping systems using a sample of Chronoprene™ 40A (Dunn Industries, Manchester). Set up as previous (Figures 3a,b,c). Initial uniaxial tests were carried out with sheep pelvic floor muscle tissue (Figure 3d).

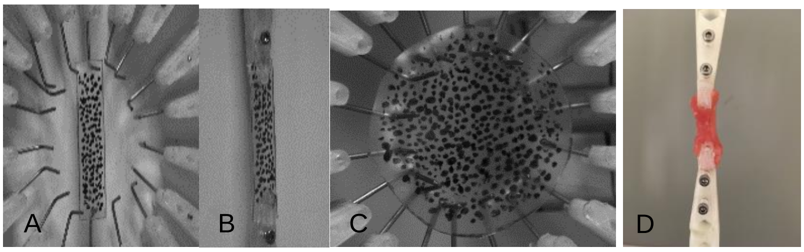

Figure 3 - uniaxial with hooks (a), uniaxial with velcro clamps (b), and (c) radial with hooks (all with speckle for DIC), (d) sheep tissue

Results

True stress results from the uniaxial tests in the rig were slightly higher than in the Lloyd test due to friction in the rig which is being rectified (Figure 4). The true stress increased significantly for the radial sample compared with uniaxial testing as expected.

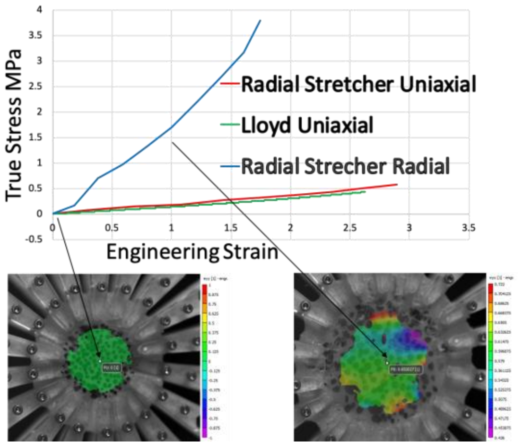

Figure 4 –True stress vs engineering strain data for three tests of Versaflex^{TM} CL2000X

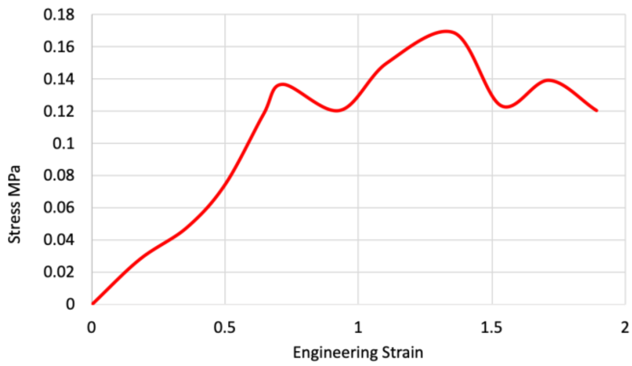

Figure 5 – Stress vs engineering strain data for initial tissue tests

Similar results were found using the radial stretch tester in a uniaxial format for both the hooks and velcro clamps and the Lloyd test. However, the sample began to tear at the hooks before a strain of 0.4 in uniaxial mode and the hooks tore the radially tested sample after a strain of 0.3. Initial tests on ovine pelvic floor tissue have been carried out in uniaxial mode (Figure 5) using grip displacement to account for strain.

Discussion

Results verify basic functionality of the radial stretcher in both uniaxial and radial modes. Initial tests with ovine pelvic soft tissue are being carried out. It is most easily available and has many similar anatomies to the human pelvic floor[6]. Current improvements include adjustments in the form of a temperature controlled bath to incorporate an environmental chamber (Figure 6). Further testing of tissue will incorporate DIC.

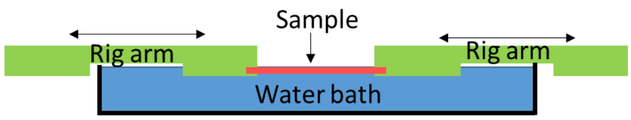

Figure 6 – Environmental chamber for sample

Due to tearing at the hooks, peak strains are below reported maximum strains of 70–100% from analogous multiaxial tests in the literature[7,8] and clamps are being redesigned to achieve higher stretch ratios. Additionally, alternatives to a load cell on each of the arms are being investigated to reduce costs of obtaining load data in multiple directions for anisotropic samples. Due to the high resolution of the cameras, the speckle pattern will be applied in a mist for a finer speckle size. Standard tension-to-failure and stress relaxation testing of pelvic floor tissue will be carried out following satisfactory performance in all verification tests.

Acknowledgements

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References

[1] Wilson, D. et al,. Obstet. Gynecol. 2001;98:398–406 [2] Boyles, S.H. et al, *AJOG*, *188*(1), 108–115.(2003) [3] Subak, L.L. et al, Obstet. Gynecol, 98(4), 646–651. [4] Mant, J et al., BJOG, 104(5), 579-585, (1997).[5] Schausberger, S.E. et al, IEEE Access, 555-561 (2015). [6] Urbankova, I et al., Gynecol Obstet Inves, 82(6), 582-591 (2017).[7]. Lally, C et al, Ann Biomed Eng. 32(10), 1355-1364 (2004). [8]. Jing, Dejun, PhD, Univeristy of Michigan (2010).