Effects of Testing Conditions on the Mechanical Characterization of the tunica albuginea

Pierre-Hugo Minster*[1], Mathis Duguey[1], Clément Parat[2], Nicolas Morel-Journel[2], Damien Carnicelli[2], Paul Neuville[2], and Karine Bruyère-Garnier†[1]

[1]Laboratoire de Biomécanique et Mécanique des Chocs – Univ Lyon, Université Claude Bernard Lyon 1, Univ Gustave Eiffel, IFSTTAR, LBMC UMR$_T$9406, *Lyon*, *France* – –*France*

[2]Service d'urologie [Centre Hospitalier Lyon Sud - HCL] – Hospices Civils de Lyon, Hôpital Lyon Sud, Service d'Urologie, 165, Chemin du Grand-Revoyet, Pierre-Bénite, France – France

Abstract

Introduction & Objectives

Erectile dysfunction is a common condition that may require penile prosthesis implantation. To improve these devices, it is essential to understand the contribution of tissues during erection with penile prosthesis, particularly the tunica albuginea (TA).

Few studies report the mechanical properties of these tissues, and those that do often test under various conditions (e.g., preload, cycling, hydration) (Berardo et al., 2024; Khorshidi et al., 2024; Kandabarow et al., 2022; Luet et al., 2021). These variations make comparisons and aggregation of results challenging.

This study aims to evaluate the effects of testing conditions on the mechanical characterization of the TA. Properties obtained from cycling loadings coupled with a saline solution bath are compared to those obtained without cycling in air.

Materials & Methods

One penile was obtained from a post mortem human subject (94 yo) and then frozen (-18∘C). After thawing, dissection was performed to isolate the TA and 10 I-shaped samples were cut along the longitudinal (n=4) and circumferential (n=6) anatomical directions.

Uniaxial tensile were realized at a 0.01 s-1 strain rate with 5 preconditioning cycles up to 10% strain followed by a test up to failure. Test were performed in a saline solution bath at approximately 37 ∘C.

For strain measurement, two points were marked at the extremities of the reduced section area and their displacements were measured by video tracking. The force was measured using a 250N sensor. The initial cross-sectional area of each sample was measured from a 3D reconstruction of each sample to calculate the nominal stress.

Nominal stress versus stretch curves were plotted for the first loading (cycle1) and the loading

*Speaker

†Corresponding author: karine.bruyere-garnier@univ-eiffel.fr

up to failure. The tangent modulus of the steepest linear region, the stretch of the low-stress region (which was defined as the stretch between the gravity configuration and the 0.01 MPa preloaded configuration) were determined for both curves. For loading up to failure, the maximum nominal stress and the strain at this maximum stress were also assessed as ultimate properties. Properties obtained for the first loading and the loading up to failure were compared. Results were also compared to those obtained by Luet et al. (2021) for 8 TA samples tested in air without cycling.

Results

About the stretch of the low-stress region, the first cycle exhibits a value of 0.03±0.02 longitudinally and 0.03±0.01 circumferentially, while the loading up to failure exhibits a value of 0.06±0.02 longitudinally and 0.05±0.02 circumferentially.

Considering the tangent modulus of the linear region, the first loading exhibits moduli of 29.8±18.7 MPa longitudinally and 23.4±12.4 MPa circumferentially, while the loading up to failure exhibits moduli of 56.5±21.4 MPa longitudinally and 41.1±19.3 MPa circumferentially. In comparison, Luet et al. (2021) observed higher moduli from tests in air, of 70±36 MPa longitudinally and 82±43 MPa circumferentially. Thus, cycling between the first loading and the loading up to failure increases the tangent modulus and the length of the low-stress region, in the both directions.

Moreover, by comparison of the first loading behavior to the results from Luet et al.(2021), hydration appears to reduce the average value and the standard deviation of the tangent moduli , suggesting less variability of the TA behaviour in bath. Finally, it is important to note that the anisotropy found in our study is the opposite of that found by Luet et al. (2021) (here, the longitudinal modulus is larger than the circumferential one).

Discussion and Conclusion

The results of this study indicate that cycling has a significant impact on the mechanical properties of the TA under hydration conditions, which might explain the significant discrepancies often observed between studies. However, the observed ultimate stress and stretch are consistent with those reported in the literature.

A major limitation of this study is the limited number of samples and the inability to decouple the effects of hydration and cycling. Future work should aim to isolate these factors to better understand their individual contributions. Additionally, while cycling provides valuable insights into material behavior, it is not necessarily representative of the physiological loadings of the TA. Further studies focusing on physiological loading conditions would be interesting.

In conclusion, this study provides important data on the mechanical behavior of the TA under specific cycling and hydration conditions. The results underscore the importance to standardize experimental conditions to offer more data describing the mechanical behavior of penile tissue in view of contributing to the improvement of penile prosthesis.

Reference

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