8th International Conference

MECHANICS AND MATERIALS IN DESIGN

Bologna/Italy, 4-6 September 2019

M2D 2019

PROGRAM

Institutional Sponsors

University of Bologna | University of Porto | APAET | University of Toronto | EURASEM | JSME | DYMAT | IMEKO | SEM

PROGRAM

MAIN TOPICS

A - Computational mechanics
B - Experimental mechanics
C - Fatigue and fracture mechanics
D - Composite and advanced materials
E - Nanotechnologies and nanomaterials
F - Tribology and surface engineering
G - Mechanical design and prototyping
H - Biomechanical applications
I - Civil engineering applications
J - Impact and crashworthiness
K - Energy and thermo-fluid systems
L - Industrial engineering management

THEMATIC SYMPOSIA

1 - Composite Materials: Theory, Experiments and Applications
2 - Experimental Mechanics and Instrumentation
3 - Additive Manufactured Materials: Production, Experiments and Applications
6 - Computational Mechanics at Varied Length Scale
7 - Cardiovascular and Orthopedic Mechanics
8 - Advances in Additive Manufacturing Process Design and Part Performance
9 - Sustainability in Design and Manufacturing
11 - Quality Management: Theory, Applications and Case Studies
12 - Trends in new product design and development strategies
13 - Modelling of fracture and fragmentation of solids under quasistatic and dynamic loading: deterministic and probabilistic approaches
14 - Biomechanics of Tissue and Biomaterials: Experiments, Design and Applications
15 - Innovative Engineering Design Education: From Lessons learned to Emerging Practices

Institutional Sponsors

Dept. of Industrial Engineering
University of Bologna, Italy

Faculty of Engineering
University of Porto, Portugal

MADL
University of Toronto, Canada

APAET
Portuguese Society of Experimental Mechanics

EURASEM
The European Society for Experimental Mechanics

DYMAT
European association for the promotion of research into the dynamic behaviour of materials and its applications

IMEKO
International Measurement Confederation

SEM
Society for Experimental Mechanics

JSME
The Japan Society of Mechanical Engineers

Co-Chairs

		
Dario Croccolo (University of Bologna)	**J.F. Silva Gomes** (U. Porto / APAET)	**Shaker A. Meguid** (University of Toronto)

Organizing Committee

Croccolo, D. (University of Bologna)
De Agostinis, M. (University of Bologna)
Fini, S. (University of Bologna)
Funaioli, S. (University of Bologna)
Olmi, G. (University of Bologna)
Paiardini, L. (University of Bologna)
Robusto, F. (University of Bologna)
Campana, G. (University of Bologna)
Fortunato, A. (University of Bologna)

International Scientific Committee

António, C.C. (Portugal)
Arcidiacono, G. (Italy)
Avalle, M. (Italy)
Belingardi, G. (Italy)
Croccolo, D. (Italy)
Crupi, V. (Italy)
Guagliano, M. (Italy)
Montanari, R. (Italy)
Hess, P. (Germany)
Ju, Y. (Japan)

Meneghetti, G. (Italy)
Mileiko, S.T. (Russia)
Meguid, S.A. (Canada)
Morimoto, Y. (Japan)
Turmanidze, R. (Georgia)
Ng, T.Y. (Singapore)
Nowel, D.I. (UK)
Reddy, J.N. (USA)
Silva Gomes, J.F. (Portugal)
Slocum, A. (USA)

Strozzi, A. (Italy)
Trster, T. (Germany)
Umehara, N. (Japan)
Van Hemelrijck, D. (Belgium)
Vaz, M. (Portugal)
Xu, H. (China)
Liu, Y. (China)
Yoshino, M. (Japan)
Zhang, X. (China)
Tomesani, L. (Italy)

PAPER REF: 143

CONTRIBUTIONS TO DISPLACEMENT AND RESISTANCE OF THE COMPONENTS OF THE MENISCUS-SUTURE COMPLEX IN TRANSTIBIAL MENISCAL ROOT REPAIR

Ana Pérez-Blanca[1(*)], María Prado Nóvoa[1], Belén Estebanez[1], Fernando Nadal[1], Alejandro Espejo-Reina[2], Marco Cecarelli[3]

[1]Laboratory of Biomechanics, University of Malaga, Malaga, Spain
[2]Hospital Vithas Parque San Antonio, Malaga, Spain
[3]Department of Mechanical Engineering, University of Rome Tor Vergata, Italy
[(*)]*Email:* anaperez@uma.es

ABSTRACT

This work analyses in a porcine model the contributions of meniscal tissue, suture thread and meniscus-suture interaction to the permanent displacements generated at the repaired root after surgery to re-insert the posterior meniscal root using a transtibial pullout technique. Medial porcine menisci with a single suture applied at the posterior horn were subjected to cyclic and load-to-failure tests. Elongations of the different components of the meniscus-suture complex were determined applying photogrammetry. Results showed that after low intensity cyclic loading, the main contribution to permanent root displacements was due to the thread (51.2%), while no cutting of the suture through tissue occur at the interface. Under load-to-failure conditions, suture cutting started at a significantly higher load level (Suture Retention Strength, SRS), always before and close to the first local maximum of the load-elongation curve, and progressed rapidly afterwards causing the final failure of all specimens.

Keywords: biomechanical properties, posterior meniscal root, Transtibial pull-out repair, permanent displacements, Suture Retention Strength.

INTRODUCTION

Transtibial root repairs are frequent as meniscal root tears become increasingly recognized. Development of permanent root displacements in the early post-operative period should be minimized (Cerminara, 2014), to re-establish proper meniscal function (Stärke, 2010). To improve the surgical technique, a better knowledge of the contributions to displacement of the different components involved in the repair is necessary. This study focus in the mechanical behavior of the isolated meniscus-suture complex, including the characterization of SRS at the posterior meniscal horn, a fundamental tissue property for surgical repair success.

Nine isolated medial porcine meniscus-suture specimens were included. Posterior horns were sutured with a simple stitch of ultra-resistant N.2 thread at 5mm of the inner edge. Ink marks located at each component identified suture thread, insertion hole and surrounding tissue (Fig. 1(a)). Specimens were subjected to cyclic loading (1000 cycles of [10,30]N (Stärke, 2013) load at 0.5Hz) followed by load-to-failure test, while video-monitored with a digital camera (Stingray F-504B®, Allied Vision Technologies, Germany) synchronized with the testing machine. Photogrammetry based on a SIFT algorithm, was applied to extract normalized elongations of the different components from recorded images and to relate these elongations to force measured during the test (Fig. 1(b)). Residual displacements were computed as the difference in elongations at 10N, before the first cycle and after 1000 cycles.

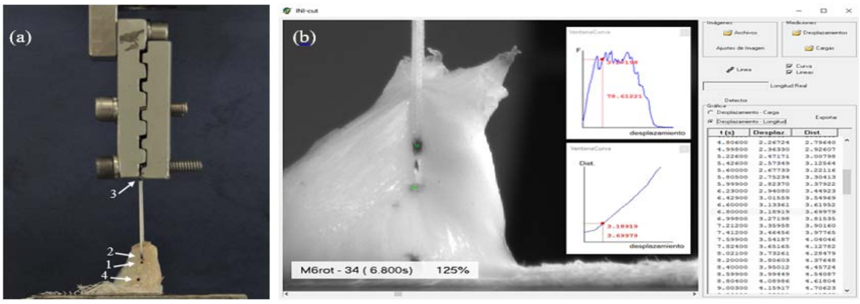

Fig. 1 - (a) Experimental setup. White arrows point out the ink marks on the different components. (b) Interface of the software Ini-cut, specifically develop to extract progression of elongations with loading from ink marks

RESULTS AND CONCLUSIONS

From cyclic test, the component that contributed the most to residual displacement was the thread with up to 51.20% of total residual displacement (Table 1). Tissue compaction at the interface contributed a 21.19%, but the suture did not cut through the tissue.

Table 1 – Initial length (L_c^0) and residual displacement ($\Delta_{res,c}$) from cyclic tests

	Insertion hole		*Suture thread*		*Meniscal tissue*		*TOTAL*	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
L_c^0(mm)	1.67	(0.51)	40.64	(5.63)	6.63	(1.45)	48.93	(5.31)
$\Delta_{res,c}$(mm)	0.37	(0.25)	1.14	(0.70)	0.50	(0.35)	2.01	(0.90)
% $\Delta_{res,c}$	21.19	(12.48)	51.20	(18.90)	27.61	(15.74)		

In load-to-failure, evolution of elongations showed a slope change at the same instant for all components (Fig. 2), coincident with the initiation of suture cutting through tissue in the images which occurred always close but before the first local maximum of the load-elongation curve (Fig. 2), at mean displacement of 3.2 mm and a mean load (SRS) of 97.5 N, a 10.2% lower than ultimate failure load (UFL). Once cut initiated, unpredictable permanent displacements generated, reaching a mean value of 6.9 mm at a UFL of 109.2N

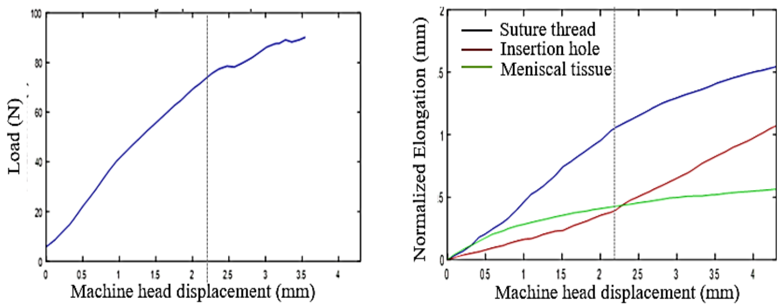

Fig. 1 – Mean curves from load-to-failure tests. Vertical lines mark tissue cut initiation.

In conclusion, suture thread contributes the most to permanent root displacements of the meniscus-suture complex in a porcine model under low intensity cyclic loading, and no cutting of the tissue occurs until SRS values of much higher intensity, after which cut progress rapidly.

REFERENCES

Cerminara AJ, LaPrade CM et al. Biomechanical evaluation of a transtibial pull-out meniscal root repair: challenging the bungee effect. Am J Sports Med, 2014, 42, p. 2988-2995

Stärke C, Kopf S, Grobel K, Becker R.The effect of a non-anatomical repair of the meniscal horn attachment on meniscal tension: a biomechanical study. Arthroscopy, 2010, 26, p. 358-365

Stärke C, Kopf S, Lippisch R, Lohman CH, Becker R. Tensile forces on repaired medial meniscal root tears. Arthroscopy, 2013, 29, p. 205-212