

METHOD FOR ASSESSING THE BREAKING STARTING STRENGTH OF MENISCAL HORNS FROM SUTURE RETENTION TESTS

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Introduction

Surgical repair of a detached meniscal root is performed via a transtibial or in situ technique, using sutures to fix the meniscus to restore knee biomechanics [1]. A critical aspect to prevent repair failure is the capacity of the tissue to hold the sutures subjected to forces throughout surgery and the postoperative period. Previously, visual inspection of video-monitored suture retention tests of meniscal horns [2] and other soft tissues [3], allowed the identification of a breaking starting point that initiates tissue damage, better representing its suture retention capacity than the final failure. In this scenario, it is key to quantifying the Breaking Starting Strength (BSS). Some studies have analyzed horn resistance at the tissue-suture interface [4-5], but a robust methodology for computing the BSS has not been described. This work proposes a method to identify the BSS directly from the load curves of suture retention tests. The methodology has been validated using meniscal horns in human and porcine models.

Methods

Eight porcine meniscal roots (5 months and 100 kg) and 60 human meniscal roots (62(20) years expressed as mean(SD)) were included in the study. A N°2 UHMWPE thread was inserted in the meniscal horn at 5mm from its internal edge and its root junction using a single simple stitch. Following the positioning protocol described by Peña-Trabalón et al. [5], the sutured menisci were subjected to displacement-controlled Load-To-Failure (LTF) tests at 0.1mm/s (Figure 1b), while continuously video-monitored at 4 fps.

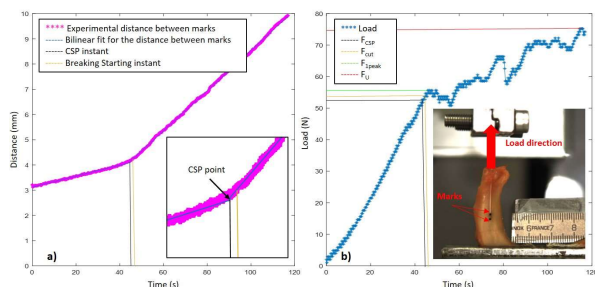


Figure 1: a) Evolution of distances between ink marks during the test. b) Test set-up and load evolution

Distances between two ink marks placed around the suture hole were computed using videogrammetry [5]. The curve of the evolution of the distances between marks (Figure 1a) was approximated by a bilinear fit. The fitting process searched the optimal transition or change of slope point (CSP) and the slopes in both intervals to minimize the RMSE. Subsequently, the time coordinate of the CSP was used to determine the traction

borne by the specimen at that instant, F_{csp} . Additionally, in the porcine group the breaking starting point was visually identified from the images in a cumbersome and subjective task and the load withstood by the specimen at that instant computed, F_{cut} .

From the load curve in the LTF test, the first peak load, F_{1peak} , and the ultimate load, F_U , were recorded. F_{1peak} was computed as the first point on the curve with a value greater than its two neighboring values, with a prominence higher than 2 and a width greater than 0.5ms. Peak width was calculated as the time distance between load curve intersections with a horizontal line under the peak at a distance equal to half its prominence. To focus on tissue strength, all forces were normalized by the horn thickness at the hole area (F_{csp}^* , F_{1peak}^* , F_U^*).

Results

In the porcine model, comparison of the observed F_{cut} and the computed F_{csp} confirmed to be virtually coincident (difference under 6.7%). In the human group, for the normalized force values (Table 1), difference between F_{csp}^* and F_{1peak}^* was 6.4%(5.1%), with F_{1peak}^* always higher. F_U was also higher than F_{csp} with a notable larger difference of 15.6%(12.2%) and, more important, with a wide variation range of [0.61, 9]%

Group	F_{csp}^*	F_{1peak}^*	F_U	Horn thickness
Porcine	30(3)	31(3)	33(4)	3.3(0.4)
Human	22(8)	23(8)	26(10)	2.9(0.7)

Table 1: Forces normalized by the horn thickness in N/mm and thickness of the meniscal horn at the suture area in mm. Values are expressed as mean (standard deviation).

Discussion

Our study found that the BSS of the meniscal horn can be determined from F_{csp} using a robust and automated algorithm with minimal errors, albeit requiring a videogrammetric system. Alternatively, F_{1peak} is proposed as a viable estimator that avoids the need for videogrammetric analysis, though it entails a mean overestimation of 6.4%, requiring consideration of a safety factor of this magnitude. In contrast, F_U is not a recommended estimator given its substantial overestimation of the breaking strength.

References

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