CRANIAL CRUCIATE LIGAMENT RECONSTRUCTION: BIOMECHANICAL ANALYSIS

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With a prevalence of 4.87% in dogs, cranial cruciate ligament (LCC) rupture is the most common orthopaedic disease of the pelvic limbs.[1] It causes joint pain, instability and leads to early osteoarthritis, Repair techniques for these ruptures, using a synthetic intra-articular ligament, have limitations that are intrinsically linked to the materials used, which can influence the functionality of the in-situ system over time.[2] A renewed interest has been initiated by the discovery of new medical grade fibers with interesting mechanical and biocompatible properties (such as UHMWPE fibers), that can be braided and used as a ligament reconstruction implant during rupture of the anterior cruciate ligament (ACL) in humans.[3]

Objective

To evaluate the cyclic mechanical behavior of canine cranial cruciate ligament-deficient stifles stabilized with an intra-articular UHMWPE implant fixed with interference screws.

Materials & Methods

Seven hindlimbs from 4 adult dogs between 25 and 35kg were taken. Dogs were of similar size and died from reasons unrelated to the focus of this study and were free of stifle abnormality. Stifles were dissected to let intact only tibia and femur. Each extremity of the bone was fixed with resin onto two supports.
Stifles were implanted with a UHMWPE implant (Novalig 8000, Novetech Surgery, Monaco) (Figure 1).

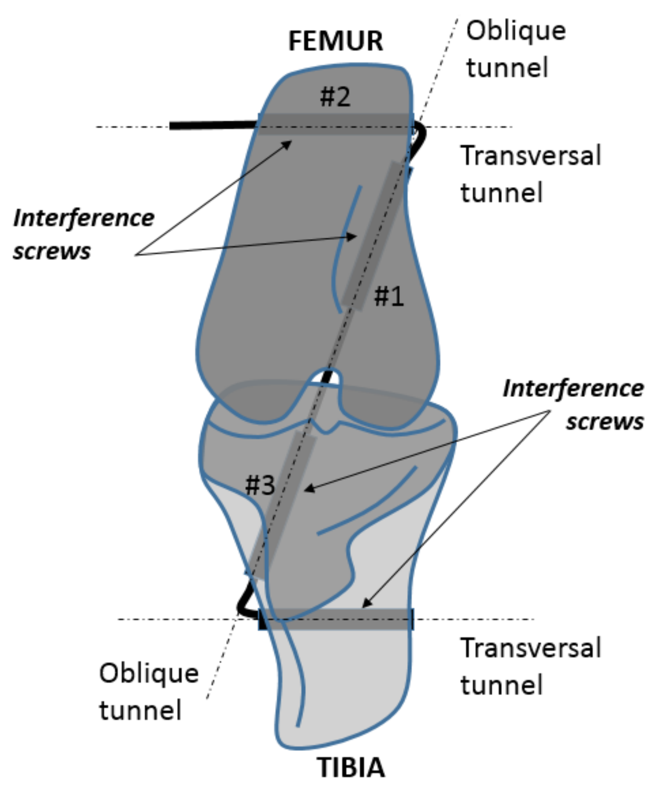

Figure 1. Scheme view of the implant procedure. The numbers refer to the interference screws inserted in both oblique and transversal tunnels in the femur and the tibia in the stifle articulation of dogs.

A total of 7 dynamic tensile tests were performed using a traction system (AGS- X Shimadzu, Japan). Sterile compresses moistened with physiological saline held with a polyethylene film were applied around each sample. A pre-test was achieved consisting of a 20mm/min traction until the load reached 100N (i.e. the initial tension). The dynamic rate was fixed at 0.58Hz during all the 100.000 cycles. The boundary limits were fixed at 100N of minimum pre-load, and a maximum of 210N. Thus a previous study reported that the ground reaction force is equal to 65% of the body weight of the dog when trotting,[4] and since the tested specimen were extracted from dogs about 30kg on average, the ground reaction force would be approximately equal to 195N (plus a 15N-safety margin, yielding to a maximum load of 210N). During tests, acquisitions of the data were carried out using the TrapeziumX software (Shimadzu, Japan). The data were processed with Matlab.

Results and Discussion

Neither screw-bone assembly rupture nor pull-out issue was observed during the dynamic tests (Figure 2). Two out of the seven set-ups exceeded a displacement of 3 mm which is the safety margin not to be exceeded to consider the validation of biomechanical test.[5] All the mean filtered displacement curves lead to a similar shape, with two major parts. The initial phase lasts until an average time of 27 minutes, this characteristic time being obtained as the intersection between the two asymptotes of the signal. This initial part could correspond to a tensioning of the UHMWPE fibers of the implant. The second phase corresponds to the slowly increasing plateau that is observable from T=10h until the end of the experiment. Thus, once the fibers have been tensioned, we observe a mechanical resistance which is stable over time.

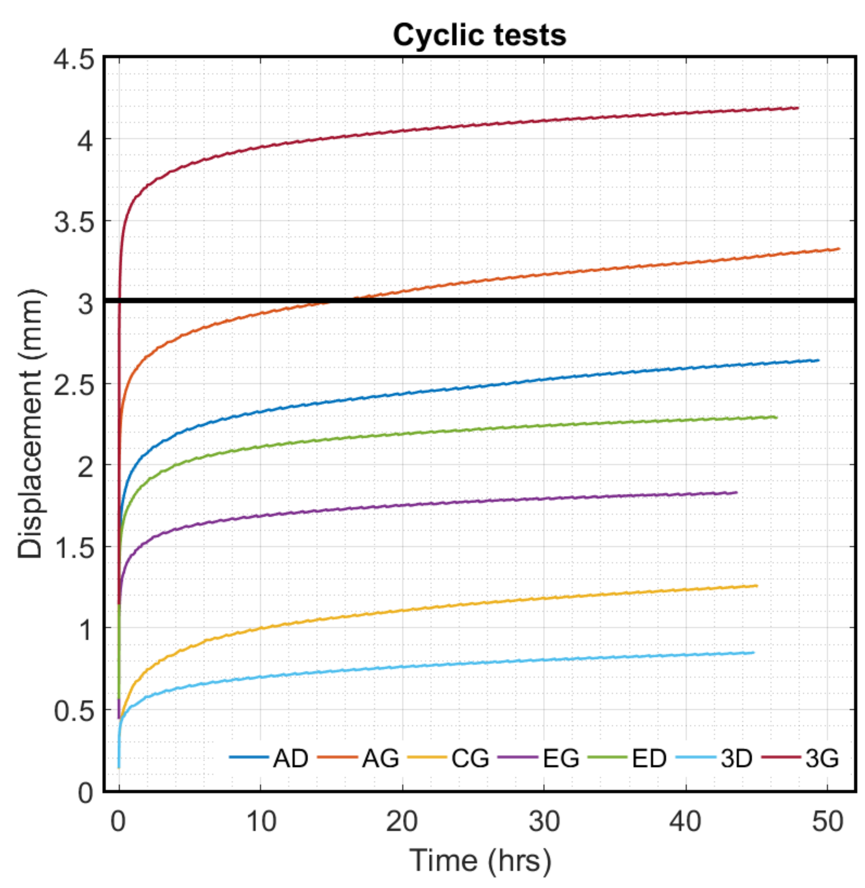

Figure 2. Evolution over time (h) of the mean filtered displacement (mm) recorded for the 7 tests performed. The safety margin of 3mm reported by Wüst has been displayed as a horizontal black line.

Neither For reasons of simplification of the experimental setup to be designed to carry out this study, the cyclic forces were applied uniaxially at 180°. However, we know that the stifle joint in dogs is 135° in a static position. We can also hypothesize that the variability in bone density of the samples taken could have induced different mechanical resistance between the tests.

Conclusions

This UHMWPE implant withstood physiological stresses exerted during 100,000 cycles without breaking. 5 of the 7 mechanical tests carried out have been validated in-vitro with regard to the literature. To our knowledge, such an in-vitro evaluation methodology has never been carried out to test a medical device for veterinary use.
Thus, these biomechanical results should revive the interest of intra-articular reconstruction after rupture of the LCC in dogs.

References

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