Biomechanical comparison of two femoral fixation methods for synthetic cranial cruciate ligament reconstruction in canine cadavers

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1. Introduction

Cranial cruciate ligament rupture (CCLr) is the most common cause of hindlimb lameness in dogs (Witsberger et al. 2008). Currently, surgical management of CCLr is mostly performed using tibial osteotomy techniques to modify the biomechanical conformation of the affected stifle (Kim et al. 2008). These surgical techniques have a significant complication rate, associated with persistent instability of the stifle which may lead to chronic postoperative pain. Over the last decade, studies have been published on various techniques of anatomical CCL reconstruction in veterinary practice, using physiological autografts or woven synthetic implants. In most techniques, the latter are secured to the bone by interference screws. High fixation strength is mandatory to achieve satisfactory clinical outcomes. A study published by Blanc and al. in 2019 reported no statistical difference in maximum pull-out strength between a physiological CCL and an ultra-high-molecular-weight polyethylene (UHMWPE) implant secured by four interference screws (two in the femoral part and two in the tibial part), highlighting the biomechanical potential of this synthetic CCL reconstruction technique (Blanc et al. 2019). Recently, Rafael et al. have shown that fixation with only two interference screws (one in the femoral part and another one in the tibial part), associated with a new surgical implantation technique, provided a level of biomechanical strength compatible with synthetic CCL reconstruction in dogs (Rafael et al. 2020). The weakest point reported in these two studies is the tibial fixation part, with slippage of the implant at the bone / UHMWPE implant / interference screw interface. Owing to this slippage observed on complete assembly (femur and tibia), the mechanical pull-out strength of the femoral fixation could not be defined (Goin et al. 2019; Rafael et al. 2020). The aim of this study was to compare the pull-out strength of two femoral fixation methods used in CCL reconstruction with an UHMWPE implant on canine cadavers.

2. Methods

2.1. Sample preparation protocol

Eight femurs were obtained from four large-breed adult dogs weighing between 35 and 45 kg and were dissected to leave only the femoral part intact. Each femur was transected at the diaphysis level to facilitate its placement into a metallic mold (7x3x3 cm) filled with resin (Goin et al. 2019).

2.2. Implantation of the UHMWPE ligament

For each femoral sample, a 4-mm wide tunnel was drilled from the caudo-lateral femoral insertion of the physiologic CCL to the distolateral femoral metaphysis. The empty tunnels were pre-formed by an interference screw (Ø5 x 20 mm). The eight femoral samples were then randomly assigned to two femoral fixation groups (n=4/group). **Group A:** A standard UHMWPE implant (Novalig 4000, Novetech Surgery, Monaco) was inserted through the pre-formed tunnel and secured by an interference screw (Ø5x20 mm) (Novetech Surgery, Monaco), implanted following the "In-Out" surgical technique (Figure 1a) (Rafael et al. 2020). **Group B:** A UHMWPE implant pre-assembled with a cortical button (Novalig 4000 Platine, Novetech Surgery, Monaco) was secured by an interference screw in the same way as in group A (Figure 1b).

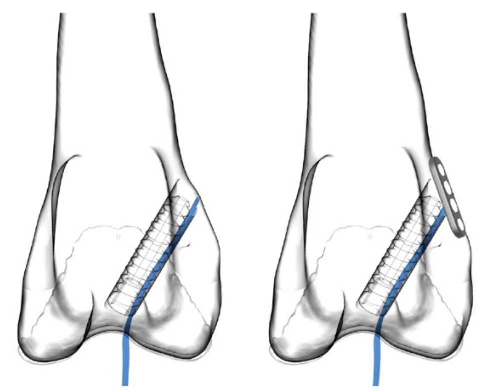

Figure 1: Diagram of the two femoral fixation groups tested

2.3. Biomechanical testing

Eight pull-out quasi-static tensile tests were performed following the same mechanical protocol (Goin et al. 2019). The samples were pre-loaded at 10N (20mm/min) before starting the pull-out failure test at 1 mm/min.

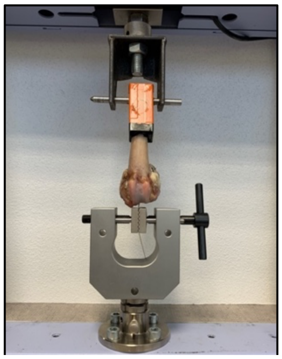

Figure 2: Biomechanical setup of an implanted femoral sample placed in the testing machine.

2.4. Data processing

Linear stiffness was assessed by calculating the slope of the load displacement curve in its linear interval for each tensile test. Yield load was defined as the load at which the first deviation from linearity in the load displacement curve was observed. Failure load was defined as the maximum force measured during each test. Statistical analyses were performed using nonparametric paired t-tests. A p-value of <0.05 was considered significant.

3. Results and discussion

Dog	Linear stiffness (N/mm)		Yield load (N)		Failure load (N)	
	Gr A	Gr B	Gr A	Gr B	Gr A	Gr B
N°1	144	156	372	620	376	675
N°2	124	92	284	1224	394	1242
N°3	116	213	358	631	576	1071
N°4	90	124	616	795	617	1122
Mean	119	146	408	818	491	1028
SD	22	52	144	283	123	246
P-value	0.377		0.104		0.018	

Table 1: Results of the eight quasi-static tensile tests

No rupture of the fixation system was observed. Failure load outcome corresponds to the loss of functionality of the implants and not to their rupture. Progressive slippage of the UHMWPE implant occurred at the bone / UHMWPE implant / interference screw interface in group A, associated with 6.2 ± 2.2 mm of displacement for the failure load output parameter. In group B, progressive slippage associated with damage of the UHMWPE implant and the cortical button was observed around 800 N during pull-out tests, before failure occurred at 12.2 ± 5.2 mm. Yield, failure load and linear stiffness output parameters were higher in group B than in group A. A significant difference was observed for the failure load output parameter (P-value = 0.018). Interestingly, the use of an UHMWPE implant pre-assembled with a cortical button secured by an interference screw increased the mechanical strength of the femoral fixation. Based on physiologic CCL failure load results reported by Blanc et al. with the same biomechanical protocol (Blanc et al. 2019), no statistical difference was found with the failure load output parameter of group B (Wilcoxon rank sum test, P-value = 0.412), while a statistical difference was observed with group A (P-value = 0.015). According to Rafael et al., the best way to maximize the fixation strength of synthetic CCL reconstruction in dogs is to associate an UHMWPE implant pre-assembled with a cortical button, secured by a first interference screw implanted following the “In-Out” surgical technique through the femoral part, and a second interference screw implanted following the same surgical procedure in the tibial part (Rafael et al. 2020). Biomechanical pull-out tensile tests will be performed to confirm these findings.

4. Conclusions

The two femoral fixations tested in this study provide satisfactory pull-out strength compatible with synthetic CCL reconstruction in dogs. This study shows that the use of a UHMWPE implant pre-assembled with a cortical button secured with an interference screw increases mechanical strength compared with a standard UHMWPE implant secured by only one interference screw. No statistical failure load difference was found between the femoral fixation of the UHMWPE implant preassembled with a cortical button secured with an interference screw and the physiologic canine CCL.

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