Biomechanical analysis of an extra-articular stabilization using a synthetic implant for caudoventral hip luxation in a feline cadaver model: preliminary results

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1. Introduction

Coxofemoral luxation is a common problem in small animal practice. Caudoventral hip luxation may occur in 3.2% of cases (Brinker et al. 1983). It is mostly observed after minor trauma, such as a jump or fall with a flexed hindlimb in internal rotation and abduction. Surgical management of caudoventral hip luxation consists in a per-operative adaptation of the hip stabilization technique by a cranio-lateral approach initially described to treat craniodorsal luxation, i.e. intra (Flynn et al. 1994) or extra-articular (Johnson and Braden 1987) synthetic ligament implantation by modifying the implantation sites of the anchoring systems, such as toggle pins, screws and anchors (Brinker et al. 1983; Johnson & Braden 1987; Flynn et al. 1994). The postoperative failure rate is estimated between 11 and 25% of cases (Helmick et al. 2018). To the authors' knowledge, there is no study published on this rare type of hip luxation and its surgical management in cats particularly by ventral approach, whether in the clinical or biomechanical fields. The aim of this study was to compare the biomechanical strength of caudoventral hip luxation for (i) physiologic hip and (ii) stabilized hip with an extra-articular UHMWPE implant secured by an interference screw in a feline cadaver model.

2. Methods

2.1. Sample preparation protocol

Six right hip joints were harvested from six feline cadavers weighing between 3.9 and 4.6 kg. These cats had died from reasons unrelated to this study. Soft tissues were removed, except the hip articular capsule and the femoral head ligament. Femoral parts were transected at the level of distal metaphysis to allow their normalized inclusion into a metallic mold (15x100 mm). Normalized drilling (Ø4 mm) was performed through the distal part of each mold in latero-medial direction, at 115 ± 1.2 mm from the great trochanter.

2.2. Implantation of the UHMWPE ligament

After performing a quasi-static traction tensile test on the physiologic hips following biomechanical caudoventral luxation, the cadaveric hip joints were stabilized with a UHMWPE implant (Novalig 2000 Platine, Novetech Surgery, Monaco). A 4-mm wide tunnel was drilled in the center of the pubis, from the ventral to the dorsal direction. The cortical button of the UHMWPE implant was then inserted in the first bone tunnel to fix the pubis (Figure 1a). A second 2.5-mm femoral tunnel was drilled at 45° in the frontal plane of the femur through the trochanter, from the medial part of the lesser trochanter to the insertion of the deep gluteal muscle. The second tunnel was tapped diameter 3 mm. The UHMWPE implant was then inserted into the femoral tunnel and tensioned in order to prevent femoral abduction, while maintaining very mild external rotation of the femur. Finally, the implant was secured with an interference screw (3x11mm), (Novetech Surgery, Monaco) implanted mediolaterally through the second tunnel (Figure 1b).

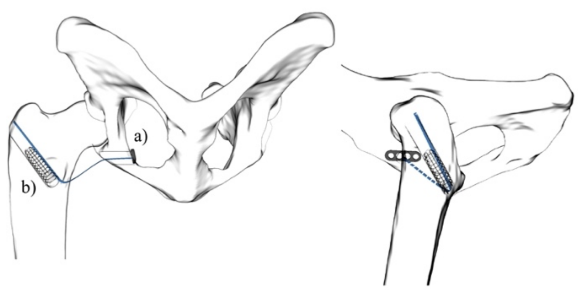

Figure 1: Diagram of the extra-articular hip joint stabilization using a UHMWPE implant for caudoventral hip luxation.

2.3. Biomechanical testing

Based on 3D reconstruction from post-mortem CT scans of cat cadavers, six biomechanical bases adapted to cadaveric pelvises were made by 3D printing. This computational design planification facilitated the correct placement and simplified fixation of the hemipelves onto the biomechanical bases in physiologic weight-bearing condition (Figure 2). A metal cable (working length: 73.5 cm) was then inserted and secured through the femoral mold drilling as far as the upper mechanical grip. No pre-loading was performed. The correct initial position of the biomechanical setup was established manually when the femoral mold was parallel to the table of the testing machine (Figure 2). The speed of the traction tensile test was set at 100 mm/min in order to induce coxofemoral luxation (Flynn et al. 1994). The traction pull-out test was manually stopped by a veterinary surgeon (E.V.) as soon as caudoventral hip luxation was observed. Given the low angle formed by the metal wire compared to the gravity axis, its impact on the load recorded not taken into account.

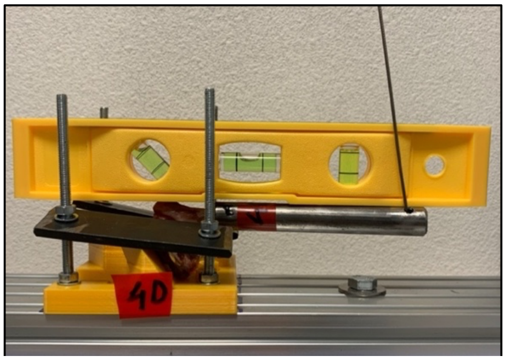

Figure 2: Biomechanical setup to simulate caudoventral hip luxation in a feline cadaver model.

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 visually observed. Failure load was designed 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

Hip joint	Linear stiffness (N/mm)		Yield load (N)		Failure load (N)	
	PHY	STA	PHY	STA	PHY	STA
N°1	28	21	163	130	163	142
N°2	25	40	213	203	213	203
N°3	27	38	181	129	195	129
N°4	22	36	113	129	113	130
N°5	32	49	126	199	126	262
N°6	31	29	156	176	156	176
Mean	28	36	159	161	161	174
SD	4	10	36	36	39	52
P-value	0.107		0.902		0.667	

Table 1: Results of the twelve quasi-static tensile tests. Abbreviations: PHY, Physiologic; STA, Stabilized

Biomechanical tests performed on physiologic hip joints demonstrated the same failure mode by caudoventral hip luxation, causing rupture of the femoral head ligament and complete tearing of the hip joint capsule at its ventral area (Table 1). For the stabilized hip joint group, no rupture of the UHMWPE implant was observed. Progressive slippage of the UHMWPE implant through the femoral tunnel at the bone/interference screw interface was observed during each test before failure occurred by caudoventral hip luxation. Biomechanical outcomes were homogeneous in both the physiologic and implanted hip joint groups. No significant difference was found between the physiologic and stabilized joint groups for yield, failure load and linear stiffness output (Table 1). The use of this type of implant was first described by Goin and colleague in 2019 as part of the reconstruction of the cranial cruciate ligament in dogs (Goin et al. 2019). The specificity of this surgical technique lies in the use of an interference screw fixation system flush with the bone surfaces, unlike the anchors (Brinker et al. 1983). This choice of fixation system would make it possible to avoid possible interference between the fixation system and the periarticular soft tissues in this area of high mobility. The imagined setup could lack stiffness, the specific biomechanical bases could have been performed by titanium 3D printing in order to overcome this potential weakness.

4. Conclusions

The biomechanical strength of extra-articular hip joint stabilization using a UHMWPE implant secured by an interference screw was not statistically different from the biomechanical strength of a physiologic hip joint tested biomechanically in conditions of caudoventral luxation. The biomechanical fixation strength of the UHMWPE implant should be suitable for extra-articular stabilization by ventral approach of the hip joint after caudoventral hip luxation in cats.

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