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Outcome and Complications following Stabilization of Coxofemoral Luxations in Cats Using a Modified Hip Toggle Stabilization—A Retrospective Multicentre Study

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Abstract

Objectives The main aim of this study was to report the surgical technique, the complications and the clinical outcomes of the mini-Tight Rope system (mini-TR) for a modified hip toggle stabilization of coxofemoral luxation in cats.
Study Design A multicentre retrospective study.
Animals Thirty-two client-owned cats.
Methods Medical records (2009–2017) of cats, which underwent stabilization of a coxofemoral luxation with the mini-TR and had at least a 3-month follow-up, were reviewed. The femoral tunnel diameter, the use of one or two FiberWire loops, perioperative complications and clinical outcomes were recorded. Follow-up information was obtained through clinical and radiographic examinations and an owner questionnaire.
Results Thirty-two cats met the inclusion criteria. Concurrent injuries were present in 16 cats. A single or double loop mini-TR was used in 21 and 12 cats respectively. One double loop (1/12 cats) and four single loop (4/16 cats) sutures failed. Moderate-to-severe coxofemoral osteoarthritis developed in 14/27 cats. Owner questionnaires revealed excellent clinical outcomes.
Clinical Significance Mini-TR with a double-stranded implant is recommended to decrease the risk of suture failure. Osteoarthritis is common after open reduction of hip luxations.

Keywords
- traumatic coxofemoral luxations
- modified hip toggle stabilization
- feline coxofemoral osteoarthritis

Introduction

Traumatic coxofemoral luxations in cats account for 90% of all joint luxations.[1] A new modified hip toggle stabilization technique, using a combination of poly-stranded suture and two titanium buttons (mini-TR, Arthrex, Inc., Naples, United States), has been described for both dogs and cats with excellent results.[2,3] Information on the surgical technique and outcomes in cats is limited, and no study assessed the progression of coxofemoral osteoarthritis (OA) in the follow-up period.[3,4]

The purpose of this multicentre retrospective study is twofold: (1) to report the results and complications of mini-

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TR for the treatment of coxofemoral luxation in cats, and (2) to compare outcomes and complications between single- and double-stranded prosthetic suture techniques. We hypothesize that the mini-TR for a modified hip toggle stabilization in cats with double strands is more secure than a single strand.

Materials and Methods

Study Population

We searched the medical records of two veterinary hospitals (Vetsuisse Faculty Veterinary Teaching Hospital University of Zurich and Veterinary Teaching Hospital University of Bern) between November 2009 and October 2017 for cats undergoing hip toggle stabilization using the mini-TR. The inclusion criteria were (1) acute (<3 days duration from trauma) coxofemoral luxation without signs of OA or intra-articular fractures, (2) surgical treatment of coxofemoral luxation with hip toggle stabilization using the mini-TR and (3) a complete follow-up as by the Cook and colleagues reference guidelines.[5] Complete follow-up was defined as a complete medical record and follow-up examination of the case at least 3 months after surgery including clinical examination and validated questionnaire answered by the owner. Cases were excluded from the study if their follow-ups were shorter than 3 months, unless the injured hip reluxated within that time. If available, orthogonal preoperative, postoperative and follow-up radiographs were included in the review.

We collected information about signalment, history, type of luxation, side of luxation, uni- or bilateral condition, concurrent injuries, surgical technique, antibiotic medication administration and complications. The surgical report was reviewed for surgical and anaesthetic time, intraoperative complications, diameter of the femoral tunnel, number of suture strands and ability to close the joint capsule. Complications were categorized as minor, major and catastrophic according to standard definitions and criteria.[5]

Surgical Procedure

The surgical technique was performed as previously described in dogs and cats using a commercially available multifilament suture-toggle-system (Arthrex mini-TR).[2,3] However, modifications of the original surgical technique in terms of diameter of the femoral tunnel (1.5, 2.0 and 2.4 mm) and use of a single or double loop suture to secure the toggle pin were used. A femoral tunnel of 1.5 mm of diameter was always associated with a single-strand implant, as two loops could not be inserted through such relatively small bone tunnel. Single or double loop suture could be inserted either in a 2.0 mm or 2.4 mm bone tunnel. The femoral tunnel preparation was always performed from the third trochanter to the fovea capitis direction, as this was the surgeons' preferred technique.

Pain medication was given perioperatively (opioids, e.g., methadone 0.2mg/kg q4hrs intravenous [iv] or similar) and continued until suture removal (non-steroidal, e.g., meloxicam 0.05 mg/kg po).

Clinical Examination

Clinical examinations were performed by the same surgeon who performed the surgery. Limb function was subjectively evaluated through passive range of joint motion, evaluation of patient discomfort during joint palpation and lameness scoring. A score from 0 to 4 (0 no lameness, 1 intermittent lameness, 2 consistent weight-bearing lameness, 3 intermittent non-weight-bearing lameness and 4 toe-touching lameness) was adopted to evaluate postoperative weight-bearing and joint function from previous studies evaluating hindlimb lameness in cats.[3,6]

Validated Questionnaire

A validated questionnaire was sent to the owners (FMPI = Feline Musculoskeletal Pain Index).[7] The owners were asked to fill a grading score form and answer 17 questions concerning cat behaviour, level of activity and quality of life. Each question ranged from 0 to 4, with 0 being not at all and 4 defined as normal. The total FMPI score is the sum of scores for each question. Higher totals indicate less impairment with a possible range of 0 to 68.

Radiographic Evaluation

Orthogonal radiographs of the pelvis were obtained pre- and postoperatively, and at each scheduled follow-up examination. The following radiographic changes of hip joint were assessed and scored by the main author and a board-certified radiologist (►**Fig. 1**): new bone formation on the femoral head, femoral neck, acetabulum and thickness of the acetabular subchondral bone (bone sclerosis) were scored (normal = 0, mild = 1, moderate = 2, or severe = 3). Those scores were summed to make a total score. The joint space width was also subjectively evaluated as normal, narrow or wide. On

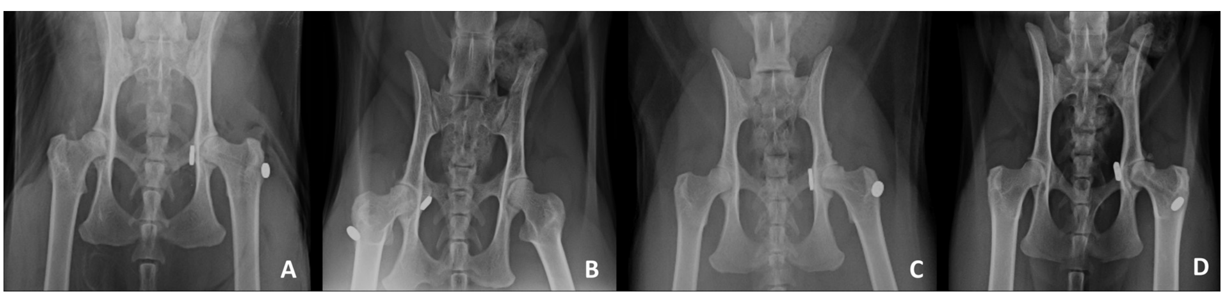

Fig. 1 Radiographs giving differently graded hips and tunnel position as an example. Radiographic scoring of new bone formation on the femoral head and the acetabulum in the luxated joint with subsequent stabilization with the mini-Tight Rope system (**A**: normal joints, **B**: mild, **C**: moderate, **D**: severe). The position of the tunnel was evaluated as following: **A**: central, **B**: central, **C**: dorsal, **D**: ventral.

postoperative and follow-up ventrodorsal radiographs, the position of the femoral tunnel within the femoral neck was recorded (dorsal, central, ventral). The diameter of the femoral neck in its narrowest point was measured along with the diameter of the femoral tunnel at the same level. The resulting ratio (femoral tunnel to femoral neck diameter) was calculated to compensate for variations in body size and radiographic magnification. Concurrent injuries or abnormalities in the pelvic region were also recorded.

Data Analysis

Spreadsheet software (Microsoft Excel for Mac) and statistical software (Graphpad Prism) were used for statistical analysis. Means, medians and standard deviations were used to summarize the data. Fisher's exact test was used to compare complications between the two surgical modifications (single vs. double strand). Odds ratios were calculated if differences between groups were detected. Correlation between body weight and total score in the FMPI and between surgical experience and surgical time were calculated using Spearman's correlation coefficient.

Results

Inclusion Criteria and Medical Records

Thirty-two cats met the inclusion criteria, but one cat luxated bilaterally giving 33 coxofemoral luxations.

The mean age of the cats was 4.1 ± 3.3 years (from 0.5 to 12.6 years), and their mean body weight was 4.2 ± 1.1 kg (from 2.7 to 8.0 kg). The predominating breed were domestic shorthairs (►**Table 1**). Eighteen cats were males and 14 females; none were sexually intact.

Sixteen out of 32 cats had concurrent injuries affecting the appendicular skeleton: Seven cats had injuries on the same side as the luxation, six cats on the contralateral side and three cats had bilateral concurrent injuries. There were six sacroiliac joint luxations, two femoral injuries and one tarsal injury.

Surgical Records

Seven-boarded surgeons and four surgical residents performed the surgeries. Mean surgery duration was 90 ± 42 minute (from 45 to 210 minute). Longer times were associated with concurrent injury repair. The correlation between surgeon experience (board-certified surgeon vs. resident) and surgical time was $r = -0.31$.

Single suture strand was used in 21 hips. In four of those, the single suture strand was passed through a 1.5mm femoral tunnel, while in 17 cats it was inserted through a 2.0 mm femoral tunnel. Double-stranded suture was used in 12 hips, either placed through a 2.0 mm femoral canal (11 hips) or a 2.4 mm canal (1 hip).

In 20 hips, the joint capsule was sutured using monofilament suture material with a simple interrupted pattern (polydioxanone 2/0 to 3/0). In 13 hips, the traumatic event severely damaged the joint capsule and it was not sutured (►**Table 2**).

All cases received perioperative cefazolin (22 mg/kg iv q 90 minute). In six cases, the antibiotic treatment was continued for at least 7 days due to other injuries (cefazolin 22 mg/kg orally q 12 hours). Postoperative management consisted of pain medication and exercise restriction.

Pain management typically consisted of methadone (0.2 mg/kg iv q 4hrs) or buprenorphine (30 µg/kg iv q 6 hours) that was continued until discharge, typically 24 to 48 hours after surgery. Additionally, non-steroidal anti-inflammatory medication was prescribed for 5 to 7 days (meloxicam 0.05 mg/kg orally q 24 hours).

After discharge, the owners were advised to keep the cats indoors and avoid exercise for 6 to 8 weeks.

Complications

No intraoperative complications were recorded. The overall major complication rate was 5/32, as 5 reluxations occurred. Of the five reluxation cases, four had a single loop FiberWire, and one had a double loop into a 2.0 mm femoral canalization. There was no statistical difference in the number of reluxations between single and double strands ($p = 0.62$).

Two of the five cats presented 4 and 8 weeks after surgery, respectively, with an acute onset of lameness on the operated limb. One was the cat that was treated with the double loop mini-TR, and the other was an acute secondary trauma during the recovery period. In both cases, the suture failed due to bone cutout at the level of the femoral head-acetabulum interface. A femoral head and neck osteotomy was performed. In the remaining three cases, the reluxation was observed during the planned follow-up examinations, as the owner did not notice any gross gait abnormality during recovery. In one case, the owner declined revision surgery. The remaining two were lost to follow-up. Neither infection nor other implant-related complications were found in the remaining 27 cats.

Clinical Examination and Questionnaire

The two cats with reluxations within the first week were not included in the follow-up examinations. The remaining 30 cats showed a lameness grade 4/4 preoperatively. Postoperative evaluation 24 hours after surgery revealed a lameness grade of 2/4 or less in all cases. At the scheduled follow-up examination, the 30 cats showed either minimal (grade ¼) or no lameness according to clinical evaluation and owner assessment. The last follow-up examinations were performed at a mean of 13 ± 13 months (from 4 months to 4 years).

The completed questionnaire was returned in 32/32 cases at a mean of 8.5 ± 14.8 months postoperatively (from 3.5 to 54 months). The mean FMPI score was $0.98 \pm 5.9\%$. There was no correlation between FMPI score and body weight ($r = -0.09$).

Questions like 'cleaning habits' and 'interaction with humans' were consistently answered with normal. Activities like 'getting up', 'moving down the stairs' and 'normal walking' were mainly classified by the owner as normal or close to normal. Scores regarding behaviour such as 'jumping up' or 'jumping to kitchen counter' activities were averaged lower, but still rated within 'normal' or 'almost normal' grades.

Table 1 Weight, age, breed, type of coxofemoral luxation, implant received and concomitant injury of the cases included in the study

Case no.	Age	Body weight	Breed	Sex	Side	Type of luxation	Concurrent injuries	Follow-up (months)	
	(y)	(kg)		(M/F)	(R/L)	(CrD/V)		Rads	FMPI
1	8	7.5	Norwegian	M	L	CrD	None	12	8.5
2	1.4	4.2	DSH	M	L	V	Wound		4
3	1.4	4.2	DSH	M	R	V	Wound		4
4	3.4	3.4	DSH	F	L	CrD	UG trauma	9	8
5	1.4	4.3	Angora	F	L	CrD	Femur Fx contralateral, wound		8
6	2	4.1	DSH	F	R	CrD	None		Reluxation
7	8.4	8	DSH	M	L	CrD	Unknown stifle pathology		32
8	9	3.5	DSH	M	R	CrD	Bilateral elbow OA	5	5.5
9	6	5.7	DSH	M	L	CrD	Wound	4	4.5
10	0.4	3.2	DSH	F	L	CrD	Symphysiolysis lower jaw		8
11	2.5	4	Abyssinian	M	R	CrD	None		9
12	12.6	5.6	DSH	M	R	CrD	None		31
13	4.3	3.7	DSH	F	R	CrD	Fx left ilium, ISL right, wound		Reluxation
14	12.3	4.7	DSH	F	R	CrD	Fx rib, Luxation Xyphoid, Amputee	10	8.5
15	2.3	3.45	DSH	M	L	CrD	Wound	11	8
16	1.3	3	DSH	F	L	CrD	None	9	6
17	10.5	5.1	Ragdoll	M	R	CrD	Wound		7
18	3.1	4	DSH	M	R	CrD	Luxation left tarsus, distal left Fx fibula		12
19	2.5	2.7	DSH	F	L	CrD	Uroperitoneum, caudal CLR		Reluxation
20	3.2	3	DSH	M	L	CrD	None	22	19
21	2.3	4.8	DSH	M	L	CrD	None		54
22	4.3	4.5	DSH	M	R	CrD	ISL left, abdominal hernia, Fx right ilium	9	Reluxation
23	3	3.9	DSH	F	R	CrD	None		33
24	3.5	3.5	DSH	F	R	CrD	None		31
25	1.1	3.7	DSH	M	R	CrD	Fx right femur, wound	6	Reluxation
26	3.5	3.9	DSH	F	L	CrD	None	15	8.5
27	0.9	3.9	DSH	M	L	CrD	Fx right femoral neck, greater trochanter avulsion	11	11
28	2	3.6	Siamese	F	R	CrD	Fx right ilium, sciatic lesion		43
29	3.1	4.1	DSH	F	R	CrD	Fx right ileum, Fx pubis, ISL left, wound	48	45
30	0.9	3.6	DSH	F	R	CrD	Fx right ilium, ISL left		4
31	7.3	4.9	DSH	M	R	CrD	None		3.5
32	3.8	4.6	DSH	M	L	CrD	None	10	7
33	3	3.8	DSH	M	L	CrD	None	12	9

Abbreviations: CLR, cruciate ligament rupture; CrD, craniodorsal; DSH, domestic shorthair; Fx, fracture; ISL, iliosacral luxation; OA, osteoarthrosis; UG, urogenital; V, ventral.

Radiographic Findings

There were 31 unilateral craniodorsal luxations, and one bilateral caudoventral luxation. Seventeen cases out of 33 were affected in the right hindlimb and 16 the left hindlimb. Fourteen of 32 cats had a radiographic follow-up study longer than 3 months, with a mean radiographic follow-up

Table 2 Cases included in the study including complications, surgical details, follow-up and radiographic score. Time of latest follow-up examination is mentioned in ►**Table 1**

Case no.	No. of FW strands	Complication	Infection	Drill tunnel (mm)		Closure of	Radiographic score	
		Reluxation		Postoperative	Latest control	Joint capsule	Postoperative	Latest control
1	2	No	None	2.4	2.6	Y	0	4
2	2	No	None	2		Y	0	
3	2	No	None	2		Y	0	
4	2	No	None	2	2.1	Y	0	6
5	2	No	None	2		Y	0	
6	2	Yes	None	2		Y	0	Reluxation
7	2	No	None	2		Partial	0	
8	2	No	None	2	2.7	Y	0	2
9	2	No	None	2	2.1	Y	0	1
10	2	No	None	2		Partial	0	
11	2	No	None	2		N	0	
12	2	No	None	2		N	0	
13	1	Yes	None	1.5		Y	0	Reluxation
14	1	No	None	2	1.6	Y	0	1
15	1	No	None	1.5	2.1	Partial	0	17
16	1	No	None	1.5	2.1	Y	0	1
17	1	No	None	2		N	0	
18	1	No	None	2		Y	0	
19	1	Yes	None	1.5		Partial	0	Reluxation
20	1	No	None	2	1.9	N	0	2
21	1	No	None	1.5		N	0	
22	1	Yes	None	2	2.5	N	0	Reluxation
23	1	No	None	2		Partial	0	
24	1	No	None	2		Y	0	
25	1	Yes	None	1.5	1.9	Y	0	Reluxation
26	1	No	None	2		N	0	4
27	1	No	None	2		Y	0	
28	1	No	None	1.5		N	0	
29	1	No	None	2	2.1	N	0	4
30	1	No	None	1.5		Y	0	
31	1	No	None	1.5		N	0	
32	1	No	None	1.5	1.5	Y	0	1
33	1	No	None	1.5	1.6	N	0	2

time of 10 ± 11 months (from 4 to 48 months). Among these 14 cats, eight had a left coxofemoral luxation, and six had a right coxofemoral luxation. Overall, no radiographic signs of OA were found preoperatively, while postoperative radiographic OA signs were observed in the femoral head (10/14), femoral neck (2/14) and acetabulum (10/14), as seen in ►**Fig. 1**. Bone sclerosis was found in one case (1/14), while joint space widening was detected in two cats (2/14).

The position of the femoral tunnel was central in eight of the 14 cats, distal in four and proximal in one cat. The mean femoral tunnel to femoral neck diameter ratio was 22.5% after surgery and 22.8% at the first follow-up recheck (►**Table 2**). The size of the femoral tunnel increased between surgery and first radiographic recheck, with a mean value of 10% (0.8 mm; range: −0.3 to 0.7 mm). No statistical significance was found between cat body weight and diameter of the femoral tunnel ($p = 0.2$). However, the time interval between these radiographs was inconsistent.

Discussion

This is the first study reporting a prolonged clinical and radiographic follow-up for the treatment of coxofemoral luxations in a larger group of cats treated with the mini-TR system. We reported a mean long-term clinical follow-up of 13 months and a mean radiologic follow-up of 10 months. Most cats had good-to-excellent hip function and quality of life, especially in terms of early return to weight bearing in the immediate postoperative period.

We observed a 15% complication rate, which is similar to other studies using either the hip toggle stabilization technique with different or similar suture material (11–14%),[4,8,9] or different surgical techniques, such as trans articular pinning (15%) and iliofemoral sling (17%).[10,11] Although the difference in reluxation rate between the double loop FiberWire (1/12 cats) compared with the single strand (4/21 cats) was non-significant, this is likely to be a type II error. Therefore, we strongly recommend the use of two strands as safety is not compromised and outcomes might be improved.

The diameter of the femoral tunnel needs to be carefully evaluated, to allow passing double loops of FiberWire while not weakening the neck. To be specific, a 2.0 mm wide tunnel is required to insert two loops. A 2.0 mm tunnel can exceed the recommended femoral tunnel-femoral neck diameter ratio of 20%, but did not create complications in our cases similar to previous studies reaching even higher ratios.[2,3] The benefit of drilling wider bone tunnels is twofold: (1) the synthetic material is easily pushed through the femoral tunnel, (2) the risk of bone friction caused by poly-stranded material that may lead to progressive bone resorption and canal widening is potentially decreased. Based on our findings, the mean femoral tunnel-femoral neck diameter ratio was already 22%, which is 2% higher than what is recommended.[2] Fractures of the femoral neck did not occur in this study despite some cats having a 2.4mm diameter tunnel. Due to the decreased femoral neck fracture risk of smaller drill canals, we feel that a 2.0mm drill canal appears to be sufficient and potentially increases the safety of the surgical technique in cats considering previously published recommendations.[2]

We observed OA progression in all the cases with available radiographic follow-up between 1 and 2 months after surgery. This finding is in agreement with the literature, where it is reported that OA in cats can occur as early as 6 weeks after hip luxation.[12] The progression of OA might explain why the questionnaire scores referring to jumping activities were lower than normal. Several factors might potentially lead to OA after coxofemoral luxation treated with hip toggle stabilization such as initial joint trauma, pre-existing coxofemoral OA, not having isometric reconstruction of the round femoral ligament, increased body condition score and concurrent injuries.[12,13] In all our cases, the traumatic event was the leading cause of the coxofemoral luxation and we suspect it to be the main contributing factor for the OA progression.[8,14] We did not observe radiographic signs of pre-existing OA in the preoperative radiographs and so it is unlikely to be a predisposing factor for the postoperative OA observed in this study.[15]

Suboptimal drilling of the femoral tunnel in terms of isometric position of the holes in the cis- and transfemoral cortices may lead to the persistence of joint instability and OA progression.[16,17] However, this has not been reported in the feline coxofemoral joint and is assumed and concluded by the authors based on stabilization techniques in other joints.[16,17]

We have evaluated the tunnel position in the postoperative radiographs to assess if we were able to drill the femoral tunnel in the isometric points to restore the physiological direction of the forces arising from the femoral round ligament. However, our investigation was based on a two-dimensional approach. Three-dimensional measurements of the femoral tunnel have shown the complexity for the assessment of optimal position for drilling (J. Bleedorn, personal communication). Based on this assumption, we cannot rule out that the tunnel position in our cases may have contributed to suboptimal anatomical reconstruction and consequent development of OA.

Concurrent injuries in the contralateral limb were detected in 33% of the cases. We may speculate that they may have also played a role for OA progression as they might have increased the joint load and stress on the previously luxated hip.

Despite the posttraumatic OA progression in the coxofemoral joint, our clinical outcome was still very satisfactory according to medical and owner reports. The early return to function that mini-TR offers along with the preservation of hindlimb muscles is a plausible explanation for the good clinical outcomes. Muscle wasting is known to be related to OA development and progression in people and might have protected hindlimb function in our cases.[18] Therefore, despite the high degree of OA observed we would encourage surgeons to treat coxofemoral luxations in cats accordingly using this technique, but also using implants providing the highest possible strength as a very strong reconstruction is necessary to avoid reluxation.

This study has limitations. First, there was some inconsistency among the medical records, including variable follow-up times and inconsistent radiographic positioning. Second, there was no comparison group, only an informal comparison to similar studies. Furthermore, the unbalanced and low number of cases included in the study might be responsible for the lack of significance. Lastly, the study was not blinded and the surgeon who did the surgery also performed the follow-up examinations; therefore, a bias might have potentially been introduced.

In conclusion, we found that the mini-TR is a safe surgical technique for the treatment of coxofemoral luxation in cats, enabling early return to function, based on a mid-term follow-up. We recommend the use of two FiberWire stranded loops, inserted into a 2.0 mm femoral tunnel.

Finally, posttraumatic OA must be expected after coxofemoral luxation and should be discussed with the owner as a potential postoperative complication.

Note
This study was presented in abstract form at the 45th Annual Meeting of the Veterinary Orthopedic Society, Snowmass, Colo, March 2018.

Authors' Contribution
All authors contributed to study design, editing of the manuscript and approval of the final version. S.C.K., N.W., A.P., and F.L. contributed to writing of the manuscript. S.C.K. and A.H. contributed to data retrieval. S.C.K. performed the data analysis.

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Conflict of Interest
S.C.K., P.A.S., and A.P. work as part time consultants for Arthrex GmbH, Munich, Germany. The remaining authors disclose no conflict of interest.

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