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Surgical Rope for Extracapsular Stabilization of the Knee in Dogs - *Ex Vivo* Model

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ABSTRACT

***Background*:** Numerous methods have been documented for the surgical rectification of cranial cruciate ligament deficiency in dogs, including intracapsular and extracapsular procedures and osteotomies. Notably, among the extracapsular techniques, the fabellotibial suture is used for small dogs, while the TightRope fiber tape system is employed for medium, large, and giant dogs. This study aimed to standardize a modified TightRope technique using polyester surgical rope number 1 for the correction of cranial cruciate ligament rupture in dogs.

***Materials, Methods& Results*:** This study evaluated tibial compression, drawer movement, and caudal displacement of the femur on x-ray at 4 distinct stages (intact ligament, failed ligament, repair with fabellotibial sutures, and repair with a TightRope modification using polyester surgical rope number 1 in 8 *ex vivo* canine pelvic limbs. Surgical cords were created using 2 sutures per kilogram of the patient's weight. The final diameters of the cords were evaluated, and the results confirmed the feasibility of the implant thickness. No significant differences were observed in drawer movement and tibial compression between the intact ligament and post-surgical restorations. However, both drawer movement and tibial compression were significantly higher ($P < 0.05$) following the failure of the cranial cruciate ligament compared to other stages. The weight of the cadavers did not significantly influence ($P > 0.05$) the drawer movement, tibial compression, or caudal displacement of the femur on x-ray. The extracapsular surgical cord success fully stabilized the knee, as there were no statistically significant differences in drawer movements and tibial compression compared to the lateral fabellotibial suture technique and the intact ligament. This indicates that both tested techniques effectively restore physiological joint stability when assessed with drawer movement and tibial compression.

***Discussion*:** Both techniques examined in this study yielded physiological joint stability for drawer movement and tibial compression. However, the modified TightRope technique utilizes more isometric points, facilitating a normal joint range of motion and reduced joint tension. The stabilization achieved with TightRope Fiber Tape is comparable to that of tibial plateau leveling osteotomy in terms of limb function and progression of degenerative joint disease. The primary drawback of this implant is its limited accessibility compared to the equipment used for osteotomies. The potential use of surgical ropes, custom-made from universally available surgical sutures (polyester number 1), significantly enhances the accessibility of the modified TightRope Fiber Tape technique. The cranial cruciate ligament in dogs can withstand 48.07 N ± 0.41 per kilogram of weight before rupturing. Research indicates that the use of number 1 polyester surgical cords allows for the estimation of force increase for each suture added to the implant (25.339 N). Consequently, an implant with traction resistance equivalent to the patient's intact ligament can be created, irrespective of size and weight. Conclusively, knee stabilization using surgical polyester rope number 1 in the "modified TightRope Fiber Tape" technique proves effective in an ex vivo dog model. We recommend further studies on living patients and long-term postoperative follow-ups.

Keywords: implants, cranial cruciate ligament, polyester, TightRope.

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INTRODUCTION

Several methods (intracapsular and extracapsular procedures and osteotomies) for the surgical correction of cranial cruciate ligament deficiency in dogs have been reported. However, no surgical technique has been identified that halts the onset or progression of degenerative joint disease. The progression of the disease will be slower or less ever with surgical stabilization compared to the absence of any treatment [3,5-7].

Extracapsular techniques involve a wide range of options using thick-caliber sutures to mitigate joint instability. The fabellotibial suture technique is commonly used for small dogs, while the TightRope fiber tape system is preferred for medium, large, and giant dogs [4].

Currently, tibial plateau leveling osteotomy and TightRope Fiber Tape techniques yield the best long-term outcomes. However, the likelihood of catastrophic failures is lower with the TightRope technique [2].

The cranial cruciate ligament in dogs supports a force of 48.07 N ±0.41 per kilogram of weight before rupturing. The use of number 1 polyester surgical cords reportedly allows for an estimation of the force increase for each suture added to the implant, which is ~25.339 N. Thus, it is feasible to construct an implant with a traction resistance equivalent to the patient's intact ligament, irrespective of its size and weight [1].

Global veterinary medicine has not widely adopted implants for cranial cruciate ligament replacement or knee joint stabilization. Herein, a viable alternative is proposed for addressing cranial cruciate ligament rupture in dogs, which involves modifying the TightRope Fiber Tape extracapsular technique using polyester surgical rope number 1.

MATERIALS AND METHODS

Delineation

Eight pelvic limbs, sourced from 4 canine cadavers, were utilized in this study. These cadavers were from patients whose cause of death bore no relation to orthopedic alterations. This study evaluated tibial compression, drawer movement, and cranial displacement of the tibia. Radiographic studies were conducted at 4 distinct stages: when the ligament was intact, when the ligament had failed, after repair using the fabellotibial suture technique, and after repair using number 1 polyester surgical rope with the "modified TighRope Fiber Tape" technique.

Crucial data, including the tibial plateau angle, whether the right or left limb was involved, and the animal's weight, were statistically analyzed. Additionally, details regarding the diameter of the drill used, the number of threads (number 1 polyester[1]) in the surgical cord (2 threads per kilogram of the patient's total weight), and the final thickness of the implants were recorded. Radiographic examinations confirmed that the limbs were devoid of macroscopic anatomical alterations and joint degeneration.

Surgical procedures

Following the preparation of the limbs, an incision was made laterally to the patella, allowing for the identification of the lateral collateral ligament. Two 1.0 mm Kirschner pins were then inserted: one in the proximal region and the other in the distal region of the ligament's insertion point. These pins served as reference markers for measuring the tibial displacement relative to the femur during both tibial compression and drawer movement (Figure 1).

All limbs were positioned medially on the surgical table and subsequently angled at 135° using a goniometer. A caliper, closed at a right angle, was guided by the previously inserted 1.0 mm Kirschner pins (Figure 2) to the lateral collateral ligament. The cranial drawer movement test and the tibial compression test were performed to assess the tibia's displacement relative to the femur. The degree of displacement between the pins was determined by the caliper reading obtained after conducting these tests.

Displacement was assessed via radiographic examination, conducted 3 times under each condition: intact cranial cruciate ligament, failed ligament, stabilization with fabellotibial suture, and reconstruction with modified TightRope Fiber Tape surgical rope. The arithmetic mean of the 3 readings was considered. All measurements were performed by the same evaluator.

Upon examination of the tests involving an intact cranial cruciate ligament, a knee arthrotomy was conducted. This was followed by the dislocation of the medial patellar and identification of the cranial cruciate ligament. The ligament was then excised using a scalpel fitted with a number 11 blade, positioned close to the tibial plateau. Subsequently, the patella was repositioned anatomically, and the joint capsule was sutured.

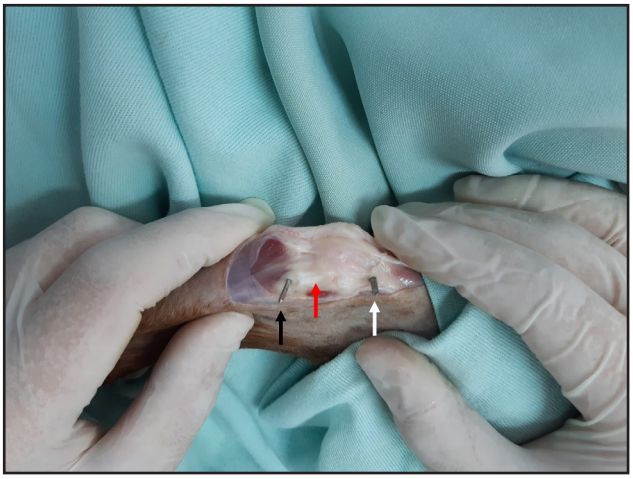


Figure 1. Two 1.0 mm Kirschner pins were inserted, one in the proximal region (white arrow) and the other in the distal region (black arrow) of insertion of the collateral ligament (red arrow).



Figure 2. Using the caliper closed at a right angle to the lateral collateral ligament, guided by the previously inserted 1.0 mm Kirschner pins..

The fabellotibial suture technique was employed for joint stabilization, utilizing a number 5 polyester suture[1]. Following the execution of tests and the acquisition of measurements, the suture was subsequently released.

Technique proposition

The repair was ultimately conducted using surgical rope, employing the modified TightRope Fiber Tape technique. Proximal fixation involved transverse perforation of the distal femoral diaphysis in a lateromedial direction. A number 2 cerclage wire was threaded through the bone tunnel, securing the number 1 polyester cord to the cerclage loop on the femur's medial surface (Figure 3). One wire of the cerclage was then returned externally, encircling the implant (Figure 4), and the cerclage was closed on the femur's lateral face (Figure 5).

Subsequently, a 2 mm drill was executed cranially and distally to the lateral fabellofemoral junction, directed towards the proximal pole of the patella on the medial aspect of the femur. The implant was threaded through the bone tunnel, emerging at the lateral femoral condyle. The proximal tibia, specifically Gerdy's tubercle, was drilled in a lateromedial direction, from proximal to distal. The implant was then threaded through this bone tunnel (Figure 6).

The "belt loop" technique was employed for distal fixation. This method involves quadruple transverse drilling of the proximal tibial diaphysis in a lateromedial direction. Subsequently, two number 2 cerclage wires were passed separately through a bone tunnel and then returned through another bone tunnel, thereby enveloping the implant twice in a "loop". This was followed by a slight flexion of the knee joint and a weak lateral rotation. The implant was then pulled distally, leading to the occlusion of the distal loop (Figure 7). Finally, the implant was pulled in the proximal direction within the proximal loop, resulting in the occlusion of the proximal loop (Figure 8).

Statistical analysis

Non-parametric tests were used to analyze the data. The Kruskal-Wallis test was employed to examine differences between evaluation times (n = 4; intact, failed, after fabellotibial, and after modified ThighRope reconstruction), cadaver weight (n = 4; 2.5, 7, 12, and 30 kg), and between limbs (n = 2; right and left). In instances where differences were detected, the Bonferroni (Dunn) test was used to compare means. The SAS® statistical program, Studio version, was used to perform all statistical analyses. A *P*-value of less than 0.05 was considered to indicate significant differences.

RESULTS

In our study, no significant differences were observed in drawer movement and tibial compression between the intact cranial cruciate ligament and its surgical restorations ($P > 0.05$; Table 1). This suggests that both techniques under investigation effectively restore physiological joint stability, as evidenced by drawer movement and tibial compression tests.



Figure 3. Anchoring the number 1 polyester cord to the loop of the cerclage on the medial surface of the femur.



Figure 4. Return of one wire of cerclage externally involving the implant.



Figure 5. Cerclage occlusion in the lateral face of the femur.

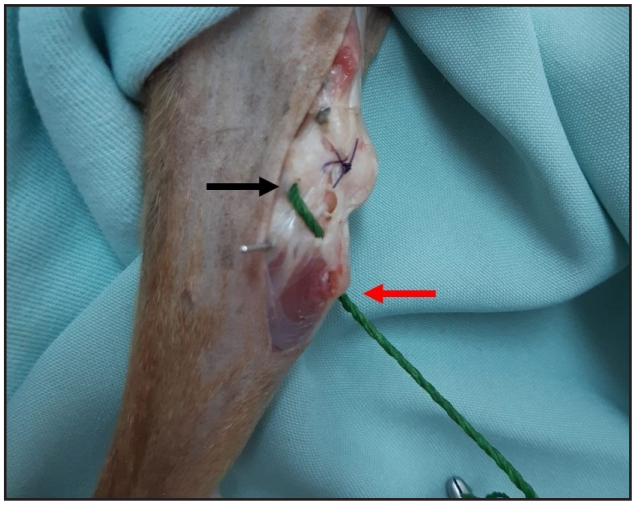


Figure 6. The implant was passed through the bone tunnel, emerging at the lateral femoral condyle (black arrow). The proximal tibia (Gerdy's tubercle) was drilled in the lateromedial direction, from proximal to distal, and the implant was passed through the resulting bone tunnel (red arrow).

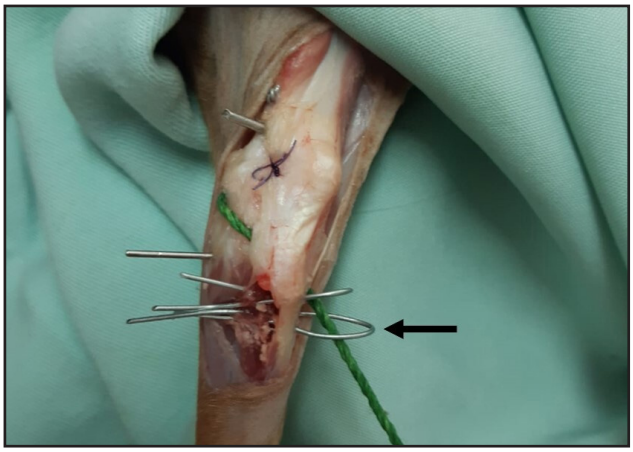


Figure 7. Distal fixation using the "belt loop" technique, involving a slight flexion of the knee joint followed by gentle lateral rotation. This allowed for the implant's distal traction and subsequent securing of the distal loop (black arrow).

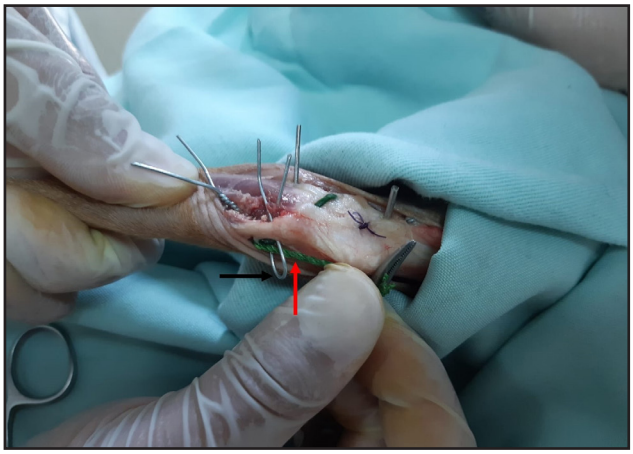


Figure 8. Traction of the implant inside the proximal loop in the proximal direction (red arrow) and occlusion of the proximal loop (black arrow).

The drawer movement and tibial compression significantly increase ($P < 0.05$) following the failure of the cranial cruciate ligament compared to other evaluated instances (Table 1). The weight of the cadavers did not significantly influence ($P > 0.05$) the drawer movement, tibial compression, or caudal displacement of the femur as observed on x-ray (Table 2).

The tibial plateau angle in the right limb was 7.3% greater than that in the left limb of the cadavers ($P < 0.05$; Table 3). However, the limb's position in the cadavers did not significantly influence drawer movement, tibial compression, or caudal displacement of the femur as observed on x-ray ($P > 0.05$; Table 3).

Surgical cords were created using 2 sutures per kilogram of the patient's weight. The final diameters of these cords were assessed, and the results confirmed the feasibility of the implant thickness. For a patient weighing 2.5 kg, 5 sutures were used, resulting in a final implant diameter of 0.49 mm and a 1.5 mm drill. In the case of a 7-kg patient, 14 sutures were used, yielding a 1.16 mm implant and a 1.5 mm drill. For a 12-kg animal, 24 sutures were employed, leading to a 1.99 mm implant and a 2.5 mm drill. Lastly, in the case of a 30-kg patient, 60 sutures were used, resulting in a 4.98 mm implant and a 3.5 mm drill.

Table 1. Drawer movement and tibial compression before sectioning the cranial cruciate ligament (intact ligament) and after surgical restorations.

Response	Moment				SEM[1]	*P**
	Intact	Failed	Fabellotibial	Tight Rope		
Drawer moviment (mm)	1.04b	12.90a	0.97b	0.43b	0.96	< 0.01
Tibial compression (mm)	1.12b	13.66a	0.80b	0.42b	1.03	< 0.01

*Probability by the Kruskal-Willis test at 5% significance (Different letters on the lines indicate differences between the moments of evaluation). [1]SEM = Standard Error of the Mean.

Table 2. The weight of the cadavers, drawer movement, tibial compression and caudal displacement of the femur on x-ray.

Response	Weight				SEM[1]	*P**
	2.5 kg	7 kg	12 kg	30 kg		
Drawer movement (mm)	3.13	3.99	3.68	4.55	0.96	0.93
Tibial compression (mm)	3.14	3.86	4.12	4.89	1.03	0.96
Caudal displacement of femur on x-ray (mm)	5.51	8.26	12.90	10.66	1.05	0.08

*Probability by the Kruskal-Willis test at 5% significance. [1]SEM = Standard Error of the Mean.

Table 3. Right limb when compared to the left limb in the cadavers. The tibial plateau angle, drawer movement, tibial compression and caudal displacement of the femur on x-ray.

Response	Limb		SEM[1]	*P**
	Right	Left		
Tibial plateau angle (TPA)	32.30a	29.95b	0.44	0.01
Drawer movement (mm)	3.78	3.89	0.96	0.73
Tibial compression (mm)	3.92	4.09	1.03	0.94
Caudal displacement of the femur on x-ray (mm)	9.35	9.32	1.05	0.77

*Probability by the Kruskal-Willis test at 5% significance (Different letters on the lines indicate different evaluated limbs). [1]SEM = Standard Error of the Mean.

DISCUSSION

Graft and prosthesis fixation methods, including interference screws, screws with washers, and cerclage wires, each present their own advantages and disadvantages [6]. This study opted for cerclage fixation owing to its versatility in accommodating implants of any diameter.

For decades, extra-articular stabilization techniques have served as a method for stabilizing the

deficient cranial cruciate ligament. The fabellotibial suture is the most commonly used technique. However, the positioning of the prosthesis anchorage points is critical for restoring normal joint range of motion and reducing changes in prosthesis tension during movement [8]. Compared to the fabellotibial suture, the TightRope Fiber Tape anchor points exhibit greater isometry. Although both techniques evaluated in this study achieved physiological joint stability for drawer movement and tibial compression, the modified TightRope technique utilizes more isometric points, thereby facilitating a normal joint range of motion and reduced joint tension.

Limb function and progression of degenerative joint disease do not differ between stabilization with TightRope Fiber Tape and tibial plateau leveling osteotomy [2]. However, the accessibility of this implant is challenging compared to the equipment used for osteotomies. The potential use of surgical ropes, custom-made from universally available surgical sutures (polyester number 1), significantly enhances the accessibility of the modified TightRope Fiber Tape technique.

CONCLUSION

The "modified TightRope Fiber Tape" technique, utilizing number 1 polyester surgical rope for knee stabilization, has proven effective in an ex vivo canine model. We recommend conducting application studies in living patients, coupled with long-term postoperative follow-ups.

MANUFACTURER

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***Declaration of interest*.** The authors declare no conflicts of interest. The authors are solely responsible for the content and writing of the article.

REFERENCES

1 **Bello L.K., Godoy F.G., Oliveira J.P.M., Cassanego G.R. & Müller D.C.M. 2021.** Proposição de técnica e comparação de materiais para confecção de corda cirúrgica. *Ciência Rural*. 51(6): e20200331. DOI: 10.1590/0103-8478cr20200331.

2 **Cook J.L, Luther J.K., Beetem J., Karnes J. & Cook C.R. 2010.** Clinical comparison of a novel extracapsular stabilization procedure and tibial plateau leveling osteotomy for treatment of cranial cruciate ligament deficiency in dogs. *Veterinary Surgery*. 39(3): 315-323. DOI: 10.1111/j.1532-950X.2010.00658.x.

3 **Hayashi K., Frank J.D., Dubinsky C., Zhengling H., Markel M.D., Manley P.A. & Muir P. 2003.** Histologic changes in ruptured canine cranial cruciate ligament. *Veterinary Surgery*. 32(3): 269-277. DOI: 10.1053/jvet.2003.50023.

4 **Kowaleski M.P., Boudrieau R.J. & Pozzi A. 2017.** Stifle Joint. In: Johnston A.S & Tobias K.M. (Eds). *Veterinary Surgery Small Animal*. 2nd edn. St. Louis: Elsevier Saunders, pp.2925-3158.

5 **Nelson S.A., Krotscheck U., Rawlinson J., Todhunter R.J., Zhang Z. & Mohammed H. 2009.** Long-Term functional outcome of tibial plateau leveling osteotomy versus extracapsular repair in a heterogeneous population of dogs. *Veterinary Surgery*. 42(1): 38-50. DOI: 10.1111/j.1532-950X.2012.01052.x.

6 **Piermattei D.L., Flo G.L. & Decamp C.E. 2009.** The stifle joint. In: Brinker W.O., Piermattei D.L. & Flo G.L. (Eds). *Handbook of Small Animal Orthopedics and Fracture Repair*. 4.ed. São Paulo: Manole, pp.562-632.

7 **Schulz K.S., Hayashi K. & Fossum T.W. 2019.** Diseases of the joints. In: Fossum T.W. (Ed). *Small Animal Surgery*. 5th edn. St. Louis: Elsevier Saunders, pp.1134-1280.

8 **Tonks C.A., Lewis D.D. & Pozzi A. 2011.** A review of extra-articular prosthetic stabilization of the cranial cruciate ligament-deficient stifle. *Veterinary and Comparative Orthopaedics and Traumatology*. 24(3): 167-177. DOI: 10.3415/VCOT-10-06-0084.