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CLINICAL RESEARCH

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Short-term outcomes of 43 dogs treated with arthroscopic suturing for meniscal tears associated with cranial cruciate ligament disease

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Abstract

Objective: To describe short-term outcomes and complications in dogs receiving meniscal suturing and concurrent tibial plateau leveling osteotomy (TPLO) with or without augmentation with an extracapsular suture.

Study design: Retrospective case series.

Animals: Forty-three client-owned dogs submitted for cruciate ligament disease.

Methods: Dogs were included if meniscal suturing was performed during or after a TPLO procedure. Criteria included an unstable medial meniscus without evidence of a tear, a caudal vertical longitudinal tear with or without displacement, or if a bucket-handle tear was debrided and the remaining rim was unstable. Stifle stabilization was performed by either a standard TPLO or an augmented TPLO (TPLO + internal brace [IB]). Outcome measures included physical examination findings, radiographs, subjective gait examination, Liverpool Osteoarthritis in Dogs (LOAD) scores, and second-look arthroscopy.

Results: Forty-four meniscal repairs were performed in 43 dogs. Five types of meniscal tears were treated employing eight suture materials. Complications were documented in 15 cases (34%). The stabilization technique had a significant impact on the outcome ($p = .049$): TPLO + IB had a 93.3% success rate and the success rate was 71.4% in the TPLO-only group.

Conclusion: Five types of meniscal pathology were addressed successfully in the study, indicating that currently accepted criteria for meniscal suturing in dogs may be overly conservative. The majority of complications were not related to the meniscal suturing itself and did not compromise the outcome. The stifle stabilization technique had an impact on outcome.

Clinical significance: The authors found arthroscopic meniscal suturing to be practical and successful in this patient population. Postoperative stifle stability had an impact on successful treatment.

Abbreviations: ACL, anterior cruciate ligament; CrCL, cranial cruciate ligament; CTT, cranial tibial thrust; IB, internal brace; LOAD, Liverpool Osteoarthrtis in Dogs; MRSP, methicillin resistant *Staphylococcus pseudointermedius*; TPCT, tibial pivot compression test; TPLO, tibeal plateau leveling osteotomy.

1 | INTRODUCTION

Cranial cruciate ligament (CrCL) disease is the predominant cause of hindlimb lameness in the dog.[1] Concurrent with, or subsequent to rupture of the CrCL, up to 55–85% of dogs will develop meniscal pathology either in the form of instability or tears to the caudal horn of the medial meniscus.[2,3] Tears to the lateral meniscus have also been documented.[4]

The medial meniscus is an important stabilizer of the canine stifle and functional loss of this structure has long-term effects on the health of the joint and clinical outcomes.[1,5–7] Instability or tears to the meniscus are also a source of significant pain and dysfunction.[8] Maintaining hoop stress in the intact meniscus is required to allow the meniscus to participate in load transmission and energy absorption.[5,6]

Currently accepted treatment options for medial meniscal pathology in dogs include debridement of tears involving part of, or the entirety of, the caudal horn of the medial meniscus or meniscal release by transection of the midbody or menisco-tibial ligament.[9,10] Dogs receiving a caudal-pole hemimeniscectomy or meniscal release may experience a clinical improvement in the short term; in the longer term, deterioration of the joint may occur compared with dogs having an intact meniscus.[1]

Meniscal suturing or repair is a long-established standard of care procedure in human patients and it is associated with a good success rate.[11,12] These procedures are generally performed arthroscopically and techniques have been described that utilize commercially available instruments and implants. Meniscal suturing has been described in dogs but is not in widespread use and no standardized techniques have been developed.[6,13,14] Literature exists describing canine meniscal repair as an experimental model for human meniscal repair.[15–17] Published reports in the veterinary literature describe open and arthroscopic techniques for the procedure but do not report on outcome.[6,13,14]

Tears involving the medial meniscus have been characterized, and the anatomy and histologic features are known.[4] Only a portion of the medial meniscus is vascularized and therefore capable of potentially healing (Figure 1). Only certain types of meniscal tears are considered amenable to repair by suturing. Specifically, these involve meniscal-capsular and/or caudal meniscal-tibial ligament tears, leading to instability of the caudal horn or tears within the meniscal parenchyma within or at the border of the vascularized zone.[6,13]

Dogs that would otherwise receive a caudal medial meniscectomy or medial meniscal release may benefit from meniscal suturing to repair or stabilize this structure. The purpose of this study is to describe the short-term outcomes and complications associated with meniscal suturing in 44 stifles in 43 dogs who received a concurrent tibial plateau leveling osteotomy (TPLO) with or without augmentation with an extracapsular suture.

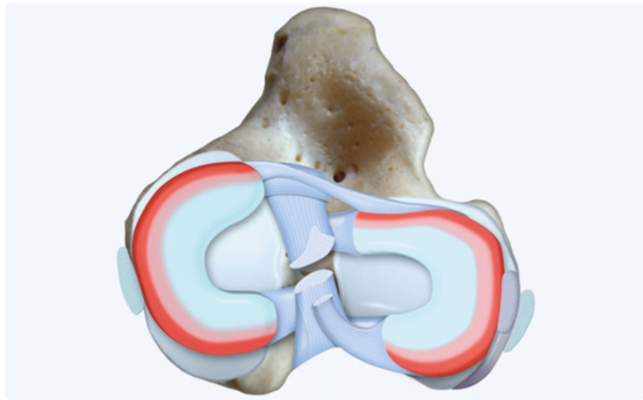

FIGURE 1 From Tobias and Johnston, depicting the vascular and avascular zones of the menisci. The vascular zones are the "red-red" (colored red) and "red-white" (colored pink), which comprise approximately the caudal third. The remainder is the avascular "white-white" zone.

2 | MATERIAL AND METHODS

2.1 | Review of medical records

Medical records were reviewed from the Espanola Animal Hospital for dogs seen for stifle-stabilization between 2020 and 2021 and 43 dogs met the inclusion criteria for the study. To be included, dogs between 1 and 12 years of age presenting for surgical treatment for naturally occurring CrCL disease had meniscal suturing performed as part of their surgical stabilization procedure. Dogs that had a postoperative meniscal tear after primary stabilization were also eligible for inclusion. Dogs had to be otherwise healthy and free of detectable systemic or dermatologic disease at the time of surgery. A minimum of 8 weeks postoperative follow up was required. Minimum data available for inclusion included preoperative and postoperative physical examination findings and subjective gait examination data. Dogs with clinically apparent concurrent systemic, dermatologic, neurological, or orthopedic disease, other than bilateral cruciate ligament disease, were excluded. Informed owner consent to perform meniscal suturing was obtained in all cases preoperatively. A lengthy consultation was conducted with all dog owners, which included discussion of the technique, rationale, potential complications including treatment failure and the current lack of published outcome data. The retrospective study was approved by the hospital's institutional animal care and use committee.

2.2 | Intake examination

Preoperative exam findings were collected for all dogs. Preoperative data reported included a Liverpool Osteoarthritis in Dogs (LOAD) questionnaire completed by the client, subjective gait examination, and a physical examination to measure cranial translation of the tibia (cranial drawer), cranial tibial thrust (CTT), and the tibial pivot compression test (TPCT) as described by Lampart et al.[18] Cranial drawer and CTT were measured in millimeters as described elsewhere[18] and TPCT was indicated as either positive or negative.

Preoperative and postoperative lameness examination was reported using a 0–4 grading system as described in Schaible et al,[19] with 0 being not lame, 1 indicating intermittent mild lameness after rest or exercise, 2 indicating mild lameness or intermittent moderate lameness after rest or exercise, 3 indicating moderate lameness or non-weight-bearing lameness after rest or exercise, and 4 being non-weight-bearing on the affected limb. An assessment of degree of internal stifle rotation on the affected limb during the load phase of the gait cycle was also reported, and was categorized as mild, moderate, or severe.[19]

2.3 | Surgical procedures

Dogs had an arthroscopic examination and meniscal treatment and either a routine TPLO or a TPLO augmented with an antirotational suture (internal brace [IB], Arthrex, Naples, Florida), denoted as TPLO + IB. Procedure selection was initially based on the degree of instability and internal rotation of the stifle during the gait exam as well as TPCT, with dogs having a high degree of palpable instability, internal rotation of the stifle, and positive TPCT receiving a TPLO + IB. In June of 2021, after the first 36 meniscal sutures had been performed, it was noted by one of the authors (PJR) that four failures had occurred in the TPLO group, whereas no failures had yet occurred in the TPLO + IB group. A failure consisted of a patient presenting with clinical signs such as lameness with or without a meniscal click and a tear or failure of the repair confirmed by arthroscopy. A statistician confirmed that this was a significant difference ($p = .02$) and therefore all dogs after this time point received a TPLO + IB if meniscal suturing was performed, regardless of whether this was the procedure initially scheduled. Again, client consent was obtained preoperatively for this procedure.

Arthroscopic examination and treatment were performed using standard arthroscopic portals and techniques.[20] A complete or incompetent partial tear of the CrCL was entirely debrided with a motorized shaver to remove all of the ligament. An incompetent partial tear was

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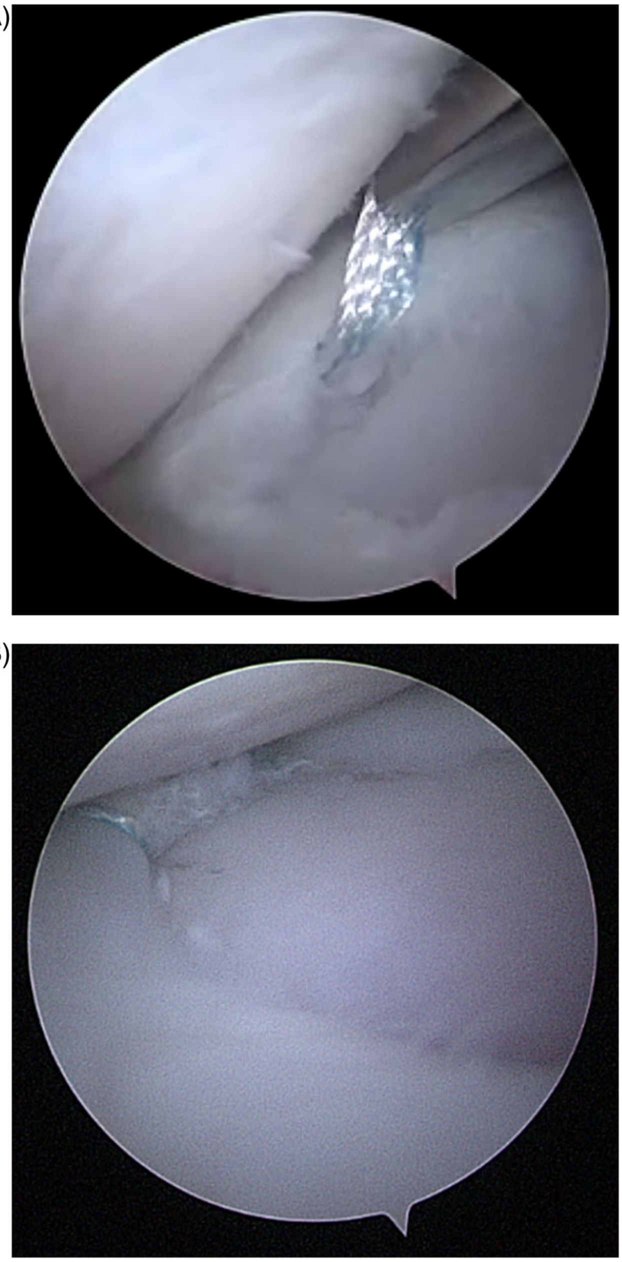
(B)


FIGURE 2 (A) Arthroscopic image of an unstable caudal vertical longitudinal tear of the caudal medial meniscus being sutured after debridement of a small displaced bucket-handle tear. (B) The same meniscus with the tear reduced and stabilized with the sutures in place.

defined as part or all of the CrCL noted physically intact but providing insufficient functional stability as demonstrated by the presence of palpable cranial drawer and tibial thrust. An examination of the medial meniscus was then carried out with joint distraction using a commercially available device (Ventura Stifle Thrust Lever, Movora, St. Augustine, Florida). To be considered for potential suturing, a tear had to be located within or at the border of the vascularized zone of the medial meniscus, as has been

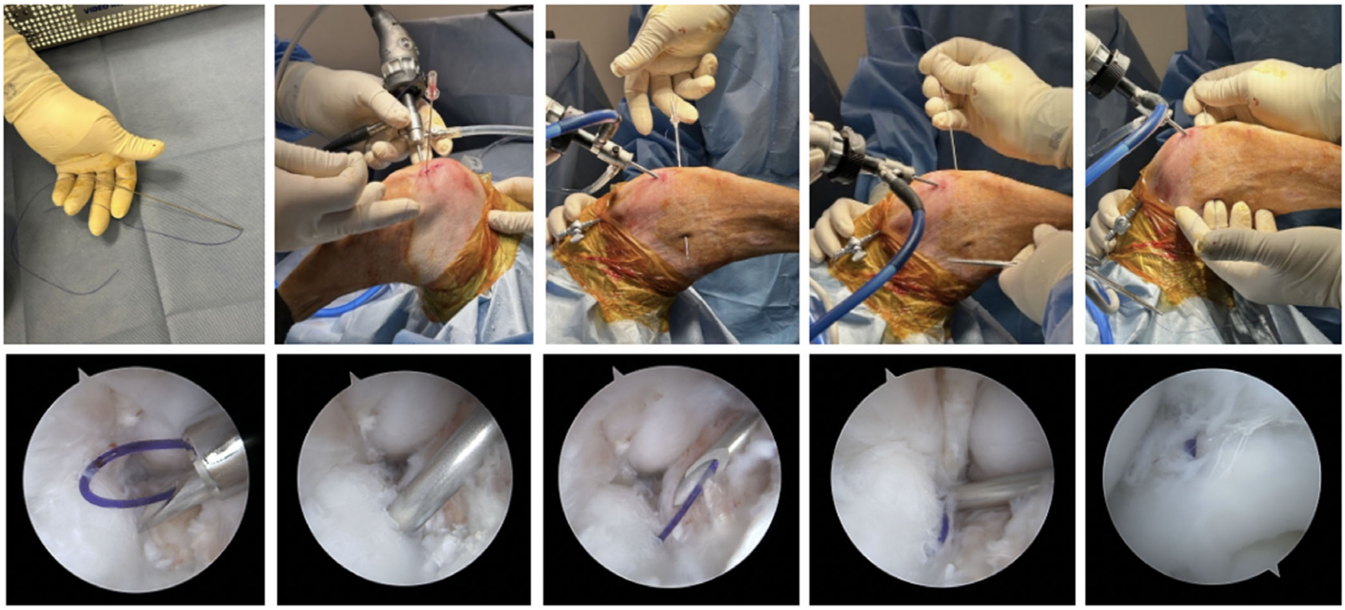


FIGURE 3 Meniscal suturing using the shuttling technique. A 14–18 gauge catheter stylet is loaded with suture and inserted through the distal instrument portal. The stylet is passed through the axial portion of the meniscus, through the joint capsule, and through the skin. The suture limb running alongside the stylet is grasped with hemostat forceps and retrieved all the way through the tissue. The stylet is retracted until the tip becomes visible arthroscopically and it is repositioned and again passed through the tissues to create a mattress suture. The remaining suture limb is then pulled through the stylet and the empty stylet is withdrawn from the joint. The suture is then tensioned with the limb in extension to reduce the meniscal tissue and both limbs are secured with a hemostat. The suture will be retrieved through the TPLO incision and tied routinely.

described elsewhere,[6,13] with no discoloration of the tissue or other indications of chronicity of the tear. In summary, this involved tears at or within the caudal third of the caudal horn of the medial meniscus (Figure 1).

Meniscal pathology was documented and considered repairable if the caudal horn of the medial meniscus was unstable with no detectable tears, unstable with a nondisplaced caudal longitudinal vertical tear in or at the border of the vascularized zone, if there was a stable meniscus with a nondisplaced caudal vertical longitudinal tear in or at the border of the vascularized zone, a displaced caudal vertical longitudinal tear in or at the border of the vascularized zone, or a tear in the nonvascularized zone that could be debrided with the remaining portion of the meniscus unstable (Figure 2). Instability was defined as the caudal horn of the meniscus, or a torn portion of, either found cranially displaced or able to be displaced cranially with joint distraction.

Meniscal suturing was carried out using one of two “inside-outside” methods using either absorbable monofilament (3–0 poliglecaprone, 3–0 polydioxanone, 2–0 polydioxanone, 0 polydioxanone) or nonabsorbable braided (2–0 polyethylene, 0.9 mm polyethylene tape, 2 metric polyethylene) sutures based on surgeon preference for the particular case. Either one or two simple vertical mattress sutures were placed based on surgeon preference for each particular case.

Technique 1 (Figure 3)—A large spinal needle or IV catheter stylet with the catheter removed, appropriate to the size of the dog, was loaded with the desired suture material. A medial optic portal and lateral instrument portal to accommodate an intra-articular joint distractor were employed and the spinal needle was advanced through the skin proximal to the joint line lateral to the patellar tendon. A standard egress portal was also employed. The loaded needle was then directed medially and advanced through the distal caudal meniscal tissue at an appropriate position between the axial and abaxial portions. The needle was advanced through the joint capsule and skin and the suture was captured with small hemostatic forceps. The needle was then carefully withdrawn until the tip and suture again became visible inside the joint arthroscopically. The needle was then repositioned to create a vertical mattress suture and advanced either through the proximal meniscal tissue or proximal to the meniscus, and advanced again through the joint capsule and skin. The suture was captured and withdrawn completely through the skin and clamped with the hemostatic forceps, freeing it from the spinal needle and creating the mattress suture. The suture was externally tensioned to reduce the unstable meniscus/

(A)

(B)

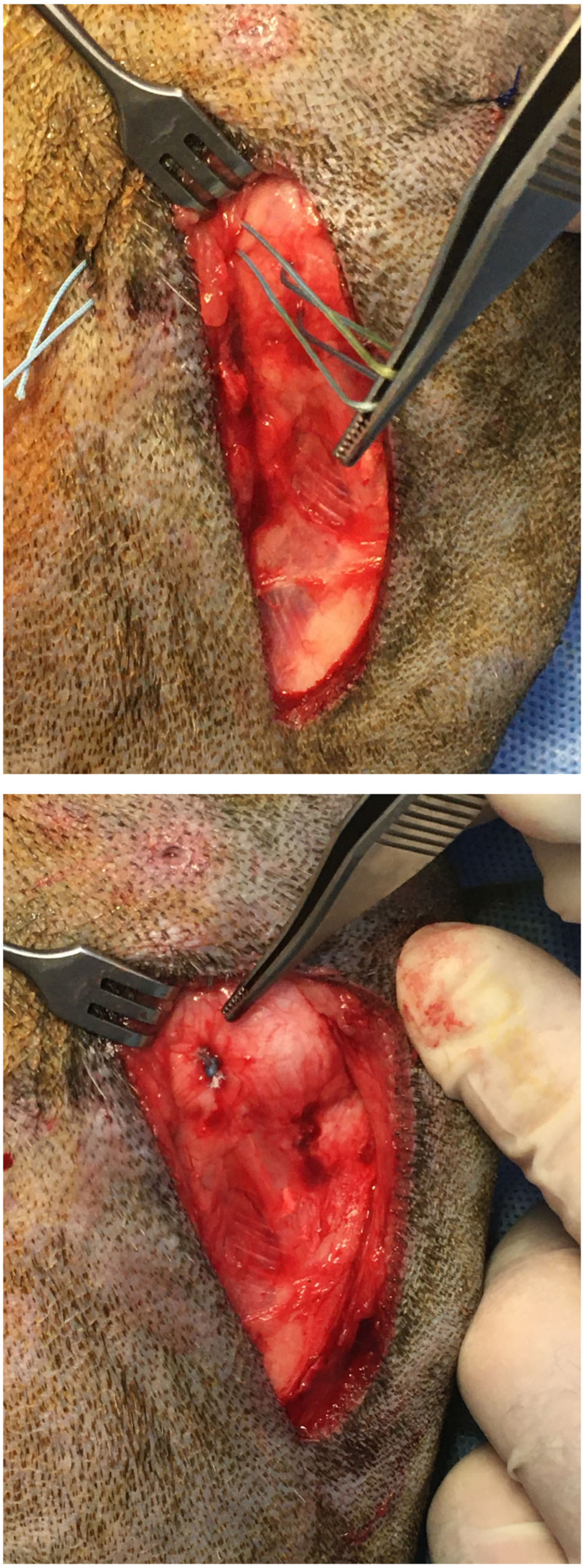


FIGURE 4 (A) Intraoperative retrieval of the sutures placed using the zone navigator technique through a proximo-medial approach to the tibia prior to TPLO jig placement. (B) The sutures are tied over the joint capsule at the joint line and excess suture is cut off.

tear, which was visually confirmed arthroscopically. If a second suture was placed, the procedure was repeated and the arthroscope and instruments withdrawn. A routine proximo-medial approach to the tibia was made to perform a TPLO and the sutures were retrieved through the approach and tied securely to the joint capsule with square knots (Figure 4).

Technique 2 (Figure 5)—A medial optic portal and lateral instrument portal to accommodate an intra-articular joint distractor were employed and a second distal lateral instrument portal was created. A standard egress portal was also employed. A commercially available device (zone navigator, Arthrex) was loaded with an implant specific to the device commonly used for human meniscal suturing. The implant was composed of two long, thin needles with swaged-on polyethylene 2–0 suture or 0.9 mm tape at each end, which were deployed one at a time through a cannulated needle attached to the device. Implant selection was based on the surgeon's preference for the particular case. The device and cannulated needle were inserted through the distal lateral instrument portal and directed medially. The loaded needle was then directed medially and advanced through the distal caudal meniscal tissue at an appropriate position between the axial and abaxial portions. The needle was advanced through the joint capsule and skin, at which point the needle tip was grasped with needle drivers and drawn through the tissue until the suture appeared through the skin and could be grasped with hemostatic forceps. The cannulated needle was then repositioned to create a vertical mattress suture and the second needle was loaded into the device then advanced either through the proximal meniscal tissue or proximal to the meniscus and advanced again through the joint capsule and skin. The second needle was then grasped and drawn through the tissue until all of the suture was pulled through the skin and the empty device was withdrawn from the joint. The suture was tensioned as previously described and repeated as necessary, then the scope and instruments were withdrawn. The excess suture was cut and the approach and tying-off of the sutures were completed as previously described.

Once meniscal suturing was completed, a standard TPLO procedure was performed and an antirotational suture was added as indicated (TPLO + IB). If a TPLO + IB was being performed, a lateral approach to the stifle was executed upon completion of the TPLO. The isometric point F2 was located as described elsewhere[20] and a bone anchor appropriate for the size of the dog was selected (2.5 mm MiniPushLock, 2.9 mm Pushlock, 3.5 mm Swivelock, 4.75 mm Swivelock or 5.5 mm Swivelock, Arthrex) and loaded with the appropriately sized polyethylene tape (1.3 mm SutureTape or 2 mm

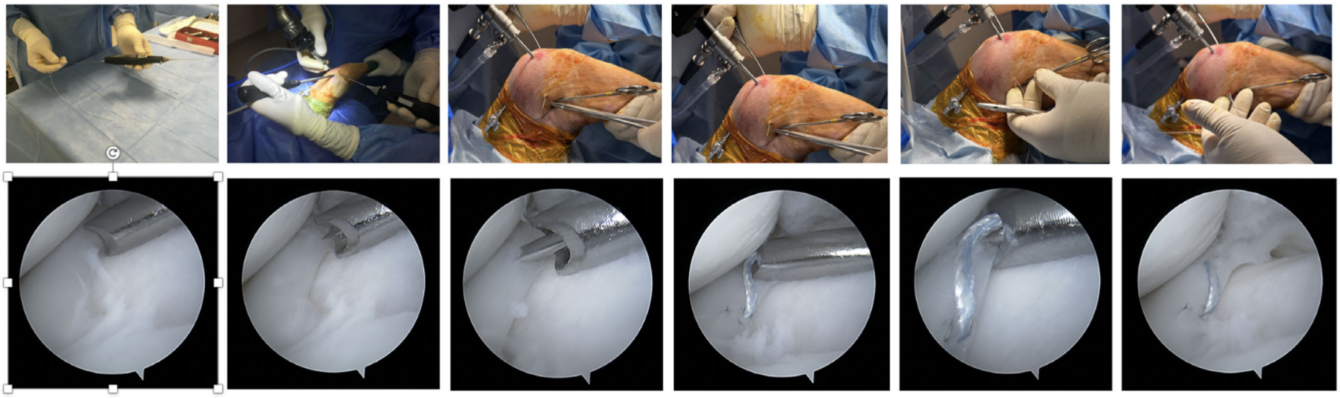


FIGURE 5 Meniscal suturing using the zone navigator technique. The zone navigator is loaded with the swaged-on suture needles and inserted through the distal instrument portal. The cannulated needle is visualized arthroscopically and positioned over the axial portion of the meniscus to be sutured. The swaged-on needle is advanced through the meniscus, joint capsule, and skin by sliding the trigger on the handle. Once the needle is visible externally it may be grasped with needle drivers and pulled through the tissue until the entire needle and approximately 10 cm of Fiberwire is visible. The other swaged-on needle is loaded into the handle and the cannulated needle repositioned and the swaged-on needle advanced so as to create a mattress suture. The second needle is retrieved all the way through the tissues and the suture limbs tensioned with the stifle in extension to reduce the meniscus. The suture is secured with hemostatic forceps and the excess cut off. The suture will be retrieved through the TPLO incision and tied routinely.

FiberTape, Arthrex). Anchor and suture size were selected based on the manufacturer's recommendations based on body weight. The appropriately sized pilot hole and tap, if required, were employed and the loaded anchor was deployed in accordance with the manufacturer's instructions. The isometric point T3 was located as described elsewhere[21] and a bone tunnel was created using a C-guide such that the tunnel would exit on the medial tibial surface next to a hole in the TPLO plate specifically designed for this purpose (Arthrex). The suture was then passed through the tunnel with a nitinol suture passer (Arthrex). One limb of each suture was passed on either side of the hole in the plate and was then loaded onto a suture tensioning device (Arthrex). Thirty to eighty Newtons of tension was applied dependent on the dog's size, the joint was cycled and internally and externally rotated repeatedly until all slack was removed from the system and the tension remained constant. The suture was then removed from the tensioning device and tied tightly over the hole in the plate to eliminate all cranial translation from the joint with two surgeons' throws followed by three half hitches. The excess suture was cut off and the incisions were closed routinely.

Dogs were hospitalized overnight and discharged the following morning on: meloxicam 0.1 mg/kg orally, every 24 h for 14 days; codeine 1–2 mg/kg orally, every 12 h for 3 days, and amoxicillin-clavulanate 15 mg/kg orally, every 12 h for 7 days. Postoperative physical rehabilitation was prescribed limiting activity to timed, controlled short-leash walks only, a passive range of motion exercises, cryotherapy, and massage during the 8 week recovery period.

2.4 | Follow up

Data from 8 week postoperative recheck examinations were reviewed and reported. Data collected at this time point included physical examination findings identical to those collected preoperatively, a gait examination as performed preoperatively, and a client LOAD questionnaire. Twenty-nine dogs had second-look arthroscopy using needle arthroscopy (NanoScope, Arthrex), which was performed whenever owners' consent to do so could be obtained. An examination was also performed under sedation to evaluate the cranial translation of the stifle and CTT. Any postoperative complications were also documented for all patients.

Examination data from a 6 month postoperative recheck was collected and reported for 16 dogs. Data collected at this time included information collected at the 8 week postoperative time, except for needle arthroscopy and sedated stifle stability evaluation data.

2.5 | Data analysis

Frequency and percentage statistics were used to describe the categorical characteristics of the samples. Descriptive statistics were used for continuous variables. Shapiro–Wilk tests were used to test for the assumption of normality for continuous variables. When normality was violated for any observation of a within-subjects observation of an outcome, nonparametric Friedman's ANOVA (three observations) or Wilcoxon signed rank (two observations) were performed. When a significant main effect was detected for Friedman's ANOVA, post hoc testing was performed using a Bonferroni correction. Medians and interquartile ranges were reported and interpreted for the within-subject analyses. For all other analyses with normal distribution of data, means and ranges were reported. A chi square analysis was used to compare the treatment arms on categorical outcomes. Statistical significance was assumed at a p-value of .05 and all analyses were performed using SPSS Version 29 (IBM Corporation, Armonk, New York).

3 | RESULTS

3.1 | Demographics and preoperative findings

Forty-three dogs ($n = 43$) representing 44 meniscal suturing cases were included in the study, one dog having had bilateral meniscal tears treated during separate stabilization procedures. Dogs were approximately evenly divided between male ($n = 21$) and female ($n = 22$) and operated limb (right $n = 22$, left $n = 22$). There were no differences noted for any of the data analyzed for sex ($p = .21$) or limb ($p = 1.0$). The dog breeds represented included mixed breed ($n = 22$), golden retriever ($n = 4$), Labrador retriever ($n = 4$), rottweiler ($n = 2$) followed by one each of Alaskan malamute, shih tzu, Australian shepherd, English bulldog, American Staffordshire Terrier, cocker spaniel, dogue de Bordeaux, American pit bull terrier, Australian cattle dog, Yorkshire terrier and great Pyrenees. Weights ranged from 3.5 kg to 64.7 kg with a mean of 34.6 kg. There was no relationship between weight and complication rates and outcome ($p = .39$) and the age distribution across the categories of procedure was the same. The age of dogs ranged between 18 months and 12 years of age with a mean of 6.15 years. Age distribution across the categories of procedure was the same and there was no effect on outcome or complications ($p = .07$).

3.2 | Intraoperative findings and surgical management

All meniscal pathology included in the study involved the caudal (Cd) horn of the medial meniscus only. Table 1 shows the number and types of meniscal tears that were treated. The most common was an unstable caudal horn, which also contained a nondisplaced caudal vertical longitudinal tear in the vascularized zone ($n = 23$).

TABLE 1 Medial meniscal pathology noted during the initial arthroscopic assessment.

Meniscal pathology	Number ($n = 44$)
Unstable caudal horn only	9
Unstable caudal horn with nondisplaced caudal vertical longitudinal tear in vascular zone	23
Nondisplaced caudal vertical longitudinal tear in vascular zone	2
Remaining unstable caudal horn after debridement of axial nonvascularized tear (i.e. small bucket handle tear)	6
Displaced caudal vertical longitudinal tear in vascular zone	4

Operative times for meniscal suturing were tested for normality by Kolmogorov–Smirnov and Shapiro–Wilk tests and were not normally distributed. Times ranged between 5 and 30 min with an average of 10.2 min. Mann–Whitney U-tests were applied and the distribution of time across procedures was the same ($p = .69$) and no impact on outcome or complications was noted ($p = .77$). Meniscal suturing by stabilization technique was as follows: TPLO ($n = 12$), previous TPLO with subsequent postoperative meniscal tear ($n = 2$), and TPLO + IB ($n = 30$).

Eight suture materials and sizes were employed for meniscal suturing using the two methods described and are summarized in Table 2. Suture material choice did not impact the success or complication rates ($p = .65$).

Two dogs had intraoperative complications. One dog had a failed attempt at an "all-inside" repair using a human device (Meniscal Cinch II, Arthrex), due to a failure of the device to deploy properly. The implant was removed and revision was successfully carried out with one of the "inside-out" procedures described. The dog experienced no further complications. A second dog had iatrogenic cartilage damage from the needle used to repair the meniscus. This damage was considered minor and appeared to produce no clinical effect. The mark was still visible during second-look arthroscopy at 8 weeks postoperative and involved a partial thickness cartilage slice along a portion of the medial condyle of the femur.

3.3 | Postoperative management

Fifteen postoperative complications occurred. These are summarized in Table 3. The majority of these complications involved the TPLO/TPLO + IB and did not affect the meniscal repair. There were six meniscal repair

TABLE 2 Suture materials employed during meniscal suturing procedure.

Suture material	Number
3–0 monocryl	1
0 PDS	3
2–0 PDS	1
3–0 PDS	1
2–0 fiber wire	3
0.9 mm suture tape	13
0.9 mm suture tape +2–0 fiber wire	7
2 metric fiber wire	15

TABLE 3 Intraoperative and postoperative complications reported during the study period.

Complication	Number ($n = 19$)
Iatrogenic damage to cartilage during needle deployment	1
Failed attempt at all-inside repair	1
Euthanized during study period (IVDD, hemangiosarcoma)	2
Patellar tendonitis	3
Surgical site infection with MRSP	3
Repair failure	6
Transient lameness after chasing squirrel in perioperative period	2
Transient neuropraxia	1

failures, four in the TPLO group, including both dogs that had subsequent meniscal tears approximately 1 year after their TPLO procedures, and two in the TPLO + IB group. Both dogs in the TPLO + IB group also had failures of their IB, exhibiting 8 mm or more of cranial translation of the tibia on sedated exam. No other dogs that received sedated exams ($n = 29$) had instability present at 8 weeks postoperatively. This is summarized in Table 4. All six dogs with meniscal repair failures had arthroscopic meniscectomies performed and resumed normal activity with good clinical outcomes.

Three of the study dogs developed infections with methicillin resistant *Staphylococcus pseudointermedius* (MRSP) and had the TPLO and IB (if applicable) removed at 12 weeks postoperatively to resolve their surgical site infections. No dogs had evidence of failure of the meniscal repair and no attempt was made to remove the meniscal sutures. All three recovered completely and went on to have good clinical outcomes.

TABLE 4 Cranial drawer recorded in TPLO + IB group preoperatively and postoperatively.

Time point	Mean (mm)	Range (mm)
Preoperatively	8.9	6–12
Eight weeks postoperatively	3.5	0–8

Two dogs died during the study period of causes unrelated to the study or procedures performed (one developed hemangiosarcoma 6 months postoperatively, and one was electively euthanized for acute intervertebral disc disease at 4 months postoperatively).

3.4 | Outcomes

The overall complication rate was 34.1% (15/44) (Table 3). With the exception of the two dogs that died of unrelated causes, all others went on to have good to excellent clinical outcomes based on improved lameness and LOAD scores.

An 8 weeks postoperative recheck examination was requested and performed for 40 dogs (mean 55 days, range 47–114 days). Twenty-nine clients consented to an examination performed under sedation which included needle arthroscopy, which was offered to owners returning for the 8 week postoperative examination. Additionally, a 6 month recheck was requested for all dogs and performed for 16 dogs (mean 202 days, range 114–292 days).

At 8 weeks postoperatively, needle arthroscopy was performed on 29/44 dogs (66%). The results are displayed in Table 5. At this time, 4/6 of the repair failures were diagnosed, with the remainder noted between 8 and 12 weeks postoperatively, all of which were diagnosed based on clinical signs (lameness). The six dogs that had repair failures were not included in the needle arthroscopy group. In the needle arthroscopy group, two dogs had very small tears noted axial to the position of the meniscal sutures, which were routinely debrided with a motorized shaver during needle arthroscopy. These dogs were not displaying any clinical signs at the time of the examination, did not have any complications during the study period and the tears were considered an incidental finding. Figure 6 shows findings in dogs that had fraying of the meniscal edge on second-look arthroscopy, which was essentially a small complex tear. These dogs were also not displaying any clinical signs and did not experience any complications. In cases where a TPLO + IB was performed, visualization of the entire meniscus was difficult due to the inability of the tibia to translate easily cranially.

TABLE 5 Second look needle arthroscopy findings at 8 weeks postoperatively.

Meniscal pathology	Number (n = 29)
No meniscal lesions	16
Fraying of edge/small complex tear	8
Small displaced longitudinal tear axial to suture(s)	2
Cartilage lesion, small focal, Outerbridge Gr 2	1

FIGURE 6 Second-look arthroscopy at 8 weeks postoperatively with needle arthroscopy. Seven dogs had mild fraying of the axial edge of the meniscus as depicted here but were not affected clinically.

Lameness scores were recorded at all time points and are shown in Table 6. Pairwise comparisons were made employing Friedman's two-way ANOVA. Significance values were adjusted by the Bonferroni correction for multiple tests. Improvements in lameness scores occurred across time in both walking ($p < .001$) and trotting ($p < .001$).

Likewise, LOAD scores were recorded at all time points and are shown in Table 7. Pairwise comparisons were made employing Friedman's two-way ANOVA. Significance values were adjusted by the Bonferroni correction for multiple tests. Improvements in LOAD scores also occurred across all time points ($p < .001$).

Successful repairs were reported in 88% (38/44) of cases during the study period. Dogs that had

TABLE 6 Preoperative and postoperative lameness scores based on a 0–4 scale reported by Schaible et al.[19]

Time point	Mean lameness grade	Range
Preoperative	2.8/4	0–4/4
Eight weeks postoperatively (n = 40)	0.04/4	0–1/4
Six months postoperatively (n = 16)	0/4	0/4

TABLE 7 Mean and preoperative and postoperative LOAD scores.

Time point	Mean LOAD score	Range
Preoperative	23.4	11–48
Eight weeks postoperatively (n = 40)	14.6	0–34
Six months postoperatively (n = 16)	12.1	2–21

Note: A decreased score indicates improved function.

nonclinically significant tears at recheck were included as successful repairs. In the TPLO group, 71.4% (10/14) of dogs had successful repairs. In the TPLO + IB group, 93.3% (28/30) of dogs had successful repairs. There was a difference between these groups ($p = .049$).

4 | DISCUSSION

Meniscal suturing was performed successfully on the majority of dogs in this study. Although it is part of the standard of care for the management of meniscal pathology in humans, this procedure is rarely reported in dogs. The existing reports in the veterinary literature provide descriptions of surgical techniques with no reports on clinical outcomes.[6,13,14] It has, however, been demonstrated that dogs with an intact meniscus have better outcomes than those receiving a meniscal release or meniscectomy.[7] The purpose of this study is therefore to provide retrospective clinical data on short-term outcomes after meniscal suturing and to establish preliminary success and complication rates for these procedures.

Results of the current study suggest that there is potential for the employment and refinement of this procedure in dogs. Several points of interest and discussion are generated from the clinical data provided here.

Sex and affected limb were evenly distributed in our sample population. A wide range of breeds were represented, and the age distribution was also representative of the population of canines typically seen for CrCL disease and meniscal pathology. Body weights were not normally distributed, with a tendency toward larger dogs, although a wide range is reported here. Notably, none of the demographic data were associated with an effect on outcome.

Five types of meniscal pathology are reported in our study with successful treatment. This differs from that previously reported and is at odds with what is currently believed viable in the veterinary context, although in line with the current treatment standard in human medicine.[6,13,16,22] This would suggest that a larger proportion of meniscal pathology may be successfully treated in the canine. Unfortunately, as ours is a retrospective clinical study, histopathology is unavailable to characterize the degree of meniscal healing in these dogs. Numerous studies have reported on this in the context of canine models for meniscal suturing described in the human literature, which demonstrated good healing and mechanical strength in the repaired tissue, with some authors demonstrating function and mechanical strength indistinguishable from the normal intact meniscus.[15–17]

Initially, Technique 1 was employed as the only practical and viable method available. As the zone navigator device became available, it was employed in larger patients using one of two available sutures. As experience with the device was gained and the technique became refined, the smaller suture (2–0 Fiberwire) was employed consistently. For smaller patients, Technique 1 continued to be employed due to perceived size limitations and physical difficulty employing the larger cannulated needles in smaller patients.

Different suture materials were employed in the repairs reported here. Suture selection and the number of sutures employed were determined by surgeon preference based on the size of the dog and the suturing technique employed. The optimum technique in terms of suture type, number, or guidelines based on subject size and type of meniscal tear has yet to be established in dogs. Moses reported using 4–0 polydioxanone with either one or two sutures, however, the authors felt that this suture material may be too light to resist the contact pressures and forces that the repaired meniscus was likely to be subjected to in most of our canine population.[13] Rovesti et al. reported using 2-metric polypropylene to execute their repairs and Theimen et al reported using 2–0 polyethylene in the form of commercially available meniscal suturing needles used for human meniscal repair (2–0 fiber wire, Arthrex).[6,14] As suture choice and number were not associated with complications or failures in our study it would be reasonable to conclude that a variety of reasonable options are available to the surgeon that will allow for successful technique execution.

Our study reports operative times that the authors feel are quite acceptable and were not shown to impact complication rates or outcome. This study also reports a substantial number of intraoperative and postoperative complications. Notably, the reported complications involved the stifle stabilization procedure and not the meniscal suturing technique. Additionally, most of the reported complications did not impact the outcome or compromise the meniscal repair. Historically, new surgical procedures tend to have higher complication rates that decrease over time as the technique becomes more refined and standardized and surgeons gain proficiency. It is also notable that a methicillin resistant *Staphylococcus pseudointermedius* (MRSP) outbreak occurred at the hospital during the study period, which adversely affected the complication rate.

There were significant improvements in lameness (p value = 0.004) and LOAD scores in the study subjects. This is not surprising as one could expect such outcomes with routine stifle stabilization and joint treatment. It is known that a repaired meniscus results in superior contact mechanics in the canine and it would be expected that would also contribute to improved lameness and LOAD scores.[6] Meniscal repair in humans has also been shown to decrease tibiofemoral contact pressure and increase contact area.[23,24] Comparative studies are indicated to investigate any potential differences in outcome between dogs that have an intact meniscus, those receiving standard meniscal treatments, and those treated with meniscal suturing.

The most interesting finding in this study is the role of stifle stability on the viability of the meniscal repair. In the human literature, residual instability is associated with a high rate of meniscal repair failure and poor outcomes.[25–27] In humans, meniscal repair performed without concurrent ACL reconstruction is also associated with a high failure rate.[28–30] Parallel results are presented in this study, where failure to augment the TPLO was associated with a substandard success rate that was significantly different from stifles that were augmented with an IB (p value = 0.005). Schiable et al. demonstrated that the addition of an antirotational suture in dogs with hyperlax stifles was successful at resolving excessive internal rotation.[19] Our data is also supportive of that conclusion and demonstrates the potential influence of rotational stability and cranial translation on meniscal repair success. The only dogs that had failed meniscal repairs in the IB groups had failures of the IB resulting in 8 mm or more of cranial translation, whereas the other dogs examined in this group did not and also had intact repairs. These findings pose wider questions regarding postoperative stifle stability that warrant further investigation.

The high success rate reported in this study is consistent with that reported in the human literature.[11,12,31,32] Short-term success rates in humans tend to be quite high but then decline in the 5–10 year postoperative range to a generally accepted success rate of approximately 80% for isolated repairs and 85–90% for those with concurrent anterior cruciate ligament (ACL) reconstruction.[11,12,32] The authors would suggest that meniscal sutures should be viewed as a temporary or intermediate-term device to keep the meniscus stable and acute tears reduced until the tear can heal or achieve fibrous union with the tibia or joint capsule. In humans, meniscal suturing of degenerative meniscal tissue in ACL reconstructed knees was not associated with a positive outcome.[33]

The authors acknowledge that this study has numerous limitations. We report on a relatively small number of dogs and future studies should provide data from a much larger data set to obtain a more accurate representation of outcome with longer follow up. The retrospective nature of this study has inherent limitations as with all such retrospective studies, including the absence of a control group and blinding of the data set to the observers.

The use of multiple suture types and patterns and the lack of a standardized repair protocol introduces unknown variables into the data which is also limited by the small sample sizes represented. As the actual numbers of each suture type employed are small, a Type I or Type II error is possible in concluding no impact on outcome or complications. The large variation in subject breed and weight, while likely representative of the actual canine populations seen by veterinary surgeons, may also influence the outcome data whereas a standardized, homogenous subject population may produce different results.

Stifle stability in dogs who had an IB may have also introduced a potential source of bias into the study. Of the dogs who received needle arthroscopy examinations at 8 weeks postoperatively, those that had an IB were frequently difficult to visualize completely. As cranial translation was limited in these patients, the caudal portion of the medial meniscus frequently could not be entirely visualized and it is possible that some nondisplaced tears may have been missed. These dogs were also clinically normal, so they were categorized as having a successful repair.

The TPCT has not yet been validated in clinical cases and the published study on this test used cadaveric limbs.[18] The lack of comparative data representing dogs with intact menisci or receiving meniscectomy is also a significant limitation.

5 | CONCLUSIONS

This technique is effective and practical, based on the dataset presented here. Meniscal suturing in this study was also associated with a positive outcome and an acceptable complication rate. Finally, stifle stability had a major impact on the outcome, and dogs receiving meniscal suturing should also receive a TPLO augmented with an antirotational suture.

Further study is indicated to evaluate the mechanical properties of these repairs as well as in vivo performance, preferably including dynamic assessment. Future studies should also evaluate comparative outcomes for dogs with an intact meniscus after stifle stabilization compared with those receiving either a meniscectomy or meniscal suturing.

AUTHOR CONTRIBUTIONS

Rocheleau PJ, DVM, CCRT: study design, data collection, and writing and reviewing of the manuscript. Robson A, BSc: study design, data collection, and writing and reviewing of the manuscript. Bird SD, BSc: study design, data collection, and writing and reviewing of the manuscript. Pickersgill MM: study design, data collection, and writing and reviewing of the manuscript. Holz KA, AAS, RVT, FFCP, CCAT: study design, data collection, and writing and reviewing of the manuscript. All authors contributed equally to the study design, data collection and writing and reviewing of the manuscript.

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CONFLICT OF INTEREST STATEMENT

Patrick J. Rocheleau is a consultant for Arthrex Vet Systems, Naples, Florida. The other authors of this study have no conflicts of interest to declare.

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