Veterinary Surgery
34:196–205, 2005

Proximal Tibial Intraarticular Ostectomy for Treatment of Canine Cranial Cruciate Ligament Injury

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Objective—To report a technique for surgical alteration of the slope of the tibial plateau by a proximal tibial intraarticular ostectomy (PTIO) after injury to the canine cranial cruciate ligament (CCL) and to determine the outcome.
Study Design—Prospective clinical study.
Animals—Dogs ($n = 52$) with CCL injury in 60 stifle joints.
Methods—CCL injury was treated by lateral stifle arthrotomy, removal of CCL remnants, and appropriate meniscal surgery. PTIO was performed to remove a wedge of bone from the proximal aspect of the tibia. The ostectomy site was reduced and stabilized using a bone plate and screws applied to the medial surface of the tibia as well as a craniocaudal positional screw. Dogs were evaluated at 6 weeks, 6, and 12 months by complication assessment, lameness scores, stifle range of motion (ROM), thigh circumference, radiographic assessment, degenerative joint disease (DJD) scores, and surgeon and owner evaluation of function.
Results—Lameness scores improved by 6 and 12 months in all but 1 dog. Thigh circumference and DJD were increased at 6 and 12 months. Complications occurred in 20% of dogs with all but 1 occurring perioperatively or within 6 weeks; most common were injury to the long digital extensor tendon (4 dogs) and plate failure (3); 2 other dogs required surgery to treat complications. Most owners (98%) reported that lameness had improved by 12 months; 90% were extremely or very satisfied with the procedure and 90% would have the same procedure performed on another dog.
Conclusion—PTIO to level the tibial plateau provided a satisfactory clinical outcome in dogs >20 kg with CCL injury and the complication rate was similar to tibial plateau levelling osteotomy (TPLO). Stifle osteoarthritis continued to progress radiographically.
Clinical Relevance—PTIO represents an alternative to TPLO that does not require specialized surgical equipment.

Key words: cranial cruciate ligament, proximal tibial intraarticular ostectomy (PTIO), CCL, osteoarthrosis, dog.

INTRODUCTION

THE CRANIAL cruciate ligament (CCL) is the main stabilizing ligament of the canine stifle and acts to limit cranial translation of the tibia in relation to the femur (cranial drawer), internal rotation of the tibia, and hyperextension of the stifle.[1] Damage to the CCL is the most common cause of stifle lameness in dogs and is the third most common orthopedic disease after hip dysplasia and degenerative joint disease (DJD).[2–4] Repair techniques are either intra- or extra-articular procedures designed to eliminate cranial translation of the tibia with respect to the femur. Reported results indicate a good to excellent response regardless of the technique used.[4,5]

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Submitted October 2004; Accepted February 2005

0161-3499/04
doi:10.1111/j.1532-950X.2005.00031.x

Return of preoperative joint laxity is reported after intra- and extraarticular techniques, which implies that joint stability may not be a paramount determinant for success.[4] Osteoarthritis (OA) is often present preoperatively and continues to develop postoperatively in most dogs.[6]

Concerns about surgical results after treatment of CCL rupture have lead to a re-evaluation of the biomechanics of the stifle. Cranial tibial thrust is created by the forces of weight bearing plus muscular compression of the tibial plateau against the femoral condyles.[1] This is balanced by the pull of the stifle flexor muscles of the thigh (active components) plus the CCL and caudal pole of the meniscus (passive components). The magnitude of the cranial tibial thrust is dependent not only on the amount of compression but also on the slope of the tibial plateau.[1] The caudal aspect of the tibial plateau slopes caudodistally. Weight bearing is supported by this slope and the degree of slope varies between dogs.[7–9] Further, the amount of tibial compression is variable and depends on the activity and size of the dog; however, the slope of the tibia can be changed surgically thereby altering the cranial tibial thrust.[1]

Slocum and Slocum[1] in 1993 described a procedure called the tibial plateau leveling osteotomy (TPLO) that involved making a radial osteotomy in the tibial plateau and rotating the caudal plateau a desired number of degrees to return the caudal plateau to 0 slope. TPLO was initially patented in the United States as a means to standardize the surgical technique and improve results; veterinarians attend a course to learn the technique and must purchase specialized equipment to perform TPLO. Widely accepted as a successful method for treating CCL injury in the United States, the patent for the technique expired in July 2004, but the surgical equipment remains protected by patent.

An alternative technique to alter the slope of the tibial plateau was developed at the University of Zurich and involves making a proximal tibial wedge osteotomy (PWO) of 10–20°.[10] In the original description, the ostectomy was reduced and stabilized using two 3.5 mm craniocaudal bone screws and the periarticular fascial tissue was imbricated to provide joint stability.[10] A report of 100 PWO cases concluded that the high incidence of complications meant that the technique did not appear to be a valid alternative to TPLO.[11] To avoid the reported complications, we modified the technique by eliminating fascial imbrication and including caudal medial meniscal release, osteotomy of the fibula, and stabilization of the ostectomy site by a bone plate and screws. We performed this modified proximal tibial intraarticular ostectomy (PTIO) technique on approximately 50 dogs since 2000 with apparent satisfactory clinical results. Thus, our purpose was to report our experience with the PTIO technique for treatment of CCL injury and to determine the outcome in the subsequent 60 consecutive dogs.

MATERIALS AND METHODS

Inclusion Criteria

Dogs were considered candidates for PTIO if they had clinical and radiographic evidence of CCL injury and weighed >20 kg. Owners were informed of the surgical technique and voluntarily consented to treatment.

Clinical Examination

A full orthopedic and neurologic examination was performed. Previous orthopedic problems or surgical procedures were recorded and an assessment of swelling, joint effusion, pain, crepitus, cranial drawer sign, and tibial compression was made on the affected stifle. Each dog was assigned a clinical lameness score, where 0 = no identified lameness, 1 = intermittent mild weight-bearing lameness with exercise, 2 = consistent mild weight-bearing lameness; 3 = moderate weight-bearing lameness, 4 = severe weight-bearing lameness, and 5 = non-weight-bearing lameness.[12–16] After anesthesia, the ROM of the affected stifle and the thigh circumference were measured in the affected pelvic limb using previously described protocols.[17]

Radiography

Mediolateral and craniocaudal radiographs of the affected stifle were used to measure tibial plateau slope and record periarticular new bone production. The caudal tibial slope was measured using reported protocols.[1,7–9] A numerical radiographic arthrosis score was assigned to each stifle preoperatively, at 6 months, and 1 year postoperatively.[18,19] Additional radiographs were obtained to assess osteotomy healing at 6 weeks postoperatively or if postoperative examination suggested implant failure.

Arthrosis scoring evaluated 12 sites of potential osteophytosis or enthesiophyte formation. The sites evaluated were the proximal femoral trochlear groove, apex and base of the patella, cranial patella, fabella, caudal tibial perichondral site, medial and lateral femoral condyles, the intercondylar fossa, the medial and lateral tibial perichondral sites, and the central tibial plateau. Osteophyte and enthesiophyte formation was scored from 0 to 3,[18] where 0 = no new bone production, 1 = osteophyte or enthesiophyte formation of ≤ 1 mm, 2 = 1–2 mm new bone production, and 3 = new bone production >2 mm.

All radiographs were obtained using a tabletop technique where a small focal spot was used at 115 cm from the cassette and a detailed film–screen combination recorded the subsequent image. For the mediolateral projection, the beam was collimated and centered on the proximal 3rd of the tibia to achieve superimposition of the tibial plateau eminences and result in a projection of the total tibial length while minimizing geometric distortion. In several instances, it was not possible to achieve superimposition of the femoral condyles using this positioning technique. Similar centering of the beam in the proximal 3rd of the tibia was used to obtain the craniocaudal projection.

Radiographs were scored in batches by 1 author; typically 6–10 dogs were scored/session. Several dogs were rescored to assess intraobserver variation. No numerical variation was recorded in dogs that were scored more than once. All 3 examinations from the same dog were scored in 1 session. The reviewer was unaware of the clinical findings on admission or the subsequent clinical progress.

Anesthesia and Analgesia

Atropine (0.022 mg/kg) and morphine (0.4–0.5 mg/kg), with or without acepromazine (0.03 mg/kg), were administered subcutaneously before induction of anesthesia. Anesthesia was induced with thiopental (20 mg/kg) or propofol (4 mg/kg), and halothane or isoflurane in oxygen were used for maintenance. Preoperatively, each dog was administered subcutaneous carprofen (4 mg/kg) or meloxicam (0.2 mg/kg), and epidural morphine (0.1 mg/kg). Bupivacaine (2 mg/kg) was administered intraarticularly after joint capsule closure. Postoperative analgesia was opioid administration (morphine 0.5 mg/kg subcutaneously or buprenorphine 0.004 mg/kg subcutaneously) as needed for 24–48 hours. Carprofen (2 mg/kg, twice daily, orally) was administered for 5–10 days after surgery.

Surgical Procedure

All procedures were performed by RMJ or AMW, and length of surgery and any intraoperative complications were recorded. After surgical preparation, a curvilinear skin incision was made from the lateral distal aspect of the femur to the distal aspect of the tibial tuberosity. Subcutaneous tissues were transected and a lateral stifle arthrotomy performed. The entire infrapatellar fat pad was resected and the cruciate ligaments and menisci inspected. Remnants of torn or partially torn CCL were removed. Partial or total medial meniscectomy was performed if medial meniscal damage was identified. If the medial meniscus was intact, a caudal medial meniscal release was performed by transecting the caudal tibial ligament of the medial meniscus.[20]

Dissection of the lateral aspect of the proximal tibia was continued caudally to elevate the cranial tibial muscle, expose the sulcus extensorius, and retract the tendon of the long digital extensor muscle. A small incision was made in the crural fascia over the proximal aspect of the body of the fibula, which was isolated using a periosteal elevator taking care to avoid the common peroneal nerve. An osteotomy of the fibula was performed using bone cutters.

The limb was repositioned to provide access to the medial aspect of the stifle joint and proximal aspect of the tibia. Partial medial stifle arthrotomy was performed and any remnants of the infrapatellar fat pad were resected. The medial crural fascia was undermined subperiosteally to expose the entire medial surface of the proximal tibia and the distal insertion site of the medial collateral ligament of the stifle. A transverse hole was drilled with a 3.5 mm oscillating drill bit through the tibia 0.5–1 cm distal to the insertion of the medial collateral ligament. The drill was then angled caudally and multiple holes were drilled to weaken the caudal tibial cortex for closure of the ostectomy. A monocortical osteotomy was made using an oscillating bone saw from the cranial aspect of the primary drill hole to the proximal intraarticular aspect of the tibia approximately 1 cm caudal to the insertion of the patellar ligament.

A 2nd monocortical osteotomy was made from the distal 1/3 of the previous osteotomy to the intraarticular region of the tibia cranial to the intermeniscal ligament (Fig 1). This cut was made using wedge-shaped templates of 5° increments between 10° and 25° depending on the preoperative tibial plateau angle (TPA). Osteotomies were continued through the lateral cortex of the tibia with retraction of the long digital extensor tendon to avoid iatrogenic damage. The

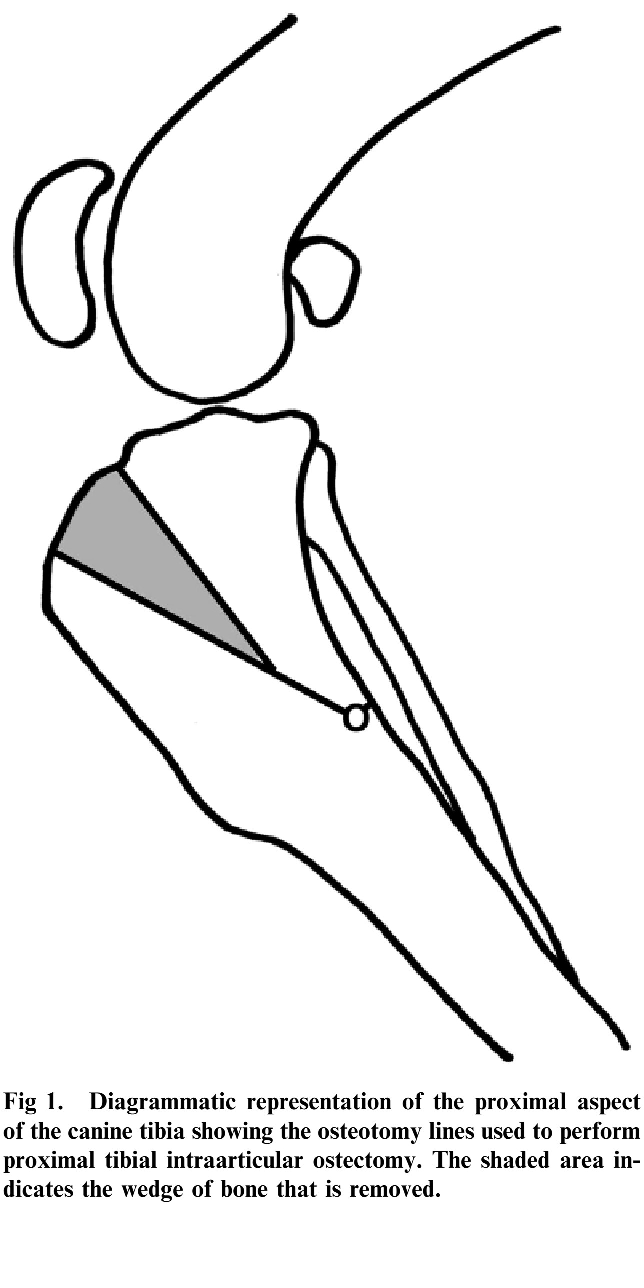

Fig 1. Diagrammatic representation of the proximal aspect of the canine tibia showing the osteotomy lines used to perform proximal tibial intraarticular ostectomy. The shaded area indicates the wedge of bone that is removed.

wedge-shaped ostectomized piece of bone was then removed from the joint by transecting any further soft tissue attachments. The wedge was wrapped in blood-soaked sponges and preserved for cancellous bone graft retrieval.

The ostectomy site was reduced using pointed bone reduction forceps; care was taken to avoid altering the axial alignment of the tibia, patella, and femoral trochlear groove. A single 3.5 mm bone screw was inserted in a positional fashion from the tibial tuberosity into the caudal tibial fragment to stabilize the ostectomy. Cancellous bone from the ostectomized wedge was packed along the ostectomy line. Further stabilization was provided by a 6 hole, 2.7 or 3.5 mm bone plate and bone screws in a buttress fashion along the caudomedial aspect of the tibia. Plate size was selected based on dog body weight.

The medial and lateral joint capsule incisions were closed using absorbable suture material in a simple continuous pattern. The medial and lateral fascial incisions were closed in a simple continuous pattern using absorbable suture material. Bupivicaine (2 mg/kg) was injected intraarticularly; then the surgical incision was closed in layers.

Radiographs were obtained to enable postoperative measurement of the TPA and confirm implant positioning (Fig 2). A padded bandage was applied and the dog recovered from anesthesia. Dogs were discharged 24–48 hours after surgery with instructions for bandage removal at 4–5 days postoperatively, sutures at 10–14 days, strict confinement for 6 weeks, and carprofen (2 mg/kg orally for 7–10 days) administration for analgesia. Instructions were given for gentle physical therapy.

Fig 2. Immediate postoperative radiograph of a dog after proximal tibial intraarticular ostectomy showing the stifle joint and typical implant position.

Postoperative Assessment

Dogs were returned for evaluation at 6 weeks. Postsurgical complications were recorded. Dogs were sedated and radiographs obtained to assess healing of the ostectomy.

Dogs were to return for re-evaluation at 6 and 12 months by examination for lameness, joint effusion, cranial drawer sign, tibial compression, pain, crepitus, ROM, and thigh circumference similar to the preoperative assessment. After sedation, radiographs of the stifle were obtained. Operated stifles were reassigned a DJD score at 6 and 12 month evaluations. At the 12 months evaluation, owners were required to complete a questionnaire about the PTIO technique. Questions asked addressed the degree of lameness, frequency, and type of anti-inflammatory medications or chondroprotective agents, and owner satisfaction with the procedure.

Data Analysis

Statistical analyses were performed using computer software. A 1-sample t-test was used to compare differences in thigh circumference and stifle ROM from before surgery with 6 and 12 months after surgery. Differences in lameness grade and radiographic DJD scores were compared between preoperative with 6 months, preoperative with 12 months, and 6–12 months using a 1-sample paired t-test. Significance was set at $P < .05$.

RESULTS

Fifty-two dogs (60 PTIO) aged 13–120 months (mean, 50.7 ± 28.5 months; median, 44 months) and weighing 20–78 kg (mean, 39.5 ± 11.5 kg; median, 37.5 kg) were included. Twenty-seven dogs (54%) were female and 25 (46%) were male. Breeds were Rottweiler (10 dogs), Labrador Retriever (9), Bull Mastiff (5), Border Collie (4), Golden Retriever (3), Boxer (3), German Shepherd (2), Chesapeake Bay Retriever (2), and Rhodesian Ridgeback (2), and 9 other breeds (American Bull Terrier, Staffordshire Bull Terrier, Maremma Sheepdog, New Zealand Huntaway, Akita, Great Dane, Neapolitan Mastiff, English Mastiff, Bernese Mountain Dog) represented by 1 dog each; 3 dogs were crossbred.

PTIO was performed on the right stifle only (29 dogs), left stifle only (23), or bilaterally (8). Lameness interval before surgery ranged from 1 to 78 weeks (mean, 17.6 ± 18.6 weeks; median, 8 weeks). Four dogs had unsuccessful surgery on the affected joint using a nylon, lateral imbrication, extracapsular technique. One dog had a previous diagnosis of immune-mediated arthritis in the affected joint. Thirty-five dogs (58%) had bilateral CCL surgery either before entering the study or after completion of the surgical part of this study. Techniques used on the contralateral limb varied and were not all performed at the authors' hospital. One dog had a previous femur fracture repair and total hip replacement in the affected limb at 4 and 24 months of age, respectively, and was 50 months at PTIO.

Initial Clinical Examination

All dogs had unilateral hind limb lameness and scores ranged from 3 to 5 (mean, 3.35; median, 3). Most dogs had pain in the affected stifle joint (97%), palpable joint effusion (92%), and a positive cranial drawer sign (92%). Stifle thickening and the presence of a medial buttress sign were identified in 85% and 70% of dogs, respectively. Crepitus was detected in 45% and a positive tibial compression test was recorded in 77% of dogs; 6 dogs had lumbosacral pain. Four dogs also had bilateral hip pain identified. One dog had concurrent medial and lateral collateral ligament damage of the ipsilateral stifle noted at the time of diagnosis of traumatic CCL rupture. One dog each had decreased ROM in both carpal joints, both tarsal joints, and both elbow joints, respectively. One dog had cervical spinal pain and pain on retraction of the left biceps brachii muscle.

Preoperative TPA ranged from 19° to 36° (mean, 26.8°; median, 27°). Only 1 dog had no evidence of preoperative DJD.

Surgical Procedure

Thirty-two dogs (53%) had complete CCL rupture. The lateral meniscus was intact in all dogs; 1 dog had a discoid lateral meniscus. Forty-two (70%) joints had an intact medial meniscus, and medial meniscal release was performed in 42 joints (70%) and partial or complete meniscectomy was performed in the remainder. The ostectomized wedge was 10° in 1 joint, 15° in 13 joints, 20° in 41 joints, and 25° in 5 joints. The osteotomy was stabilized using a 2.7 mm dynamic compression plate (DCP) in 46 joints and a 3.5 mm DCP in 14 joints. Operative time ranged from 80 to 180 minutes (mean, 116 minutes; median, 117.5 minutes). Mean postoperative TPA was 9° (range, 2–22°; median, 9°).

Complications

Intraoperative. Nine intraoperative complications occurred in 8 joints (13%). The long digital extensor tendon was partially severed during osteotomy in 4 procedures requiring repair using polybutester suture in a locking loop pattern. Intraarticular placement of the proximal screw in the plate occurred in 2 dogs and required replacement with a shorter screw in 1 dog. In the other dog, medial patella luxation was noted during closure; the implants were removed and repositioned to avoid the joint space after realignment of the femoral trochlear groove and tibial tuberosity. The DCP was located too proximal in 1 dog to allow placement of the proximal screw without damaging the articular surface of the tibia. This screw hole was left empty. In another dog, valgus malalignment of the tibia was identified requiring removal and repositioning of the implants after realignment of the osteotomy.

Postoperative. Immediate postoperative complications occurred in 4 dogs (7%). One dog had a mild incisional infection that responded to antibiotic administration. One dog had only minimal alteration in postoperative TPA (30–22°) and had repeat PTIO 3 months later because of persistent lameness. The final postoperative TPA was 12°. Valgus malalignment was still noted on postoperative radiographs of the dog where intraoperative valgus malalignment correction was attempted. The craniocaudal screw was judged to be excessively long in 1 dog although apparently it did not cause clinical signs.

Radiographic Findings

At 6 weeks, 53 of 57 (93%) joints had radiographic evidence of complete bone healing and stable surgical implants. Three dogs without complete bone healing had a broken 2.7 mm DCP at the osteotomy; 1 dog had valgus malalignment noted immediately postoperatively. All 3 dogs had bilateral CCL injury at admission and were > 30 kg. In one of these dogs, valgus malalignment occurred because of DCP failure (Fig 3); no further treatment was performed.

One dog fell 2 days before re-examination and became acutely non-weight bearing; pain was elicited on palpation of the fibular osteotomy site. Normal bone healing was evident on radiographs and lameness resolved after carprofen administration.

Six Months Outcome

Fifty-seven joints (95%) returned for evaluation; none had evidence of joint effusion or mensical click. Three joints (5%) had pain and 34 (60%) had crepitus on manipulation of the operated stifle joint. Three joints (5%) had a mild positive tibial compression test and 48 joints (84%) had a positive cranial drawer sign. Twelve dogs had a lameness score of 1 and the remainder had a score of 0. New complications were not recorded. The valgus deformity noted in 2 dogs at 6 weeks was still present but was not causing clinical signs. Corrective osteotomy was offered to 1 dog owner but was declined. There was a significant increase in thigh circumference measurements between preoperative and 6 months measurements ($P < .05$). There was a significant increase in stifle ROM

Fig 3. Immediate postoperative (A) and 12 month (B) craniocaudal views of the same dog after proximal tibial intraarticular ostectomy demonstrating valgus deviation caused by failure of a 2.7 mm bone plate.

measurements from preoperative to 6 months ($P = .013$). There was a small but statistically significant increase in DJD scores from preoperative to 6 months values (mean difference, 4.26; $P < .005$).

12 Months Outcome

Fifty-eight joints (97%) returned for evaluation. One dog had pain evident on stifle manipulation and a lameness score of 5. On stifle radiographs, there were erosive changes on the distal aspect of the femur and proximal aspect of the tibia with concurrent joint effusion. These changes were not evident on previous radiographs at 9 months for assessment of sudden onset lameness. Carprofen administration resolved that episode of lameness. At the 12 months assessment, arthrocentesis was performed and cloudy synovial fluid was submitted for cytologic analysis. There were large numbers of non-degenerate neutrophils with no evidence of microorganisms. An exploratory medial stifle arthrotomy was performed and joint fluid and synovium samples were submitted for bacterial culture and histopathology. All surgical implants were removed. On histopathology, findings were consistent with chronic, ulcerative arthritis, and there was no growth of bacteria on aerobic or anaerobic cultures. The dog was administered carprofen and amoxicillin-clavulanic acid (10 mg/kg every 12 hours) for 6 weeks then re-evaluated 1 and 3 months after implant removal. Pain and lameness had resolved at both evaluations and the owner indicated that the dog was clinically normal.

Intermittent lameness was reported in 1 dog with previously identified valgus deformity because of DCP failure; no pain was elicited on stifle manipulation. Lameness (score, 1) was recorded in 4 dogs and was attributed to other hind limb orthopedic conditions in 3 dogs (hip pain,[2] contralateral CCL injury[1]). All other dogs (91%) had a lameness score of 0.

Twenty-six joints (45%) had crepitus noted on stifle manipulation, 39 joints (67%) had a positive cranial drawer sign, and 1 had a mild positive tibial compression test. There was a statistically significant increase in thigh circumference between preoperative and 12 month measurements ($P < .05$) but no significant increase between 6 and 12 months. No significant change in ROM occurred between preoperative and 12 month measurements; however, there was a small but significant decrease in ROM between 6 and 12 months (mean difference, -4.6°, $P < .05$). There was a significant increase in DJD scores between preoperative and 12 month measurements (mean difference, 5.7; $P < .05$), and between 6 and 12 month measurements (mean difference, 1.4; $P < .05$; Fig 4).

Owner Evaluation

Owners completed questionnaires for 58 joints at 12 months; 53 owners indicated that their dog had no lameness or some lameness after exercise, but were mostly normal. Only 1 owner reported that their dog had non-weight-bearing lameness; this dog had inflammatory arthropathy that required implant removal. Fifty-seven (98%) owners reported that their dog had improved after surgery compared with the lameness identified before surgery. Thirty-four owners (58%) indicated that their dog never had signs of pain on the operated leg whereas 16 owners (28 %) reported infrequent pain (0–1 times monthly). Only 8 owners were administering non-steroidal anti-inflammatory medication infrequently (0–1 times monthly) or occasionally (2–3 times monthly) and 2 owners were using the medication for orthopedic problems unrelated to the operated stifle (hip and shoulder

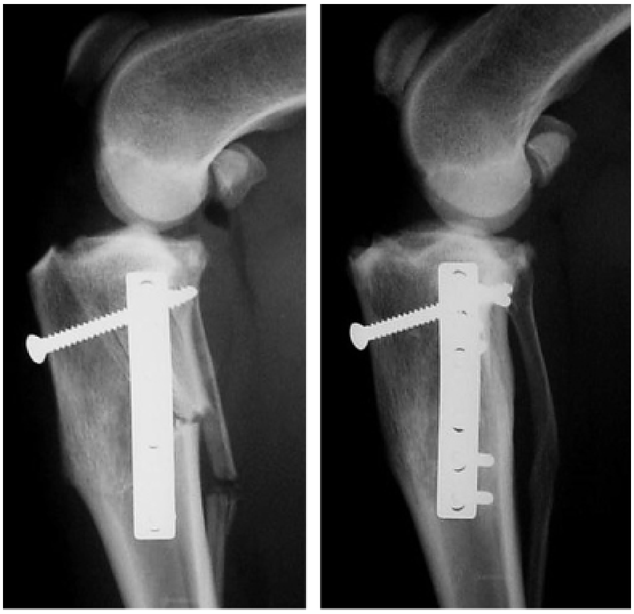

Fig 4. Immediate postoperative (A) and 12 month (B) radiographs of the same dog after proximal tibial intraarticular ostectomy demonstrating mild progression of degenerative joint disease within the stifle joint.

pain). Twenty-one (36%) owners were supplementing their dogs with chondroprotective agents. Fifty-two (90%) owners were extremely or very satisfied with PTIO and 54 (93%) agreed that they would have the procedure performed on another dog with CCL injury.

DISCUSSION

Our results suggest that PTIO is an effective treatment for CCL injury in dogs > 20 kg. Damur et al[11] recently concluded that PWO was seemingly not a valid alternative to TPLO because of the complication rate. Our overall complication rate (25%) and owner satisfaction (90%) for PTIO agree satisfactorily with reported complication rates and owner assessment of TPLO.[21–23] PTIO like TPLO has a steep learning curve but does not require specialized surgical equipment beyond that available for orthopedic surgery.

Many surgical techniques have been reported for the treatment of CCL injury and most reports rely on subjective clinician and owner assessment to evaluate postoperative outcome.[6,13,15,16,19,22,24–28] A direct comparison of PTIO and other techniques was not possible because of differences in study design, variability in clinical disease, and subjectivity of postoperative assessment. Montavon[10] described PWO and reported results for 100 joints.[11] At 4 months, 86% of dogs were assessed as normal and 34% had intra- or postoperative complications, the most common being valgus malalignment (12%) and meniscal injury (10%).[11] PTIO is a modification of Montavon's procedure where medial meniscal release, fibular osteotomy, and bone plate stabilization are performed to reduce reported complications.

With PTIO, valgus malalignment occurred in 1 dog intraoperatively and despite attempted realignment, malalignment persisted and DCP failure was noted at 6 weeks. Valgus malalignment occurred in another dog after DCP failure but not in a third dog with DCP failure. Plate failure occurred with 2.7 mm DCP and all 3 dogs were > 30 kg and had bilateral CCL injury. Subsequent dogs with bilateral CCL injury were stabilized using a 3.5 mm DCP and plate failure did not occur.

We did not identify medial meniscal injury in any dog up to 12 months postoperatively. Medial meniscal injury has been reported in 13.8% dogs after intra- or extracapsular stabilization,[25] and medial meniscal release is recommended with TPLO technique to avoid this complication.[29,30] Despite the absence of clinical reports on the effect of meniscal release it appears to reduce the risk of postoperative meniscal injury after TPLO and the PTIO technique we report.[21,22]

Injury to the long digital extensor is reported with PWO and also occurred with PTIO.[11] Care must be taken to protect the long digital extensor tendon when making the caudal osteotomy; however, long-term complications after repair of a partially severed tendon were not apparent in our study. Intraarticular screw placement is reported with TPLO and PWO,[11,21,22] and occurred in 2 of our dogs necessitating screw replacement in 1 dog and limb realignment in the other. Because PTIO involves stifle arthrotomy, the joint can be easily inspected after implant placement to ensure that a screw has not entered the joint space.

The cause of erosive arthritis noted in 1 dog at 12 months is unknown despite synovial histopathology and bacterial culture. Clinical improvement after implant removal and antibiotic administration suggest implant-associated septic arthritis. Other reported complications of PWO and TPLO including injury to the popliteal vasculature, tibial fracture, osteomyelitis, patella tendon swelling, patella fracture, peroneal nerve injury, and draining tracts were not identified in our dogs.[11,21,22]

It has been suggested that PWO does not provide adequate leveling of the tibial plateau to a recommended TPA of 5–6.5°.[29–31] PTIO resulted in a mean postoperative TPA of 9° (range, 2–22°) that is comparable to reported postoperative TPA angles with TPLO.[22] The cranial osteotomy was made creating a wedge of bone with the distal apex two-thirds of the way distally on the caudal osteotomy. Closure of the proximal aspects of the 2 osteotomies provided cranial tipping of the tibial plateau segment and subsequent satisfactory leveling of the tibial plateau. PTIO was observed to move the tibial intercondylar eminences and hence the tibial functional axis cranially because of removal of bone cranial to the point of insertion of the CCL. In a recent geometric analysis, the effect of placing the center of TPLO osteotomy cranial to the proximal tibial long axis point resulted in an increase in the postoperative tibial plateau slope.[32] Clinically, this effect may result in an increase in the postoperative tibial plateau slope of up to 4°. The effect that altering the tibial functional axis has on stifle biomechanics is unknown, but it has been speculated that alteration in the relationship between the patellar tendon insertion on the tibia and the distal femur could cause the suspected patellar tendonitis reported after TPLO.[32] However, in our dogs after PTIO, no complications were recognized involving the patella or patellar tendon and we speculate that cranial advancement of the tibial functional axis may not be the only potential causative factor of postoperative TPLO patella tendonitis.

The overall complication rate for the PTIO compares favorably with those reported for TPLO, but is higher than suggested for other methods of surgical management of CCL injuries.[21,22] Most complications occurred intraoperatively or within the 1st 6 weeks, which probably reflects the technically demanding nature of the procedure. A similar observation has been made regarding TPLO.[21,22]

Based on clinical assessment, lameness scores improved by 12 months in all but 1 dog (erosive arthritis). There was a significant increase in thigh musculature between preoperative and 6 months evaluations that probably indicates an increase in limb use; however, this was not compared with the contralateral limb. An increase in thigh circumference has been reported to correlate with increased muscle strength and improved stifle function in experimental dogs treated with electrical muscle stimulation after extracapsular CCL repair.[17] There was no significant change in passive ROM of the operated stifle joint by 12 months indicating that PTIO did not result in loss of ROM.

The major limitation of our study was the subjective nature of the postoperative assessment.[12,23,33–38] Unfortunately, objective methods for evaluating postoperative limb function such as force plate, force platform, or kinematic gait analysis were not performed because equipment was not available. The high percentage (58%) of dogs that had contralateral CCL injury either before or during the study may have made accurate assessment of force plate analysis difficult.[39] Biomechanical analysis of the effect of PTIO on cranial and caudal tibial thrust would be required to enable superior comparison of this method of tibial plateau leveling with TPLO.

OA progresses in CCL deficient stifle joints after all surgical techniques currently reported including TPLO.[2–4,6,12,13,16,19,23,34,40] We observed a significant increase in DJD scores between preoperative and 6 month evaluations. A smaller but significant difference was also recorded between 6 and 12 months examinations. OA was evident on stifle radiographs taken preoperatively in all but 1 dog despite only 53% of joints having complete CCL rupture. The presence of DJD in stifles with partial CCL injury is thought to result from degradation of cartilage matrix because of the degenerative processes of mild ligament damage.[2,4] Although one of the purported goals of surgical treatment of CCL injury is to prevent progression of DJD, it appears unlikely that any surgical technique will achieve that goal. In addition, it has been shown that there is no correlation between radiographic evidence of stifle DJD and limb function;[41] therefore, postoperative radiographic changes do not appear to be predictive of clinical outcome.

Using owner evaluations to assess surgical outcome is questionable, as a difference has been reported between owner perceptions of the degree of lameness and the results of force plate analysis in dogs treated with intracapsular repair of CCL injury.[42] Because objective measurements of postoperative function are generally limited to academic institutions, most veterinarians in clinical practice rely on postoperative owner information and clinical evaluation to assess the success of surgical procedures. Owner satisfaction of PTIO was high and most owners indicated their willingness to have the same procedure performed on another dog in the future. Very few owners were administering non-steroidal anti-inflammatory medications 12 months after surgery. Several extraneous factors may influence the owners' opinion of surgical outcome such as procedure expense, a positive relationship with the hospital or veterinarian, and their expectations of activity level of the dog.[42] Despite these reservations, owner satisfaction can be used to estimate functional outcome after surgery but should not replace clinical evaluation by a veterinarian.[42]

We found a satisfactory clinical outcome after a modified procedure to level the tibial plateau in dogs with CCL injury. There was improvement in the degree of lameness, pain, and thigh circumference by 6 and 12 months after surgery. There was radiographic evidence of progression of stifle DJD, yet owner satisfaction was high. The complication rate was high but compared satisfactorily with other tibial osteotomy techniques. PTIO may be a valid alternative to TPLO that does not require use of specialized surgical equipment.

ACKNOWLEDGMENTS

The authors thank Dr. Darryn Pegram and Mr Glenn Cook from Pfizer, New Zealand, for supplying the carprofen and the staff of Veterinary Specialist Group for their technical support.

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