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SHORT CASE SERIES

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Center of rotation of angulation-based leveling osteotomy for stifle stabilization in skeletally immature dogs

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[Correction added on 09 February 2022, after first online publication: The first name of Dr. Rodrigo Roca was incorrectly spelled in the initial publication. It has been corrected in this version.]

Abstract

Objective: To describe short-term outcomes of center of rotation of angulation (CORA)-based leveling osteotomy (CBLO) in skeletally immature dogs with cranial cruciate ligament (CrCL) injury.

Study design: Retrospective case series.

Animals: Fifteen skeletally immature dogs (16 stifles).

Methods: Medical records of dogs with CrCL injury and radiographically documented open proximal tibial physis and tibial tuberosity apophysis managed with CBLO were reviewed. Clinical assessment, radiographic assessment, and complications were reviewed.

Results: Fifteen dogs (16 stifles) with radiographically documented open proximal tibial physis and tibial tuberosity apophysis and CrCL injury underwent a CBLO. Mean tibial plateau angle (TPA) was 26° preoperatively, 9° postoperatively, and 9° at final recheck. One dog developed 10° recurvatum of the proximal tibia secondary to inadvertent over rotation of the tibial plateau (TPA 3°) to protect primary repair of an insertional CrCL avulsion. Correction of the recurvatum was declined as the dog had full limb function. Two dogs developed a valgus deformity secondary to a plate screw engaging the distolateral aspect of the proximal tibial physis. Owners of these dogs reported normal function but requested surgical revision to prevent long-term problems secondary to abnormal weight bearing. Both dogs regained full function following recovery from revision surgery. At a mean time of 23 months following surgery, all dogs continued to have full function as per phone conversation with owners.

Conclusion: With proper preoperative planning, CBLO is an option for skeletally immature dogs with CrCL injury.

1 | INTRODUCTION

Cranial cruciate ligament (CrCL) rupture is one of the most prevalent injuries of the canine stifle.[1–3] The prevalence of CrCL ruptures is increasing but the age at the time of rupture is decreasing.[4,5] Injury of the CrCL leads to lameness and instability that predisposes the stifle to osteoarthritis.[6,7] Dogs with CrCL injury cannot compensate for stifle instability with secondary muscular stabilizers or gait alteration so conservative treatment is often unsatisfactory.[8,9] As such, the majority of veterinary surgeons recommend surgical stabilization of the stifle.[10] Stabilization procedures have been divided into 2 methods. First are techniques that simulate the function of the native CCL through strategic placement of extra-articular or intra-articular materials or tissues.[11] Second are techniques that stabilize the stifle by altering the mechanics of the joint with tibial osteotomies.[12] In large, active dogs, tibial osteotomies result in superior function in comparison with extracapsular or intracapsular techniques.[13,14] When managing CrCL instability in a juvenile dog with tibial osteotomies, caution must be exercised to prevent inadvertent damage to the proximal tibial physis. A previously described technique that may not interfere with the proximal tibial physis is the center of rotation of angulation-based leveling osteotomy (CBLO).[1,15] The osteotomy is positioned distal to the proximal tibial physis thereby allowing the use of this technique in dogs with active growth potential. The objective of this manuscript is to describe the outcome of the CBLO procedure in skeletally immature dogs with CrCL injury.

2 | MATERIALS AND METHODS

Medical records from 3 veterinary specialty hospitals were reviewed to identify skeletally immature dogs with CrCL injury managed with a CBLO. The institutions were Department of small animal clinical sciences (SACS), Texas A&M University (TAMU) CVM (Peycke, Hulse), Austin Veterinary Emergency Center (AVES, Hulse, Roca), and the Veterinary Orthopedic and Sports Medicine Group (McDougall, Dycus). To be included, signalment, body weight, intra-articular structure status, and tibial plateau angle (TPA) (preoperatively and postoperatively and at final recheck) must have been documented in the medical records. Radiographs for short-term assessment of osteotomy healing (minimum 4 weeks postoperatively) and appearance of the proximal tibial physis and apophysis were also required. Long-term subjective owner outcome assessment was conducted via phone conversation and responses for limb function was classified as full, acceptable, or unacceptable as defined by a previous study.[16] Medical records documenting any complications (if present), management of complications, and outcome of cases reporting complications were required.

Preoperative radiographs were taken to assess the proximal tibial physis and determine the location and magnitude of the CORA. The canine tibia has a proximal procurvatum and midshaft recurvatum when viewed in the sagittal plane.[17] As such, the canine tibia has a proximal CORA and a distal CORA. The proximal CORA was determined by the intersection of the proximal and distal mid diaphyseal lines. The position of proximal CORA was defined at the intersection of the proximal and distal mid diaphyseal lines. In the case of a biapical CORA (such as the tibia), the distal mid diaphyseal line of the proximal CORA was represented by an intermediate segment.[17] The magnitude of the CORA was the vertical angle formed at the intersection of the 2 diaphyseal lines.

Once the location and magnitude of the CORA were determined, the appropriate saw-blade template was positioned such that the center of the saw blade was at the CORA. The CORA was located at the intersection of the proximal and distal mid diaphyseal lines or along the transverse bisecting line.[17] Three measurements were made to determine the appropriate position of the osteotomy relative to the proximal tibial physis: (1) (D1) the distance from the insertion of the straight patellar tendon to the point where the saw blade crossed the cranial cortex of the tibia; (2) (D2) the distance from the joint line just caudal to the tibial eminence to the point where the

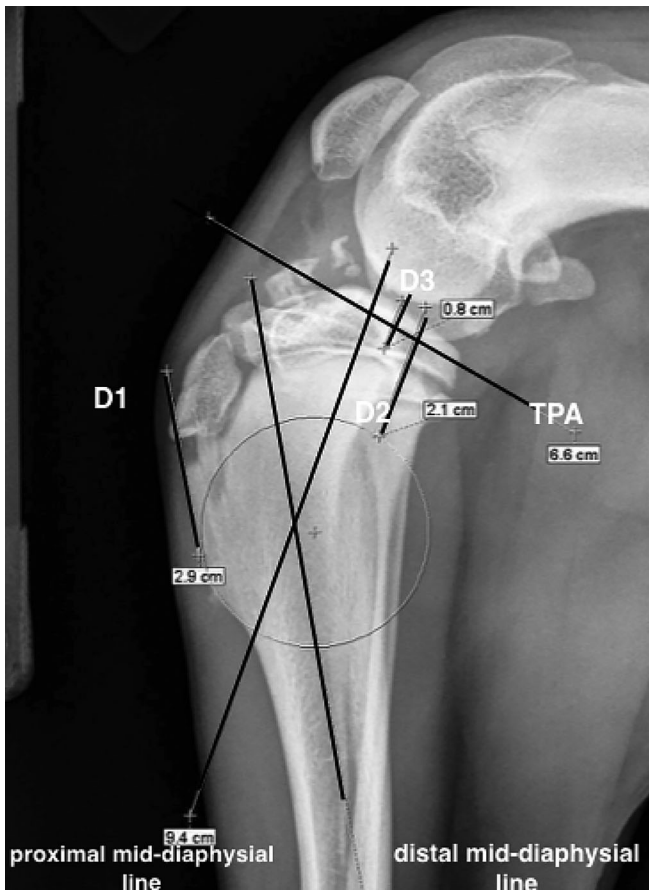

FIGURE 1 Case 15: Lateral radiograph showing measurements for D1, D2, and D3 relative to the joint line and proximal tibial physis as described in the manuscript

TABLE 1 Table of weight, age, TPAs, radiographic healing, functional outcome and owner assessment

Name	Breed	Sex	Weight (kg)	Age (months)	Pre-OP TPA	PO TPA	TPA at healing	Time to radiographic healing (weeks)	Function at time of radiographic healing	Client assessment of function and limb alignment at last follow up	Complications
Case 1	Great Pyrenees	Male	60	7	24	9	9	4	Acceptable	Normal alignment, full function 35 months PO	None
Case 2	Chow chow	Male	50	6	32	12	12	6	Full	Normal alignment, full function at 22 months PO	None
Case 3	GSD	F/S	76	10	20	7	7	7	Full	Normal alignment, full function at 10 months PO	None
Case 4	Labrador	F/S	73	8	22	9	9	7	Full	Normal alignment, full function at 7 months PO	None
Case 5	Great Dane	Female	92	7	37	10	9	8	Full	Normal alignment, full function at 32 months PO	None
Case 6	Labrador	Female	42	5	33	13	13	6	Full	Normal alignment, full function at 98 months PO	Screw engaged distal aspect of physis resulting in 19 degrees valgus of proximal tibia
Case 7	Labrador	F/S	50	6	24	11	11	7	Full	Normal alignment, full function at 7 months PO	None
Case 8	English bulldog	Male	52	7	31	12	12	8	Full	Normal alignment, full function at 34 months PO	None
Case 9	Pit bull	Male	45	5	20	7	7	4	Acceptable	Normal alignment, full function at 12 months PO	None
Case 10	Labrador	Male	25	4	25	8	9	7	Full	Recurvatum, full function at 36 months PO	10 degrees recurvatum from over rotation
Case 11	Golden retriever	Female	35	5	33	10	11	4	Acceptable	Normal alignment, full function at 4 months PO	None
Case 12	Border collie	Female	36	7	32	7	7	4	Acceptable	Normal alignment, full function at 6 months PO	None
Case 13	Labrador	Female	55	8	20	6	6	7	Full	Normal alignment, full function at 4 months PO	None
Case 14	Labrador	Female	55	9	23	6	6	8	Full	Normal alignment, full function at 5 months PO	None

(Continues)

TABLE 1 (Continued)

Name	Breed	Sex	Weight (kg)	Age (months)	Pre-OP TPA	PO TPA	TPA at healing	Time to radiographic healing (weeks)	Function at time of radiographic healing	Client assessment of function and limb alignment at last follow up	Complications
Case 15	Labrador	Male	57	6	26	12	12	5	Full	Normal alignment, full function at 36 months PO	None
Case 16	Golden retriever	Female	32	5	20	10	10	5	Full	Normal alignment, full function at 22 months PO	Screw engaged lateral region of physis resulting in 19 degrees valgus

Abbreviations: F/S, female spayed; GSD, German Shepherd Dog; lbs, pounds; PO, post operative; TPA, tibial plateau angle.

FIGURE 2 Case 15: cranial caudal radiograph at 5 months postoperatively showing continued growth of the proximal tibial physis

saw blade crossed the caudal cortex of the tibia; and (3) (D3) the distance from the joint line just caudal to the tibial eminence to the proximal tibial physis (Figure 1). A detailed description of the determination of a final TPA, osteotomy rotation, and implant application were discussed in previous manuscripts.[1,15]

3 | RESULTS

Fifteen skeletally immature dogs (16 stifles) with CrCL injury managed with a CBLO were identified (Table 1). Ten breeds were represented including Labrador retrievers (6), Great Pyrenees, German shepherd, chow chow, Great Dane, English bulldog, Pitt Bull, border collie, giant schnauzer and golden retriever (1 each). There were 6 intact males, 5 females, and 4 spayed females. The mean age was 6.6 months (range 4-10 months) and a mean weight of 52 lbs (range 25-92 lbs). Physical exam revealed all dogs had a weight-bearing lameness, a positive cranial drawer test and other examination findings suggesting stifle instability (proximal tibial medial buttress, stifle effusion, muscular atrophy, abnormal sit test).

FIGURE 3 Case 3: lateral radiograph taken 4 weeks postoperatively in a dog 10 months old at initial surgery. Note the CCS has closed the tibial apophysis

FIGURE 4 Case 15: lateral radiograph at 5 months postoperatively showing that the apophysis remained open when stabilized with K-wires at initial surgery when the dog was 5 months of age

Radiographs confirmed the presence of open proximal tibial physis and tibial tuberosity apophysis. Arthroscopy revealed complete midbody tears in 6 stifles, partial midbody tears in 6 stifles, and ligamentous insertional avulsions in 4 stifles. There were no meniscal tears, and the articular cartilage appeared normal, as did the caudal cruciate ligament in all stifles. Implants included 4 tibial plateau leveling osteotomy (TPLO) plates (DuPuy Synthes Vet, West Chester, Pennsylvania) and 12 dedicated CBLO plates (Veterinary Orthopedic Implants, St Augustine, Florida). Of 16 stifles, 8 stifles had additional stabilization with a countersink compression screw (CCS),[5] 5 stifles had additional stabilization with 2 × 0.062 K-wires, and 3 stifles received a single plate alone to stabilize the osteotomy. Three dogs underwent primary repair of the avulsed CrCL from the tibial plateau. Immediate postoperative radiographs confirmed that limb alignment was acceptable in all dogs. The mean time to radiographic union of the osteotomy was 6 weeks (range 4-8 weeks) and the radiographs confirmed continued growth of the proximal tibial physis (Figure 2). In stifles with an additional CCS, the tibial tuberosity apophysis was noted to be closing or closed at the time of radiographic union of the osteotomy (Figure 3). In stifles with a plate alone stabilization, or K-wires for additional stabilization, the tibial apophysis did remain open (Figure 4). Mean (range) TPA was 26° preoperatively (range 20-37°), 9° postoperatively (range 4-13°) and 9° at final recheck (range 6-13°). Physical exam findings revealed full limb function at a mean time of 4 months following surgery. One dog developed a recurvatum of the proximal tibia (10 degrees) secondary to inadvertent over rotation of the tibial plateau (TPA 3°) to protect primary repair of an insertional CrCL avulsion. The owner elected not to correct the recurvatum as the dog had full limb function and was last examined 36 months following surgery. In 2 dogs, a proximal plate screw engaged the distolateral aspect of the proximal tibial physis resulted in 19° valgus deformity in both dogs (Figure 5). Both dogs underwent correction of the deformity (Figure 6) and regained full function following recovery from revision surgery. Client assessment at a mean range of 23 months (4-98 months) following surgery revealed that all dogs returned to full function with no detectable side-to-side difference in limb appearance with the exception of the dog with 10° recurvatum.[1,16]

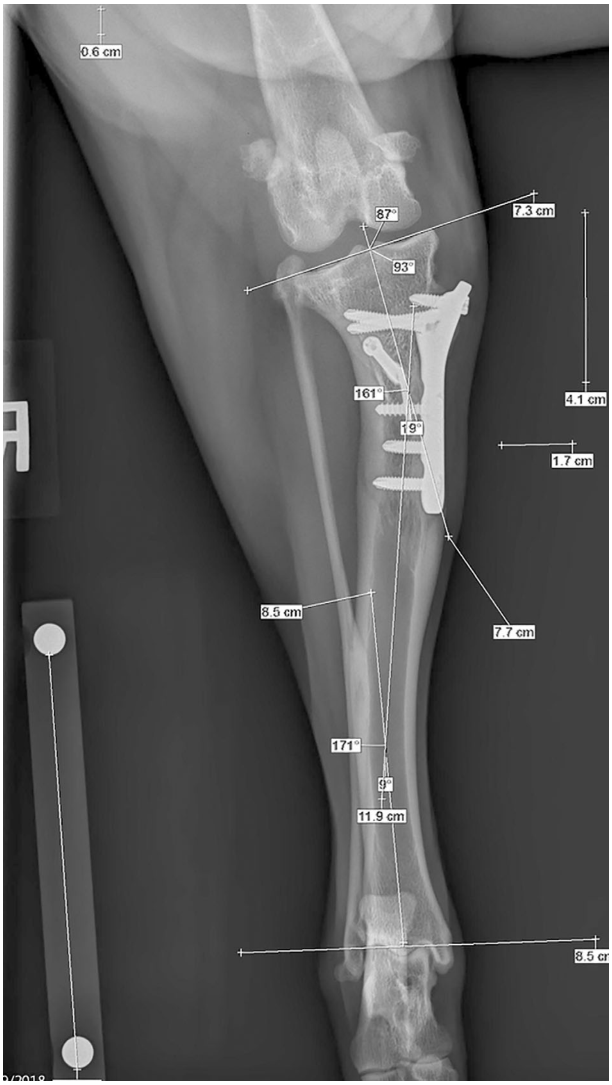

FIGURE 5 Case 16: cranial caudal radiograph showing 19 degrees valgus and measurements for location and magnitude of CORA to execute corrective osteotomy

FIGURE 6 Case 16: cranial caudal radiography immediately following corrective osteotomy

4 | DISCUSSION

The advantage of CBLO for management of CrCL injury in skeletally immature dogs was that the osteotomy does not penetrate the proximal tibial physis. There was also typically ample room for implant application distal to the tibial physes. Inherent to other techniques described for management of CCL is the potential of altering normal growth pattern of the proximal tibia.[4] Other techniques, such as the tibial plateau leveling osteotomy, employ the use of a proximal tibial osteotomy that will cross and penetrate the proximal tibial physis. With extracapsular suture techniques, the location of the femoral and tibial attachment sites dictate that the stabilizing suture will cross the distal femoral physis and proximal tibial physis. Crossing an active physis with an oscillating saw, implants or a femorotibial suture may disturb normal growth patterns, thereby increasing the risk of development of an angular or rotational deformity.

With CBLO, the osteotomy and position of the bone plate and plate screws should be distal to the proximal tibial physis and when caution is exercised, plate screws should not engage the proximal tibial physis. The CCS used for compression of the osteotomy in dogs greater than 7 months of age prematurely closed the tibial apophysis. No adverse clinical effect of this was noted in this group of dogs. Uninhibited proximal tibial physeal growth was appreciated in 14 stifles. In 2 dogs, the most caudal proximal plate screw engaged the distolateral region of the proximal physis. In 1 dog, the penetration of the growth plate was noted on postoperative radiographs and replaced immediately with a shorter screw. In the second dog, the screw did not cross the physis but lodged adjacent to the most distal part of the lateral growth plate and was not recognized on postoperative radiographs. Nevertheless, a valgus deformity of the proximal tibia developed in both dogs. Even with the presence of a valgus deformity, both dogs were perceived by the clients to have full function; the clients requested revision because of the potential for future arthritis associated with an abnormal weight-bearing forces. Limb alignment was achieved with revision surgery and both dogs regained full function following recovery from revision surgery.

Inherent to CBLO, the center of the saw blade is centered at the CORA; rotation of the epiphysis therefore results in alignment of the proximal and distal longitudinal axis after osteotomy rotation. The result is a nonarticular osteotomy with excellent bone contact and the ability to compress the osteotomy. The tibial apophysis in this series of cases was bridged with a CCS compression screw or K-wire in 13 of 16 stifles. This did not interfere with continued growth of the proximal tibial physis nor result in tibial deformity. Compression coupled with bone contact led to rapid primary bone union. The rapid healing could be attributed to the healing characteristics of a young animal and stable osteotomy. It is ideal for primary bone union to be rapid and potentially allow for an early return to activity. Mean time to bone union was 6 weeks in this series of cases with younger dogs healing as early as 4 weeks postoperatively. It is possible that dogs radiographed at 8 weeks were actually healed prior to the 8-week time period, but were not asked to return for radiographic assessment until 8 weeks following surgery.

Limitations identified in this study are the small number of cases (15 dogs, 16 stifles) that qualified for inclusion. Prospective examination of these injuries should be conducted that would assist with standardization of all parameters. Additionally, more objective assessment of return to function such as force plate analysis rather than client observation would be a more accurate assessment of outcome.

The focus of this study was to assess and describe a treatment option for stifle instability in skeletally immature dogs with CrCL injury. In dogs with an active proximal tibial physes, treatment options for the CCL-deficient stifle are limited due to the potential injury to the physes. This case series confirmed that the CORA-based leveling osteotomy was effective in returning juvenile dogs to full function. However, caution must be exercised when applying proximal plate screws as a proximal screw engaged the proximal tibial physes in 2 dogs resulting in a valgus deformity.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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