Double-cut center of rotation of angulation–based leveling osteotomy for treatment of cranial cruciate ligament deficiency and excessive tibial plateau angle secondary to growth anomaly in two dogs

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CASE DESCRIPTION

A 4-year-old female Staffordshire Bull Terrier (dog 1) and a 6-year-old male Yorkshire Terrier (dog 2) were evaluated because of left pelvic limb lameness.

CLINICAL FINDINGS

Both dogs had a partial rupture of the left cranial cruciate ligament associated with a unilateral excessive tibial plateau angle (51° in dog 1 and 41° in dog 2) secondary to a growth anomaly.

TREATMENT AND OUTCOME

Both dogs underwent a double-cut center of rotation of angulation–based leveling osteotomy combining rotation of the proximal fragment with a cranial closing wedge ostectomy. The procedure allowed leveling of the tibial plateau to a final angle of 11° in one dog and 10° in the other without perioperative complications. Both dogs had excellent functional outcomes ≤ 4 months after the surgery. No postoperative complications were reported during follow-up (12 months and 9 months for dogs 1 and 2, respectively).

CLINICAL RELEVANCE

Results for these dogs suggested that double-cut center of rotation of angulation–based leveling osteotomy can be considered as a viable treatment option for cranial cruciate ligament deficiency associated with excessive tibial plateau angle. (*J Am Vet Med Assoc* 2021;259:885–891)

A 4-year-old female Staffordshire Bull Terrier (dog 1) was evaluated because of persistent left pelvic limb lameness of 3 months' duration. Clinical signs had appeared after running with another dog. The dog had a history of traumatic injury from attempting to jump through a window as a puppy; the owner had not noticed any obvious lameness at the time.

On examination, non–weight-bearing lameness of the left pelvic limb was observed at walk. Orthopedic examination revealed joint effusion and a positive cranial drawer test result for the left stifle joint. The dog was premedicated with medetomidine hydrochloride (5 µg/kg, IV) and diazepam (0.25 mg/kg, IV) and anesthesia was induced with propofol (4 mg/kg, IV). Radiography of both pelvic limbs was performed **(Figure 1)**. Signs of intraarticular effusion were noticed in the left stifle joint, and the left tibia had an excessive TPA (51°). Osteophytes were identified on the sesamoid bones, the edges of femoral trochlea, the femoral condyles, the tibial plateau, and the base and apex of the left patella. The right tibia had a TPA of 22°. To fully evaluate the limb deformity, a CT scan was performed during the same anesthetic episode **(Figure 2)**. No valgus, varus, or torsional deformity was detected on evaluation of CT images of the left tibia.

A double-cut CBLO for treatment of the CCLD and excessive TPA was planned on the basis of measurements on preoperative radiographs. The CORA was located at the intersection between a proximal tibial axis (drawn to reflect the desired postoperative angle) and the distal tibial anatomic axis. The aim was to create a postoperative TPA of 11° in this instance.[1,2] The measured magnitude of the CORA (ie, angle between the aforementioned axes) was 47°. To align the proximal axis and the anatomic distal axis of the tibia, part of the correction was planned to be performed with a 15° cranial closing wedge ostectomy and the remaining part with a 6.5-mm cranial rotation of the proximal tibial fragment on the basis of information in a CBLO rotation chart[3] to achieve the targeted postoperative TPA of 11° **(Figure 3)**. A few days after the diagnostic imaging procedures, the dog was anesthetized with the same premedication and anesthetic induction protocol used previously. Morphine (0.3 mg/kg, IV) and amoxicillin (12.5 mg/kg, IV) were administered for preemptive analgesia and antimicrobial prophylaxis. Arthroscopy of the left stifle joint revealed that approximately 60% of the CCL was torn, with a discrete fibrillation of the

ABBREVIATIONS

CBLO	Center of rotation of angulation–based leveling osteotomy
CCLD	Cranial cruciate ligament deficiency
CORA	Center of rotation of angulation
mMPTA	Mechanical medial proximal tibial angle
TPA	Tibial plateau angle
TPLO	Tibial plateau leveling osteotomy

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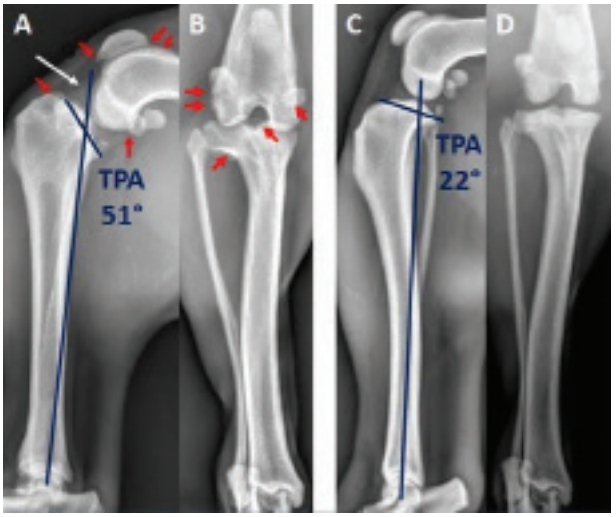

Figure 1—Preoperative mediolateral (A and C) and caudocranial (B and D) radiographs of the left (A and B) and right (C and D) tibia and stifle joint of a 4-year-old female Staffordshire Bull Terrier (dog 1) that was evaluated because of persistent left pelvic limb lameness. Caudocranial images of the right hind limb are shown with the lateral side to the left to aid visual comparison. The left TPA was 51°, and the right TPA was 22°. Notice the evidence of joint effusion (white arrow) and presence of osteophytes (red arrows) in the left stifle joint region.

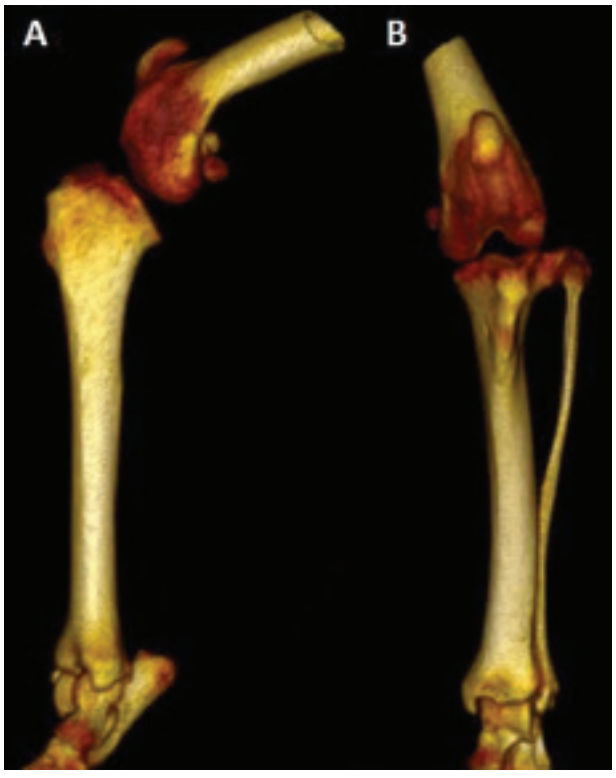

Figure 2—Preoperative 3D-reconstructed CT images showing the medial (A) and cranial (B) aspects of the left tibia and stifle joint of dog 1. No valgus, varus, or torsional deformity of the limb was evident.

caudal cruciate ligament and no meniscal lesion. The 15° cranial wedge ostectomy was performed with a 12-mm circular TPLO saw blade; the final cranial width of the wedge was 6 mm. The proximal epiphysis of the tibia was then rotated 6.5 mm cranially. The proximal and distal fragments were stabilized with a 3.0-mm headless compression screw and a medially placed 3.5-mm small CBLO plate with 1 compression screw and 5 locking screws. The immediate postoperative TPA was 11° **(Figure 4)**.

Amoxicillin–clavulanic acid (12.5 mg/kg, PO, q 12 h) was prescribed for 5 days after surgery. For pain management, cimicoxib (2 mg/kg, PO, q 24 h) and tramadol (2 mg/kg, PO, q 12 h) were prescribed for 7 days. Exercise restriction was recommended for 2 months.

At a recheck examination 2 months after surgery, the dog was using its left pelvic limb well when walking and mild lameness of the affected limb was evident at a fast-walking pace. No lameness was detected at a follow-up examination 4 months after surgery. Radiographs obtained 2 and 4 months after surgery showed excellent bony union of the osteotomy line as evaluated according to a previously described radiographic scoring system for bone healing,[4] with a final TPA of 11° **(Figure 5)**. No progression of osteoarthritis was noticeable on these radiographs. In a telephone interview 1 year after the surgery was performed, the owner reported being unable to detect a difference between the treated and unaffected pelvic limbs from a functional perspective.

A 6-year-old male Yorkshire Terrier (dog 2) was evaluated because of persistent left pelvic limb lameness of 3 weeks' duration. The dog had a history of jumping down from a raised surface approximately 1 m high at 7 months of age. No obvious lameness had been observed at the time. The dog had undergone a CBLO of the contralateral pelvic limb 2 months prior to this consultation. At the time of the CBLO on the right pelvic limb, the measured preoperative right TPA was 29° **(Figure 6)**.

Constant weight-bearing lameness of the left pelvic limb was observed during gait evaluation. Orthopedic examination revealed joint effusion and a positive cranial drawer test result for the left stifle joint. Premedication and anesthesia protocols were as described for dog 1. Radiography of the left pelvic limb was performed (Figure 6). Evidence of intraarticular effusion in the stifle joint was noticed in addition to an excessive TPA (41°) and valgus of the proximal aspect of the tibia (mMPTA, 96°). Moderate signs of osteoarthritis were present on the edges of femoral trochlea, femoral condyles, tibial plateau, and apex of the left patella. A CT scan of the left pelvic limb was performed during the same anesthetic episode, and no torsional deformity of the tibia was detected **(Figure 7)**.

A double-cut CBLO was planned. The CORA was measured as previously described; the magnitude was 35°. A 13° cranial wedge ostectomy combined with a 4-mm cranial rotation of the proximal fragment were planned to achieve the targeted postoperative TPA of 9°. The mild valgus deformity of the proximal portion of the tibia was not corrected, as the mMPTA of the left tibia was not substantially different from that

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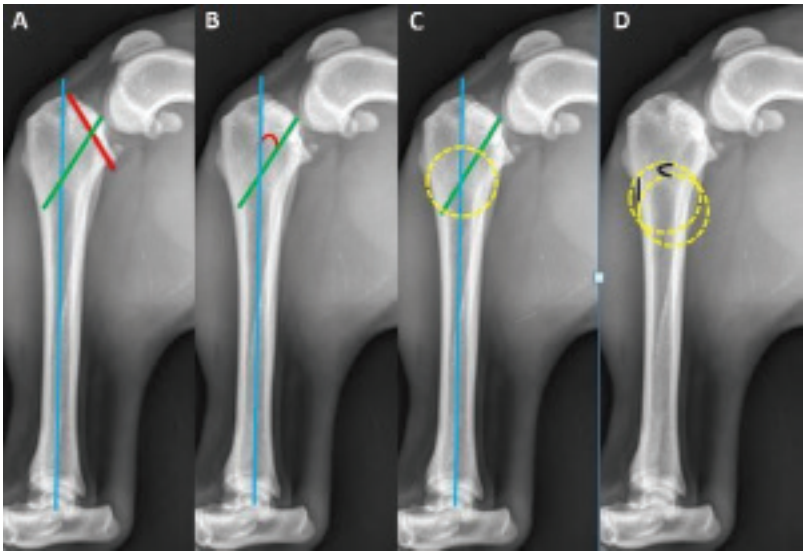

Figure 3—Mediolateral radiographic images depicting surgical planning for a double-cut CBLO of the left tibia for dog 1. A—The CORA was located at the intersection between the proximal tibial axis (green line) and the distal tibial anatomic axis (blue line); the straight red line indicates tibial plateau axis. The proximal tibial axis was drawn to reflect the desired postoperative angle of 11°. B—The measured magnitude of the CORA was 47° (angle illustrated with a curved red line). C—A circle with a 12-mm radius centered at the CORA was drawn to simulate the first tibial osteotomy (yellow circle). D—To align the proximal axis and the anatomic distal axis of the tibia, part of the correction was planned to be performed with a 15° cranial wedge ostectomy (angle illustrated with a curved black line) with a cranial width of 6 mm (straight black line). Finally, a 6.5-mm cranial rotation of the proximal tibial fragment was planned on the basis of values in a CBLO rotation chart[3] to achieve the postoperative TPA of 11°.

of the right tibia (94°) or from a previously reported mean ± SD value for 105 dogs of various breeds (93.30 ± 1.78°).[5] Morphine and amoxicillin were administered for preemptive analgesia and antimicrobial prophylaxis as described for dog 1. Arthroscopy of the left stifle joint revealed that approximately 50% of the CCL was ruptured. No meniscal lesion was evident. The 13° cranial wedge ostectomy was performed with a 10-mm circular TPLO saw blade (final cranial width of the wedge, 4.1 mm). The proximal epiphysis of the tibia was then rotated 4 mm cranially on the basis of information in the previously described CBLO rotation chart.[3] The osteotomy was stabilized first with a 1.8-mm Kirschner pin placed in a craniproximal to caudodistal direction. A bone forceps was placed across the osteotomy along the same direction as the pin to apply compression between the 2 bone fragments. Then, a 2.4-mm CBLO plate was placed medially with 1 cortical screw and 5 locking screws. Finally, a tension band wire was placed between the Kirschner pin and a drilled 1.1-mm distal bone tunnel to maintain the compression and counteract the patellar ligament strain. The final TPA angle was 10° **(Figure 8)**.

Postoperative medication and exercise restriction were as described for dog 1. At recheck examinations 2 and 4 months after surgery, no lameness was detected. Radiographs showed excellent bony union of the osteotomy site[4] with a TPA of 10°. No progression of osteoarthritis was noticeable **(Figure 9)**. The dog was presented to the hospital 9 months after the surgery for an issue not related to CCLD. No left pelvic limb lameness was detected at that time.

Discussion

Both dogs of the present report underwent a double-cut CBLO for simultaneous treatment of CCLD and excessive TPA secondary to a growth anomaly. The TPA has been reported to have a mean value of 22° to 28° in dogs,[6–9] but can range from 12° to 59°.[6,9,10] Small-breeds dogs typically have higher TPAs than large-breed dogs (mean difference, approx 3.1°).[9] Usually, a TPA > 35° is considered excessive.[5,11,12] Several studies[13–15] have shown that the TPA is not significantly different between the right and left stifle joints of dogs with or without CCLD. Sabanci and Ocal[16] demonstrated a mean difference of 1.06° between left and right stifle joints of orthopedically normal dogs. Considering that the contralateral TPAs were 22° and 29°, respectively, the TPAs of 51° and 41° measured for the left stifle joints of dogs 1 and 2 of the present report were each characteristic of a unilateral excessive TPA. Similar craniproximal and caudodistal inclination of the proximal tibial joint surface has been previously reported secondary to avulsion of the tibial tuberosity and fracture of the proximal tibial epiphysis in immature dogs. Staffordshire Bull Terriers and small and toy terrier-breed dogs are reportedly predisposed to this type of fracture after a jump, fall, or collision.[17–19] In Staffordshire Bull Terriers, this predisposition has been proposed to be secondary to the highly developed quadriceps muscle strength of this breed.[19] In cases of proximal physis fracture, the tibial tuberosity is pulled proximally at the insertion point of the patellar ligament, and the extensors of the tarsus (ie, hock) induce traction of the proximal tibial epiphysis and femur in a caudodistal direction.[17,20] In small terrier-breed dogs, some authors suggest that the tibial tuberosity and proximal tibial physis could be weaker than in other breeds.[17] A pathologically weakened growth plate may be associated with disturbances in endochondral ossification and genetic, nutritional, and hormonal factors.[19] Immediately after traumatic proximal tibial physis fracture, the mean measured TPA of affected limbs was significantly greater than that of the unaffected contralateral limb.[17,18] Without proper fragment reduction and osteosynthesis, an abnormally increased TPA may persist as the fracture heals.[18] An undiagnosed fracture of the proximal epiphysis and tibial tuberosity of the left tibia ap-

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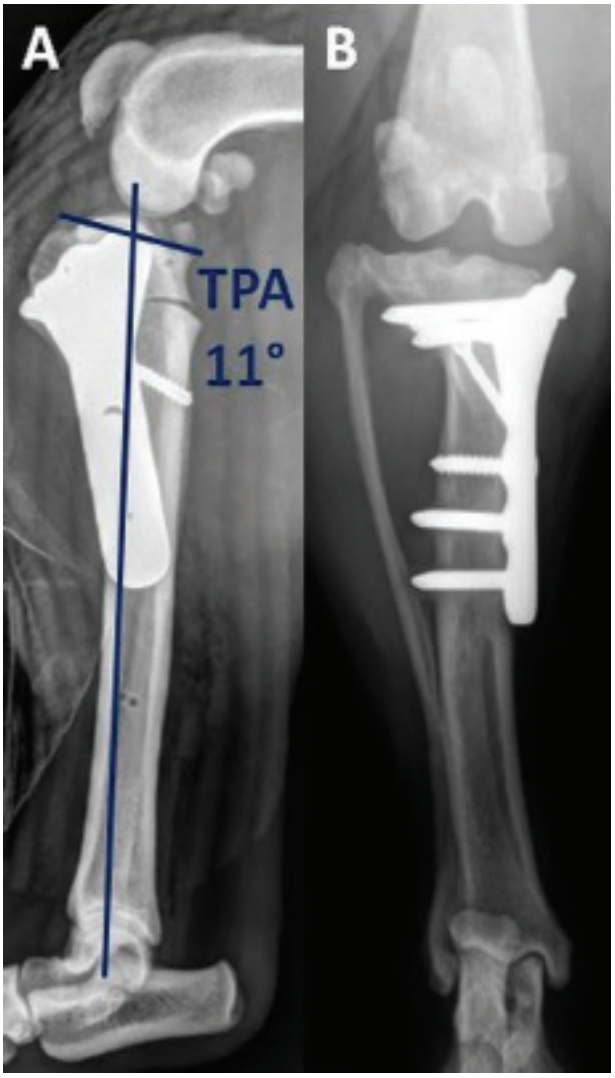

Figure 4—Immediate postoperative mediolateral (A) and caudocranial (B) radiographs of the left tibia and stifle joint of dog 1. The measured TPA was 11°.

peared to be the most likely cause of the unilateral excessive TPA in the dogs described here.

Tibial plateau leveling osteotomy, cranial closing wedge ostectomy with or without extracapsular suture placement, or a combination of TPLO and cranial closing wedge ostectomy have been used to treat dogs with CCLD and excessive TPA. Surgical treatment of CCLD in dogs with excessive TPAs appears more challenging, compared with that for dogs with moderate TPAs. In a retrospective study[10] that evaluated various surgical techniques for treatment of CCLD in large-breed dogs with and without excessive TPAs (n = 58/group), an overall consequential (major and minor) postoperative complication rate of 40% was found for dogs with excessive TPAs. Major postoperative complications rates of 0% to 8.3% and 9.5% to 11% are described for treatment of CCLD in dogs without excessive TPAs by means of TPLO and cranial closing wedge ostectomy, respectively.[4,10,21,a] Some authors have recommended creating a postoperative TPA of 5° to 6.5° when performing TPLO to optimize clinical outcomes.[6,22] This TPA may be difficult to achieve in dogs with excessive TPAs. Rotation of the tibial plateau distal to the patellar ligament insertion point on the tibial tuberosity (termed the safe point) may predispose dogs to tibial tuberosity fractures.[10] Postoperative tibial tuberosity fractures occurred in 7 of 54 (13%) of stifle joints of dogs with excessive TPA in 1 study,[10] and were almost 11 times as likely in dogs with than without excessive TPA before surgery. Use of a so-called under-rotated TPLO and a TPLO combined with a cranial closing wedge ostectomy are surgical options that can avoid rotation of the tibial plateau distal to the safe point. An under-rotated TPLO has been associated with a suboptimal limb function in dogs that have a postoperative TPA > 14°.[10] Results of 1 study[23] revealed a complication rate of 14 of 18 (78%) when TPLO was combined with a cranial closing wedge ostectomy in joints with excessive TPAs, and a second surgical procedure was required in 6 of the 18 (33%) joints at a mean of 40 weeks after the first procedure. The overall client satisfaction with these techniques was good despite the high complication and second procedure rates.[10,23] Two more recent reports[24,25] describe a modified cranial closing wedge ostectomy for treatment of CCLD in limbs of dogs with excessive TPAs; the technique was associated with a good subjective outcome and to-

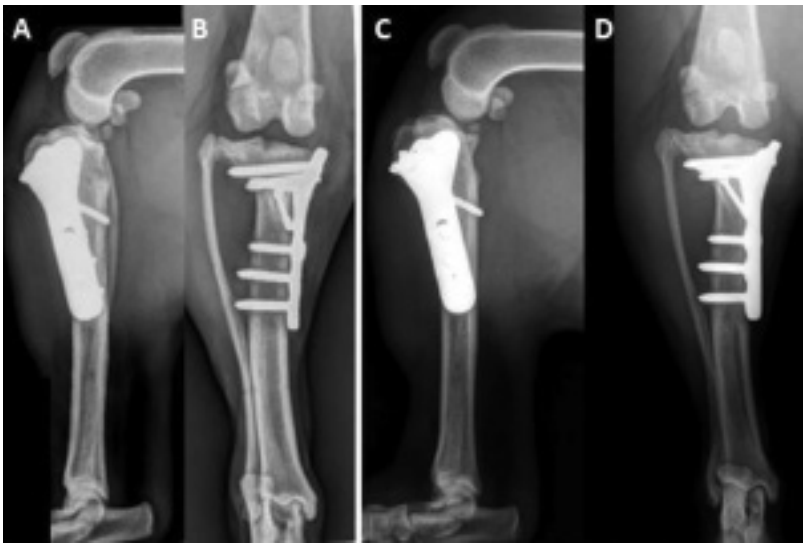

Figure 5—Mediolateral (A and C) and caudocranial (B and D) radiographs of the left tibia and stifle joint of dog 1 obtained at recheck examinations 2 (A and B) and 4 (C and D) months after surgery. The radiographs showed excellent bony union of the osteotomy line with no modification of the TPA (11°), compared with the TPA measured on radiographs obtained immediately after surgery. No progression of osteoarthritis was detected.

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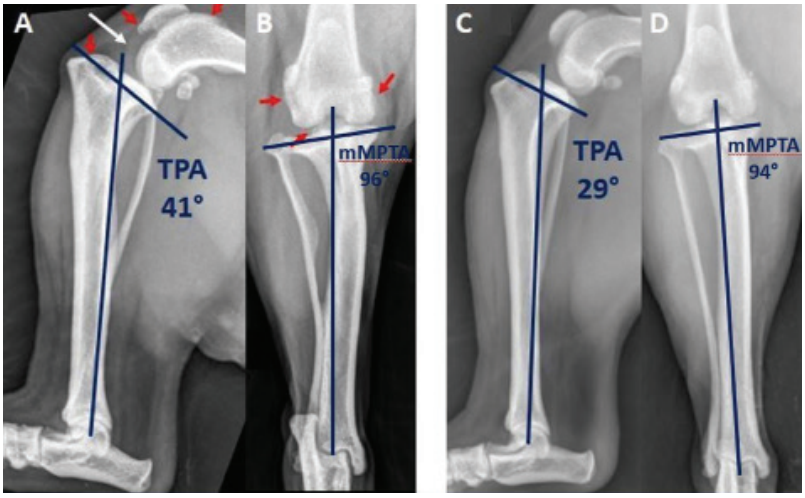
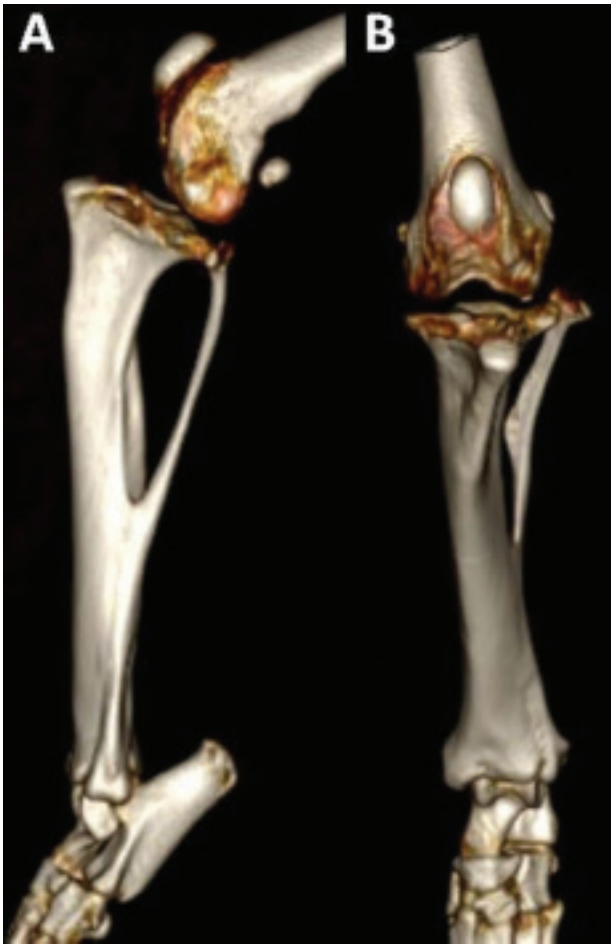


Figure 6—Preoperative mediolateral (A and C) and caudocranial (B and D) radiographs of the left (A and B) and right (C and D) tibia and stifle joint of a 6-year-old male Yorkshire Terrier (dog 2) that was evaluated because of persistent left pelvic limb lameness of 3 weeks' duration. Images of the right pelvic limb were obtained prior to CBLO of that stifle joint 2 months before the consultation for the left pelvic limb. The left TPA was 41°, and the right TPA was 29°. Valgus of the proximal aspect of the left tibia (mMPTA, 96°) was noted, but the finding was not substantially different from that for the right side (mMPTA, 94°). Note the evidence of joint effusion (white arrow) and presence of osteophytes (red arrows) associated with the left stifle joint. ***See*** Figure 1 for remainder of key.

tal short-term complication rates of 4 of 19 (21%) joints in one investigation[24] and 2 of 32 (6%) joints in the other.[25] Further studies would be needed to assess outcome associated with this technique, as to the authors' knowledge, only a relatively short postoperative follow-up period (8 weeks) has been documented.[24,25]

For CBLO as a treatment of CCLD in dogs, an overall complication rate of 11 of 70 (16%) stifle joints was found in 1 study.[1] A good outcome was reported for 67 of 70 (96%) joints.[1] The double-cut CBLO combines a cranial rotation of the proximal fragment and modified cranial closing wedge ostectomy performed with a second, more distal cut created with a radial saw. This allows correction of excessive TPA without excessive rotation of the proximal fragment. Compared with TPLO combined with a cranial closing wedge ostectomy, in which the 2 osteotomies are independent, only 2 bone fragments need to be stabilized when a double-cut CBLO is performed. As the fragments are stabilized with the same methods used for a standard CBLO, it seems very likely that a complication rate similar to that for the standard CBLO could be expected. The rotated proximal fragment of the tibia is larger in CBLO than in TPLO. This makes stabilization of the osteotomy easier, particularly in small patients.[10,24,b] For the 2 clinical dogs of the present report, no postoperative complications developed and clinical outcome was very good at contact times of 9 months for one dog and 12 months for the other.



The most common major complication with the techniques previously quoted (TPLO, under-rotated TPLO, cranial closing wedge ostectomy, and TPLO combined with cranial closing wedge ostectomy) is the loss of tibial plateau leveling during the first months after surgery. In 1 retrospective study,[10] 22 of 53 (42%) stifle joints had a ≥ 5° increase in TPA when measurements on immediate postoperative radiographs were compared with those on radiographs obtained at subsequent recheck examinations. Whereas TPLO has been associated with a significant change in postoperative TPA during healing, with reported mean ± SD changes of 1.29 ± 0.22° when locking screws are used,[26] no significant TPA shift has been reported after CBLO (0.52 ± 1.61°) or modified cranial closing wedge ostectomy (mean change of 0.55°).[2,25] No change in TPA was noticed during the bone healing period for the dogs of the present report.

Figure 7—Preoperative 3-D reconstructed CT images showing the lateral (A) and cranial (B) aspects of the left tibia and stifle joint of dog 2. Valgus of the proximal aspect of the tibia (mMPTA, 96°) was confirmed, but no torsional deformity was detected.

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A cranial closing wedge ostectomy is associated with distal displacement of the patellar ligament insertion point that could lead to patella baja.[10,24,25] Changes in the biomechanics of the stifle joint are likely to be more pronounced with the modified cranial closing wedge ostectomy technique. However, to the best of the authors' knowledge, no previous investigation has fully evaluated the biomechanical impact of secondary patella baja and the long-term clinical outcome after cranial closing wedge ostectomy or modified cranial closing wedge ostectomy.[23,26–28] Distal displacement of the patellar ligament insertion point is less pronounced when TPLO is combined with a cranial closing wedge ostectomy or with double-cut CBLO.

The positive clinical outcomes for the dogs of the present report suggested that double-cut CBLO can be considered for the treatment of CCLD associated with excessive TPA secondary to a growth anomaly. However, prospective studies that include larger numbers of dogs are needed to evaluate long-term outcome and complications for these procedures.

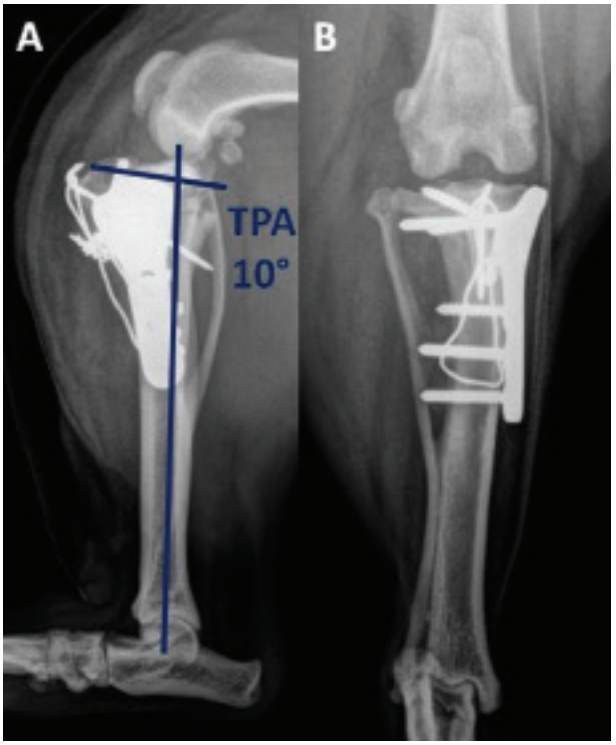

Figure 8—Immediate postoperative mediolateral (A) and caudocranial (B) radiographs of the left tibia and stifle joint of dog 2. The measured TPA was 10°. One proximal screw appeared to impinge on the joint on the caudocranial view, but the mediolateral view showed that it was sufficiently cranial to avoid interference with the articular cartilage.

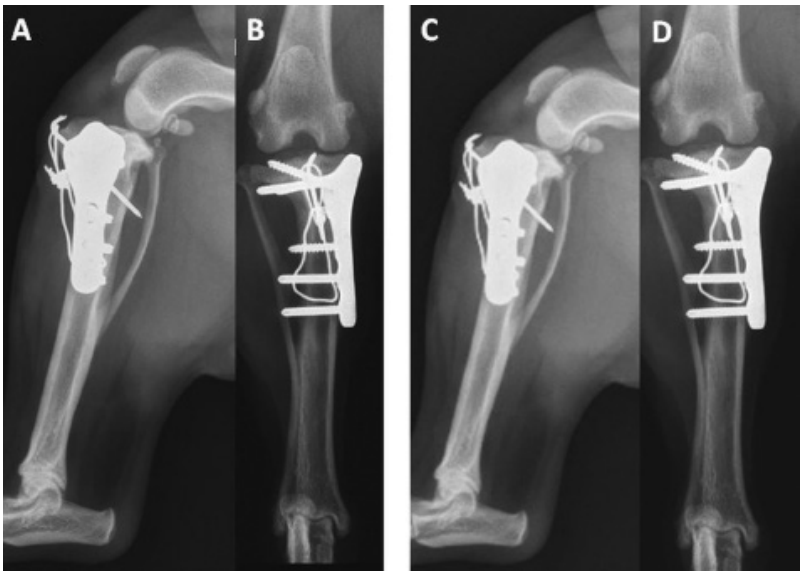

Figure 9—Mediolateral (A and C) and caudocranial (B and D) radiographs of the left tibia and stifle joint of dog 2 obtained at recheck examinations 2 (A and B) and 4 (C and D) months after surgery. The radiographs showed excellent bony union of the osteotomy line with no modification of the TPA (10°), compared with the TPA measured on radiographs obtained immediately after surgery. No progression of osteoarthritis was detected.

Acknowledgments

The authors declare that there were no conflicts of interest.

Footnotes

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