

Caudal Cruciate Ligament Rupture in an Adult Dog 8.5 Years Post Juvenile Tibial Plateau Cranial Hemiepiphysiodesis

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Abstract

The aim of this study was to report a case of caudal cruciate ligament rupture in a 9-year-old dog who underwent juvenile tibial plateau cranial hemiepiphysiodesis that was performed to treat a partial cranial cruciate ligament rupture and excessive tibial plateau angle. A 9-year-old, 45 kg, male Bernese Mountain dog was referred for a non-traumatic acute right pelvic-limb lameness. At the age of 5 months, the dog underwent bilateral tibial plateau cranial hemiepiphysiodesis to treat a bilateral partial cranial cruciate ligament rupture and excessive tibial plateau angles. At clinical examination, a caudal tibial subluxation of the right stifle was detected. The right tibial plateau angle was 3 degree. Arthroscopy confirmed a complete caudal cruciate ligament rupture. The cranial cruciate ligament was partially torn. A diagnosis of caudal cruciate ligament rupture 8.5 years post juvenile tibial plateau hemiepiphysiodesis was made. A tibial plateau overcorrection might have contributed to caudal cruciate ligament rupture in this dog.

Keywords

- ▶ tibial plateau levelling osteotomy
- ▶ canine cruciate ligament rupture
- ▶ stifle
- ▶ caudal cruciate ligament

Introduction

The cranial cruciate ligament (CrCL) is responsible for counteracting cranial translation and internal rotation of the tibia relative to the femur. In contrast, the caudal cruciate ligament (CaCL) is the primary stabilizer against the caudal tibial subluxation.¹ Rupture of the CrCL is one of the most common causes of hindlimb lameness in dogs. Its etiopathogenesis is related to a gradual degenerative process.² Rupture of the CaCL is reported as a rare condition, and it is commonly associated with severe trauma or stifle luxation.^{3,4} Injuries of CaCL have been associated with CrCL disease.⁵ The most common reported conformational variation as a potential contributor to cranial or CaCLs rupture is the tibial plateau angle (TPA) variation.^{6–9} The dogs' normal TPA ranges from 18 to 26 degrees.¹⁰ During weight-bearing, the forces transmitted by the femoral condyles to the tibial plateau result in a

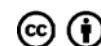
force directed cranially, known as cranial tibial thrust (CTT), counteracted in a healthy stifle by the CrCL.^{6,8,11} As the TPA increases, the CTT increases accordingly,^{6,11} leading to continuous excessive stress on the CrCL that may lead to its rupture.^{6,12} In a stifle affected by CrCL rupture, the CTT is no longer counteracted, and a cranial subluxation of the tibia will occur.^{6–8} The real contribution of the TPA to CrCL disease has not been completely clarified. Many dogs with steep TPA do not develop CrCL rupture.^{10,13} However, common types of CrCL rupture surgeries, such as tibial plateau levelling osteotomy (TPLO),^{6,8,11} modify the TPA, aiming at functional TPA nearly perpendicular to the functional axis of the tibia, thus nullifying the CTT.¹⁴ Postoperatively, during the stance phase, the tibial plateau assumes a cranial orientation, eliciting a caudal tibial thrust (CaTT) counteracted by the CaCL.¹⁴ Levelling the tibial plateau to an angle of 6.5 degrees

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eliminates cranial tibial subluxation by converting cranial tibial thrust into CaTT that must be constrained by the intact CaCL.¹⁴ Progressive levelling from 6.5 degrees toward 0 degree further increases demand on the CaCL.¹⁴ As the CTT may be the cause of CrCL disease, CaTT may lead to CaCL tears. Caudal cruciate ligament disease secondary to tibial plateau over-rotation was hypothesized by Slocum and Devine-Slocum as a possible complication after TPLO.¹¹ However, this complication has never been reported. A dog affected by limb deformity, including negative TPA, had concomitant partial rupture of the CaCL.⁹

With the same purpose of the TPLO, screw fixation of capital tibial physis for tibial plateau levelling in growing dogs was first introduced by Slocum¹⁵ and later reported by Vezzoni and colleagues as 'proximal tibial epiphysiodesis'.¹⁶

There are two growth plates in the proximal tibia as the tibial-tuberosity apophysis and the tibial plateau physis. Because only the cranial part of the tibial plateau is modulated, tibial plateau cranial hemiepiphyodesis (TPCHE) is proposed in this manuscript for naming the surgical technique in question.

Tibial plateau cranial hemiepiphyodesis modifies the normal growth pattern of the cranial aspect of the tibial plateau physis while allowing the caudal part of the physis to continue growing. The cranial aspect of the tibial plateau growth is arrested at the point of a transphyseal screw insertion.

Tibial plateau cranial hemiepiphyodesis should be performed in puppies before the proximal tibial growth plate loses adequate growth potential (4–7 months of age).¹⁶

We report a case of a monolateral CaCL rupture in a dog 8.5 years post bilateral TPCHE.¹⁴

Case Report

A 9-year-old, 45 kg, male Bernese Mountain dog was referred for a 2-month history of right pelvic-limb weight-bearing lameness. Sudden onset of lameness occurred while the dog was walking on the leash without a history of trauma.

Clinical Examination

On palpation, mildly distended stifle joints were detected. Discomfort was elicited upon flexion and extension of the right stifle. Caudal tibial subluxation of the right stifle was recognized during the drawer test.⁸ A positive tibial sag test was detected on the right stifle.⁸ Tibial compression tests were negative.⁸

Medical History

At the age of 5 months, the dog underwent bilateral TPCHE to treat bilateral partial CrCL rupture that was confirmed during the arthrotomy.^{15,16} Preoperative right TPA was 33 degrees, while left TPA was 30 degrees (►Fig. 1A, B). Postoperative radiographs showed a 32 mm length, 4 mm diameter cancellous screw inserted into each tibial plateau cranial aspect. Mechanical medial proximal tibial angle (mMPTA) was 98 degrees bilaterally. The screws had a proximal-distal, craniocaudal and mediolateral direction. Three weeks after surgery the lameness was not noticed at clinical examination. Radiographic examination revealed a TPA of 22 and 23 degrees right and left respectively (►Figs. 1C and 3D). Mechanical medial proximal tibial angle was 99 and

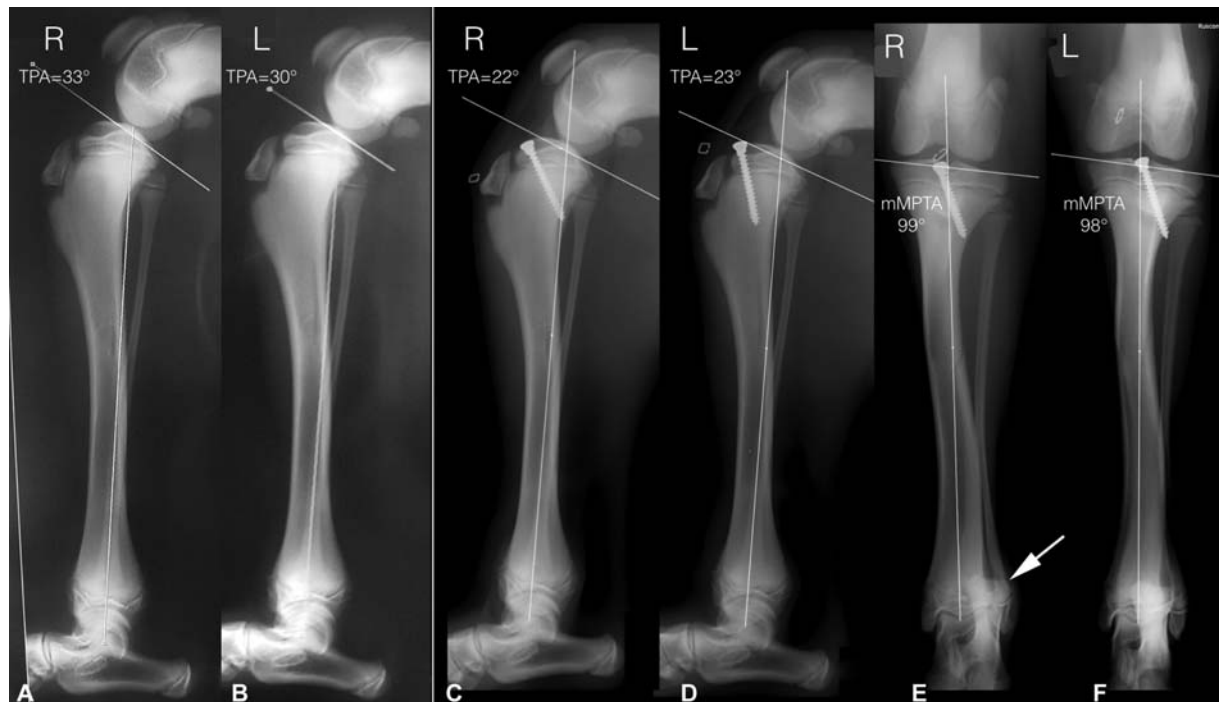


Fig. 1 Bernese Mountain dog, male, 5-month-old. Preoperative mediolateral radiographs of the right (A) and the left (B) tibiae. Right tibial plateau angle (TPA) was measured as 33 and (A) 30 degrees (B) right and left respectively. Three weeks follow-up postoperative radiographs from tibial plateau cranial hemiepiphyodesis of the right (C, E) and left (D, F) tibiae. Right TPA = 22 degrees, left TPA = 23 degrees. Right mechanical medial proximal tibial angle (mMPTA) was 99 degrees while the left was 98 degrees. Note the right tibia was not positioned properly (E, arrow).

98 degrees right and left respectively (►Fig. 1E, F). At 7 weeks follow-up, no limb dysfunction was detected or reported by the owner. The radiographs showed correction of the TPA to 6 degrees bilaterally (►Fig. 2A, B). Screw removal was planned for the following week. The owners did not show up for the surgery. Surgery was postponed to week 9. At 9 weeks follow-up, the dog was walking indistinguishable from a normal dog. Tibial plateau angle was 3 degrees bilaterally (►Fig. 2C, D). Mechanical medial proximal tibial angles were 97 and 95 degrees right and left respectively (►Fig. 2E, F). The screws were removed bilaterally.

Medical Diagnostic Imaging at 9 Years

Radiographs

Mediolateral radiographs showed increased soft tissue opacity consistent with joint effusion or oedema of the infrapatellar fat pad bilaterally (►Fig. 3A, B). Osteoarthritis was detected bilaterally. On the mediolateral projection of the right stifle, a caudal subluxation of the tibia of 11 mm relative to the femur further corroborated the diagnosis of CaCL rupture (►Fig. 3A; ►Video 1). Tibial plateau angles were measured as 3 and 8 degrees for right and left tibias respectively (►Fig. 3A, B). Caudocranial radiographs showed mMPTA of 94 and 95 degrees for right and left tibias respectively.

Arthroscopy

The right stifle was examined through a lateral parapatellar arthroscopic portal utilizing a 2.7 mm, 30 degrees fore-oblique arthroscope. At the intercondylar fossa level, arthroscopy revealed synovitis, with abundant villous projections and

copious vascularity of the synovium. Trochlear groove and both medial and lateral femoral condyles seemed normal. A partial CrCL tear was noted (►Fig. 4A, B). The CaCL was completely disrupted (►Fig. 4C, D). The medial meniscus was inspected and palpated with a meniscal probe. No meniscal lesions were identified.

Treatment

Medical treatment was chosen. At 3 months follow-up examination, the dog showed no swelling of the joint or pain and was subjectively indistinguishable from normal at walk or trot.

Discussion

Rupture of the CrCL commonly affects adult dogs, with a peak of incidence at 7 to 10 years of age.¹⁷ Rottweilers, Newfoundlands and Staffordshire Terriers had the highest prevalence of CrCL rupture in a study.¹⁸ Breed predisposition was detected in dogs < 2 years old for Neapolitan Mastiff, Akita, Saint Bernard, Rottweiler, Mastiff, Newfoundland, Chesapeake Bay Retriever, Labrador Retriever and American Staffordshire Terrier.¹⁷ Our case was a Bernese Mountain dog.

In one study, all the 14 puppies affected by partial (12 out of 17 stifles) or complete (5 out of 17 stifles) juvenile CrCL rupture were large or giant dogs as was our case.¹⁶ Dogs weighing > 22 kg have a higher prevalence of CrCL rupture and tend to rupture their CrCL at a younger age.¹⁸

Neutered dogs have a higher prevalence of CrCL rupture than sexually intact dogs. Early neutering is a significant risk factor for the development of excessive TPA in large-breed



Fig. 2 Seven weeks radiographic examination. Mediolateral projections of right (A) and left (B) tibias. Tibial plateau angle (TPA) was measured as 6 degrees bilaterally. Nine weeks radiographic examination (C–F). Tibial plateau angle was 3 degrees bilaterally (C, D). Mechanical medial proximal tibial angle (mMPTA) was 97 degrees for the right (E) and 95 degrees for the left side (F). Note the right tibia was not positioned properly (E, arrow).

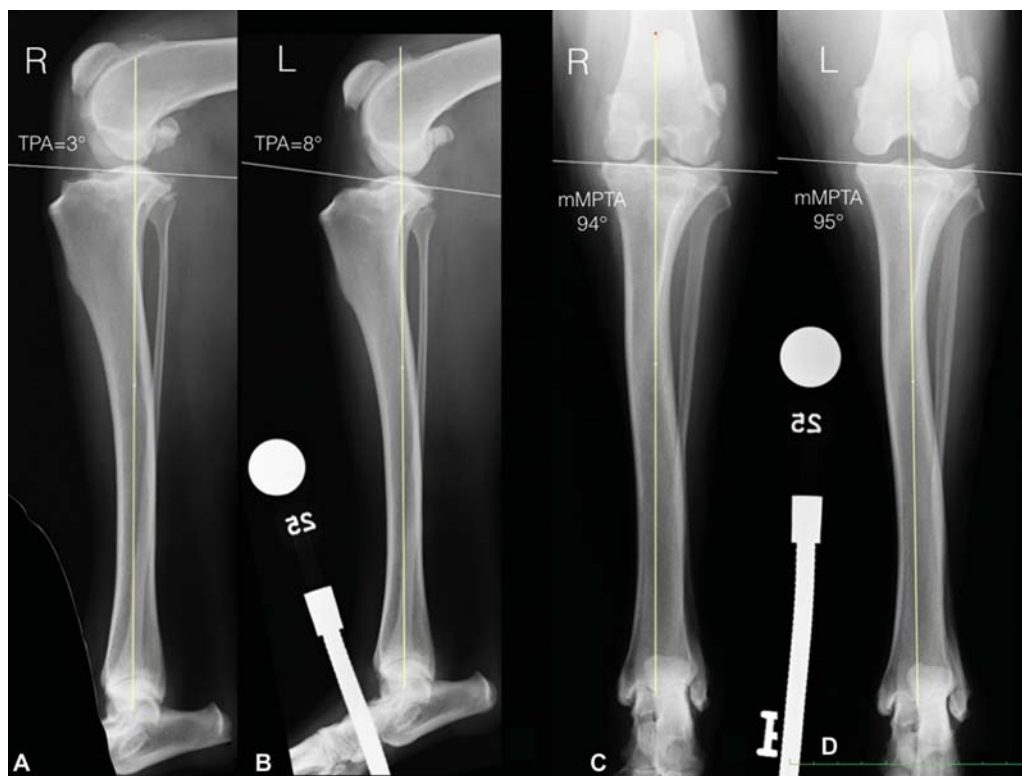


Fig. 3 Same dog at 9 years of age. Mediolateral and caudocranial right and left tibias radiographic projections. Bilateral joint effusion and peritrochlear osteophytes (A, B). The right stifle joint was the most severely affected (A). Note the caudal tibial subluxation relative to the femur, suggesting caudal cruciate ligament rupture (A). The radiographs were taken without tibial compression test in a neutral position. Tibial plateau angles (TPAs) = 3 and 8 degrees for right (C) and left joints (D) respectively. Mechanical medial proximal tibial angle (mMPTA) was 94 and 95 degrees right (C) and left (D), respectively.

Video 1

Caudal subluxation. Online content including video sequences viewable at: <https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1717125>.

dogs with CrCL disease.¹⁹ In one study neutered dogs had a higher TPA of 29 degrees than non-neutered dogs with an average TPA of 27 degrees.²⁰

All the 14 dogs affected by juvenile CrCL rupture reported by Vezzoni and colleagues were sexually intact, as was the Akita earlier reported by Slocum or our case.

Thirteen out of fourteen dogs reported by Vezzoni and colleagues had normal TPA (18–28 degrees), while one had a TPA = 30 degrees. At the age of 5 months, the puppy here described had a right TPA of 33 degrees, while the left measured 30 degrees. Given the absence of trauma in the anamnesis and the bilateral simultaneous partial rupture of the CrCLs, the steeper TPA might have varied the joints biomechanics leading to CrCL rupture.^{6,11–13} In a recent study of TPA in dogs undergoing surgical stabilization for CrCL rupture, the 40 Bernese Mountain dogs reported had an average TPA of 30 degrees.²⁰ Average TPA in Bernese Moun-

tain dog not experiencing CrCL disease is not known, thus it could be as well normally higher than in other breeds.

Nine weeks after TPCHE, TPAs were considered bilaterally overcorrected, measuring 3 degrees in the puppy here described. Screw removal was performed to avoid overcorrection in 2 out of 22 joints in Vezzoni and colleagues report.¹⁶ Two female boxers of 5 and 6 months of age at the time of treatment achieved 8 degrees TPA in 40 and 60 days respectively (14 and 12 degrees of change at 2.3 and 1.4 degrees per week speed). The maximum and the minimum TPA change were 24 (case no. 8, 4.5-month-old Labrador Retriever) and 6 degrees respectively (case no. 5, 8-month-old Dogue de Bordeaux).¹⁶ The Akita reported by Slocum was 5-month-old at the time of surgical treatment with a TPA of 18 degrees. A TPA of 5 degrees was measured at the 1-year postoperative radiographic examination.¹⁵ In our patient, TPA-change was 30 degrees after 9 weeks for the right side and 24 degrees for the left one. We may assume that a younger and larger sized male dog might have a higher residual potential growth at 5 months.²¹ According to this statement, the younger and the larger the patient, the greater the change achieved. The larger/younger the patient, the more frequently the TPA should be checked after TPCHE.

At 3-week examination post-TPCHE, the dog was able to walk indistinguishably from normal, with a TPA of 22 and 23 degrees right and left respectively. Lower slopes with partial CrCL ruptures could have improved the clinical signs in this puppy.

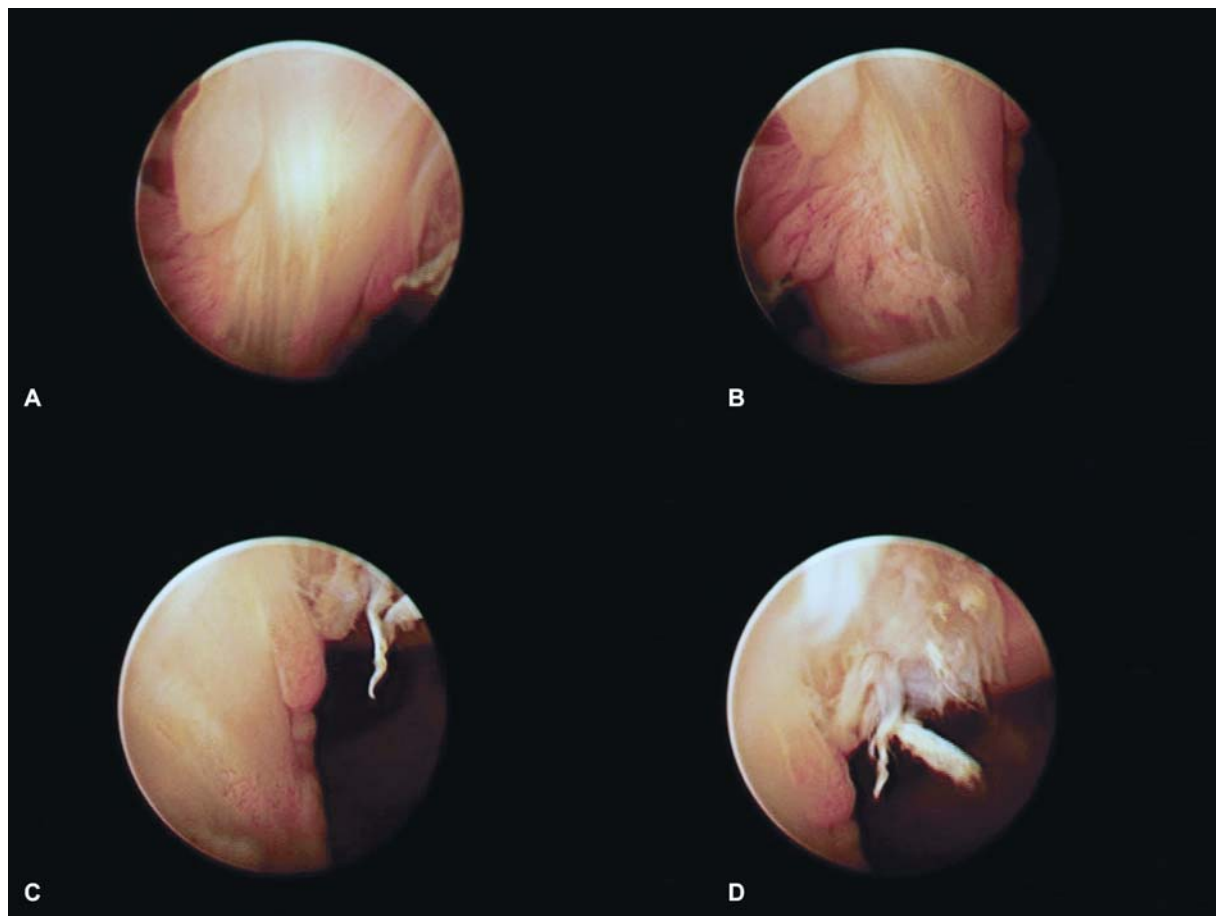


Fig. 4 Partial cranial cruciate ligament tears with synovitis (A, B). Complete disruption of the caudal cruciate ligament (C, D).

In total, 27 and 24 degrees of correction were planned for the right, and the left TPAs, respectively, with a bilateral TPCHE target slope of 6 degrees. Tibial slopes changed from 33 to 22 degrees and from 30 to 23 degrees for right and left stifle joints respectively in 3 weeks. A correction of 41 (11/27) and 29% (7/24) was obtained for the right and the left TPAs in 3 weeks. At the 7-week radiographic examination, a TPA of 6 degrees was measured bilaterally. A further gain of 16 (59%) and 17 degrees (71%) was obtained for the right and the left TPAs in 4 weeks. From week 7 to week 9, TPAs changed to 3 degrees.

Mean correction was 3.9 and 3.4 degrees per week for the right and the left tibial plateau slope respectively. In the first 3 weeks, the mean rate of correction was 3.6 degrees per week and 2.3 degrees per week for the right and the left TPA respectively. From week 4 to 7, speed of correction was ~4 degrees per week. In the first 3 weeks, left and right TPA changed at a different speed, while from week 4 to 9 correction appeared symmetric. Regular radiographic examination every 2 to 3 weeks would have assessed the plateau inclination more appropriately.

In the dog reported, the speed of correction was higher at 6 months of age than at 5 months of age. Why the left and right TPAs changed at different rates is not known. The longitudinal growth of bones is apparently controlled by the numbers of growth plate chondrocytes in the proliferative zone, their rate of proliferation, the amount of chon-

drocyte hypertrophy and the controlled synthesis and degradation of matrix throughout the growth plate. These variables can be influenced to produce a change in growth rate in the presence of sustained or cyclic mechanical load. There is little information about the effects of time-varying changes in volume, water content, osmolarity of matrix etc. on differentiation, maturation and metabolic activity of chondrocytes. Also, the impact of shear forces and torsion on the growth plate is incompletely characterized.²²

Tibial plateau cranial hemiepiphysiodesis eccentric screw insertion may affect frontal plate growth-plate development.^{15,16} Intraoperative verification of Kirschner wire and screw position by fluoroscopy or radiography has been suggested.^{8,16} Both screws were inserted slightly medially (►Figs. 1E, F, and 2E, F). A bilateral slight frontal-plane change occurred in the dog here reported. Mechanical medial proximal tibial angle changed from 98 to 97/95 degrees for right and left tibiae respectively in 9 weeks. Right tibiae anteroposterior view at 9 weeks were taken with the same positioning of the previous radiographic examination for comparison (►Figs. 1E and 2E, white arrows).

The screw crossing the growth plate arrests the growth plate at its point of insertion.¹⁶ The screws were almost centrally inserted with a proximodistal, craniocaudal and mediolateral direction. Growth plate modulation was affected by the pressure exerted by the screw-head and thread at the cranial aspect

of the tibial plateau physis. Growth plate modulation did not seem to be affected by screw inclinations in this dog.

Eight and a half years after implant removal, the right TPA measured 3 degrees, while the left one measured 8 degrees. Left and right TPA discrepancy could be the result of a different limb positioning during X-rays survey²³ or due to the observer variability.²⁴ Tibial plateau angle discrepancy might be related to a rebound effect²⁵ or because there was still an asymmetrical residual growth-plate potential at time of screws removal. Different screws positioning or inclinations might have affected the two growth plate potentials (left and right) differently.

At 8.5 years radiographic examination, both stifle joints showed signs of osteoarthritis. It was not possible to exclude that the osteoarthritic changes on the contralateral knee (8 degrees TPA) could also be the result of a partial CaCL disease. Caudal cruciate ligament rupture can occur in association with CrCL rupture, although ligament fraying rather than gross rupture is more common.⁵ Left stifle arthroscopy was not performed. The osteoarthritis on the contralateral stifle most likely was the result of the CrCL disease. However, it could not be excluded that a partial tear of the caudal ligament was present as well. Other possible causes of osteoarthritis were not excluded.

Treatment of isolated CaCL rupture is controversial. Experimental and clinical studies on dogs that underwent CaCL resection without any surgical stabilization did not show any lack of limb function.^{26,27} Mild radiographic osteoarthritis changes were detected at the 2-month mediolateral right-stifle radiographic examination.²⁸ This was consistent with an experimental study where isolated transection of the CaCL produced minimal clinical and pathologic changes in dogs during 6 months.²⁶ Caudal cruciate ligament rupture optimal treatment is not established yet.

During weight-bearing, in stifle joints with sole CaCL rupture and a physiologic TPA, a CTT will occur, counteracted by a healthy CrCL. Thus, the absence of a gross instability may explain the absence of severe limb dysfunction. Slocum described a mild but persistent limp when a CaCL rupture is left untreated and reported the tibial tubercle recession as surgical treatment.²⁹ This procedure aims to create a subtle cranially directed force on the tibia that functionally stabilizes the stifle. A healthy CCL is necessary to be included for this treatment.

A case with rupture of both CrCL and CaCL with a negative TPA was treated through a reverse TPLO.^{9,30} Since the target of 6.5 degrees TPA is contraindicated in case of CaCL disease,¹⁵ Vincenzi and colleagues aimed for 15 degrees TPA nullifying the CaTT and obtaining normal limb function.^{9,31}

Overcorrection after TPCHE was documented in this dog. Based on this case report, we conclude that it is prudent to frequently re-evaluate puppies undergoing TPCHE to minimize the risk of tibial plateau over-levelling.

Authors' Contributions

M.P. and M.D. wrote the manuscript. M.P. and A.F. performed the surgeries, clinical and radiographic examinations, radiographic measurements, and supervised the manuscript as well.

Conflict of Interest

None declared.

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