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Complications and Outcome of Cranial Cruciate Ligament Disease in Small Dogs Treated with Tiny TTA Rapid

Jessica Entoft[1] Ditte Skytte[2] Hugo Schmökel[3] Barbara Dyall[4]

[1] Evidensia Specialistdjursjukhuset Strömsholm, Stromsholm, Vastmanland, Sweden
[2] Surgical Department, Specialistdjursjukhuset, Strömsholm, Sweden
[3] Specialistdjursjukhuset – Ryggcenter, Strömsholm, Sweden
[4] Awake Djursjukhus, Stockholm, Sweden

Address for correspondence Jessica Entoft, DVM, Evidensia Specialistdjursjukhuset Strömsholm, Djursjukhusvägen 11, Stromsholm, Vastmanland 73495, Sweden (e-mail: jessica.entoft@evidensia.se).

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Abstract

The aim of this study was to evaluate the complications and the long-term outcome of TTA Tiny in small dogs using data from pressure-sensitive walkway analysis and the Liverpool Osteoarthritis in Dogs (LOAD) questionnaire. This is a retrospective study. Dogs under 15 kg were included. Breed, weight, gender, age, and lameness were recorded. Clinical examination, radiographs, and pressure-sensitive walkway analysis were performed during the long-term follow-up visit. Radiographs were assessed for the postoperative patellar tendon angle (PTA), bone healing, and implant position, and the postoperative complications were recorded. Twenty-nine stifles were included. One dog (3%) had an intraoperative major complication and 14 (48%) had minor complications. Medium- to long-term follow-up was available in 20 of the 23 dogs (87%). Eight (40%) dogs were followed up by telephone using the LOAD questionnaire and 12 dogs (60%) came back for a long-term follow-up appointment. The average LOAD score was 3.6 and the average lameness score was 0. All the dogs presented at a clinical follow-up were considered lame free. All the owners were pleased with the long-term result after surgery based on the LOAD score and the return to normal activity. The result from this study showed low rate of perioperative complications with the use of the TTA Tiny implant in small dogs and a good long-term outcome based on client questionnaire and the result from pressure-sensitive walkway analysis.

Keywords
- cruciate ligament disease
- TTA
- small dog
- force plate

Introduction

Cranial cruciate ligament disease (CCLD) is one of the most common causes of hindlimb lameness in dogs.[1–5] The condition is described as a degenerative and progressive weakening of the ligament and the pathology behind the degeneration is not yet fully understood.[4]

Previous studies have shown that the degenerative changes in the stifle joint develop at a slower rate and seems to be less severe in small breed dogs; hence, presentation is usually in the middle age to older dogs.[2,3] Treatment options for cranial cruciate ligament (CrCL) insufficiency in small breed dogs include conservative management, extracapsular stabilization, cranial closing wedge ostectomy, tibial plateau levelling osteotomy, center of rotation of angulation (CORA) based levelling osteotomy (CBLO), and tibial tuberosity advancement.[4,6]

Conservative treatment and lateral fabella suture for CrCL insufficiency in small breed dogs has previously been the

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most common treatment and still is in some reports.[7,8] Studies have shown that conservative management is likely to result in prolonged average recovery time of approximately 4 months.[6,9]

Dyall and Schmökel reported good to excellent midterm outcome using the TTA Rapid implants in 48 stifles in small breed dogs.[3] Since 2019, the Tiny TTA Rapid implants (TTA Tiny) have been available with a new geometry of the cages accommodating for the larger advancement often needed in small breed dogs, combined with a shorter osteotomy cut. There are only a few reports describing the complication rates and outcome of the TTA and TTA with the tibial tuberosity transposition (TTTA) procedure in small breed dogs.[3,10,11] The main aim of this study was to evaluate the perioperative complications of TTA Tiny in small breed dogs and to evaluate the long-term outcomes including objective data from pressure-sensitive walkway (PSW) analysis in TTA Rapid and TTA Tiny in small breed dogs.

Material and Methods

Dogs with a body weight of 15 kg or less were included in this study. The dog's breed, weight, gender, age, and degree of lameness were recorded. Evaluation of preoperative lameness was graded using a scale from 0 to 4,[12] with 0 representing no lameness, 1 mild lameness, 2 moderate lameness, 3 severe lameness, and 4 non-weight-bearing lameness.

Dogs that had or developed CrCL insufficiency in the contralateral limb had staged TTA surgeries performed at least 6 weeks apart.

Preoperative Planning

Craniocaudal and lateral digital radiographs of the affected stifle joint and tibia in full extension were obtained in all the dogs. The tibia plateau angle (TPA) was measured, and the desired advancement of the tibial tuberosity was measured with the anatomical landmark method in all stifles.[13] In stifles with clear tibial subluxation, additional measurements were made on the contralateral healthy stifle using the anatomical landmark method.[14,15]

Anesthesia and Pain Medication

Each dog was premedicated with acepromazine (Plegicil vet, Pharmaxim AB, Helsingborg, Sweden) 0.02 mg/kg or dexmedetomidine (Dexdomitor, Orion Pharma Animal Health, Danderyd, Sweden) 2 to 5 µg/kg subcutaneously, methadone (Semfortan vet, Dechra Veterinary Products AB, Upplands Väsby, Sweden) 0.3 mg/kg intramuscularly, and induced with propofol (PropoVet Multidose, Zoetis Finland Oy, Helsinki, Finland) 2 to 4 mg/kg intravenously to effect. Anesthesia was maintained with isoflurane (IsoFlo vet, Zoetis Finland Oy, Helsinki, Finland) in oxygen and air (FiO_2 0.55).

None of the dogs received perioperative antibiotic medications, and only one dog was administered postoperative antibiotic medications due to reasons not concerning the surgery (amoxicillin 15 mg/kg every 24 hours for 3 days). Pain management consisted of a preoperative epidural injection with morphine (Morfin Epidural Meda) 0.1 mg/kg; methadone (Metadon; Recip) 0.3 mg/kg every 4 to 6 hours for the first 12 to 24 hours; robenacoxib (Onsior; Elanco Denmark) 1 mg/kg once daily for 7 to 14 days; or meloxicam (Metacam; Boehringer Ingelheim Vetmedica) 0.1 mg/kg once daily for 7 to 14 days.

Surgical Procedure

All surgeries were performed by a board-certified surgeon or a surgical resident under direct supervision. All stifles were examined with a medial mini-arthrotomy or arthroscopy for evaluation of the cruciate ligaments, joint surfaces, and the lateral and medial menisci. Remnants of ruptured cruciate ligaments were debrided and, when indicated, partial meniscectomy was performed. No releasing procedure was performed for intact menisci, and in cases of a partial CrCL rupture, the functioning part of the CrCL was left in place. The joint was flushed prior to closure, followed by a medial approach to the proximal tibia. In all cases, the osteotomy of the tibial tuberosity was performed with an oscillating saw (Colibri, Synthes) using saw guide from the Tiny TTA Rapid produced by Rita Leibinger Medical, Germany. The dedicated spreader was used to achieve the advancement, followed by placing the cage. The cage was fixed with 1.5- or 2.0-mm titanium screws depending on available bone stock and size of the dog. The tibial cortex was inspected for fissures at the end of the osteotomy. Fissures with intact periosteum and no displacement were left to heal conservatively, as these were expected to heal rapidly with no further stabilization. No graft material or bone graft substitutes were used in the osteotomy space. The surgical field was flushed, followed by routine closure. Postoperative radiographs were taken in extension to assess implant position, to check for tibial fissuring, and to measure the postoperative patellar tendon angle (PTA). Intra- and postoperative complications were defined according to Cook and colleagues.[16] Major complications were defined as those requiring any further surgical or medical treatment, and minor complications as those not requiring such treatment. All the owners were advised to restrict exercise to short duration leash walks for the first 4 weeks, followed by leash walks of gradually increasing duration of 5 minutes per week, three to four times a day during weeks 5 through 8.[17] They were also advised to start formal rehabilitation including water treadmill after 2 weeks to enhance limb function and muscle circumference.[18,19]

Follow-Up

All the dogs were reevaluated 4 to 6 weeks postoperatively by a board-certified surgeon or a surgical resident under direct supervision. Clinical progress and clinical examination, including palpation and observation of the surgical area, were recorded. Caudocranial and lateral radiographs were taken in sedation of the stifle joint and the proximal tibia. The radiographs were assessed for bone healing as well as implant position. All postoperative complications were recorded and addressed accordingly. Medium- to long-term outcome was evaluated with an owner questionnaire using the standardized Liverpool Osteoarthritis in Dogs (LOAD) by phone interview or at the beginning of a medium- to long-term follow-up visit. This follow-up visit included a clinical examination, lameness evaluation score, and gait analysis using a PSW analysis (Tekscan's animal walkway high-resolution HRV6). Each dog was acclimated to the room and the walkway for a minimum of 5 minutes prior to a run. The dogs ran a total of five times on the PWS, all with a speed of 1.5 to 2 m/s, corresponding to trot and without any pull on the leash. Maximum force, maximum peak pressure, impulse, the length, acceleration and velocity of the stride, and the time of the stand, swing, and stride were recorded. Symmetry index (SI) was calculated using the maximum force (kg) and impulse (kg*sec). A healthy control group of small breed dogs with no orthopaedic disorders were used to test and calibrate the PWS. A group of small breed dogs operated on for a cranial cruciate deficiency using the older version of the TTA Rapid implants were also included in the PSW study. The owners were contacted again and invited for a clinical and PWS examination 2 to 4 years after the TTA procedure. These dogs were a part of a previously published study, but the PWS had not been available at the time.[3]

Statistical Analysis

The mean and standard deviation were calculated, and a statistical software (Social Science Statistics) was used to perform a Wilcoxon rank-sum test to compare the paired lameness scores and Mann–Whitney *U* test to compare the nonpaired results of the PSW in the two groups. A test result of *p*-value less than 0.05 was considered significant.

Results

Twenty-nine stifles in 23 dogs were included in the study. Six dogs (26%) had staged TTA surgery performed on both stifles. Eleven dogs were males (47%), of which four were castrated (36%). Twelve dogs (52%) were female, of which one was castrated. The breed distribution was 15 mixed breeds (65%), 2 Yorkshire Terriers (8%), 2 Bichon Havanais, 1 Border Terrier (4%), 1 Mittelspitz (4%), 1 Jack Russell (4%), 1 Chihuahua (4%), 1 Lancashire Heeler (4%), 1 Shetland Sheepdog (4%), and 1 Bichon Frisé (4%). Their bodyweight ranged from 2.3 to 15 kg with a mean of 7.9 kg. The mean age was 8.6 years, ranging from 4 to 11.5 years.

Of the 29 stifles, 15 were on the right hindlimb (52%) and 14 were on the left hindlimb (48%). Three dogs were lost to long-term follow-up, providing only perioperative and short-term (4–6 weeks) data. The average preoperative lameness score was 3 out of 4. The 4- to 6-week lameness score was 0.62 out of 4 ($p < 0.00001$). The mean preoperative TPA was 27.3 degrees (range: 18–35.2 degrees). The mean postoperative PTA was 92.2 ± 4.06 degrees (range: 85.1–105.2 degrees). The CrCL was completely ruptured in 27 (93%) stifles and partially ruptured in 2 (7%). Six stifles (20%) had medial meniscal injury with a bucket handle tear and were treated with debridement of the damaged bucket handle. No lateral meniscal injury was noted. The preoperative mean TPA in the stifles with meniscal injury was 24.25 (range: 18–31.5) and the preoperative mean TPA in the stifles without concurrent meniscal injury was 27.5 (range: 18.4–35.2).

Intraoperative Complications

One dog had an intraoperative fracture of the distal tibial tuberosity attachment with complete detachment in conjunction with implant placement. In this case, the tibial tuberosity was additionally stabilized with a 0.8-mm cerclage wire, and therefore was considered a major complication.[16] Fourteen dogs (48%) had a small cranial cortical fissure at the distal tibial tuberosity attachment visible on the postoperative radiographs. These were subperiosteal and were left to heal without additional stabilization or any changes to postoperative protocol. Therefore, they were classified as minor complications. All such fissures were healed at the 4- to 6-week postoperative radiographs.

Postoperative Complications and Outcome at the Short Term

All the dogs had a control visit and suture removal on days 10 to 12 and were seen by physiotherapists from day 14 on and had the first follow-up visit (average 6 weeks) with radiographs and outcome assessment. Postoperative radiographs at the first follow-up visit showed stable implants and bone healing at the osteotomy site in all the dogs. The lameness score at reevaluation was considerably improved with an average score of 0.6. One owner failed to show up at the 6-week appointment but came for a long-term reevaluation at 18 months postoperatively. No dog presented with a surgical site infection, implant failure, or tibia fracture.

Medium- to Long-Term Outcome

The medium- to long-term follow-up was available in 20 of the 23 dogs (87%) with a range of 6 to 38 months (mean: 18 months). Eight (40%) dogs were followed up by telephone interview using the LOAD questionnaire and 12 dogs (60%) came back for a long-term follow-up appointment. Three dogs (13%) were lost to long-term follow-up. The average LOAD score was 3.6 (ranged: 0–13) and the average lameness score was 0. All the dogs presented at a clinical follow-up were considered lame free.

All the owners were overall pleased with the long-term result after surgery based on the LOAD score and the return to normal activity.

Result from Pressure-Sensitive Walkway

Gait analysis was performed as early as 6 months after the TTA procedure (up to 4 years postoperatively). The SI impulse of the hindlimbs was 1.04 ± 0.08 in the control group, 1.02 ± 0.12 in TTA unilateral, and 1.10 ± 0.15 in TTA bilateral. The SI maximum force of the hindlimbs was 1.02 ± 0.07 in the control group, 1.02 ± 0.09 in TTA unilateral, and 1.08 ± 0.14 in TTA bilateral. The SI maximum force of the frontlimbs was 1.05 ± 0.06 in the control group (►**Table 1**), 1.03 ± 0.10 in TTA unilateral, and 1.01 ± 0.09 in TTA bilateral. The SI maximum force of the frontlimbs/hindlimbs was

Table 1 Results of the PSW examination of healthy control dogs ($n = 9$) and TTA rapid/tiny (unilateral, $n = 19$; bilateral, $n = 7$)

	Control	TTA unilateral	TTA bilateral
SI impulse of the hindlimbs (kg*sec)	1.04 ± 0.08	1.02 ± 0.12	1.10 ± 0.15
SI maximum force of the hindlimbs	1.02 ± 0.07	1.02 ± 0.09	1.08 ± 0.14
SI maximum force of the frontlimbs	1.05 ± 0.06	1.03 ± 0.10	1.01 ± 0.09
SI maximum force of the frontlimbs/hindlimbs	1.68 ± 0.13	1.77 ± 0.2	1.85 ± 0.31

Abbreviation: PSW, pressure-sensitive walkway; SI, symmetry index.
Note: $p > 0.05$ for all measurements.

1.68 ± 0.13 in the control group, 1.77 ± 0.2 in TTA unilateral, and 1.85 ± 0.31 in TTA bilateral. There were not any differences in the SI maximum force and impulse between the healthy control group and the dogs treated with TTA ($p = 0.7113–0.872$; ►**Figs. 1** and **2**). There was no difference between the TTA Rapid and the TTA Tiny groups in all the measured parameters ($p = 0.7565–0.9681$).

Discussion

The overall clinical outcome was good to excellent in the previous TTA rapid study[3] and in this study describing the new TTA Tiny. The PSW results have been validated in several studies, confirming that it is more sensitive and specific than the visual lameness examination, as well as more repeatable when compared to the force plate systems.[20–26]

Brønniche Møller Nielsen and colleagues questioned the reliability of the SI in their study, which showed an insufficient overlap performance, indicating lack of ability for the SI to clearly distinguish healthy from lame dogs.[27] Despite this, SI is currently one of the most utilized modalities.

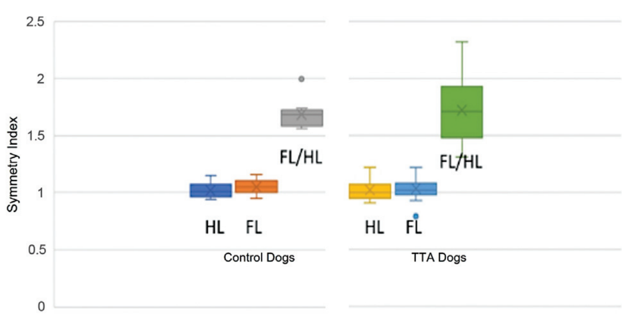

Fig. 1 Symmetry index (SI) maximum force (kg) of control dogs and unilaterally TTA treated dogs 6 to 48 months postoperatively ($n = 19$). FL, frontlimbs, HL, hindlimbs.

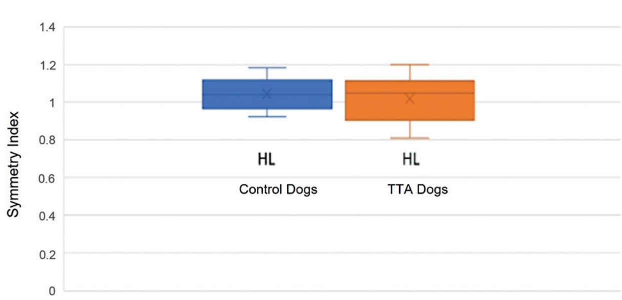

Fig. 2 Symmetry index (SI) impulse (kg*sec) of control dogs and unilaterally TTA treated dogs 6 to 48 months postoperatively ($n = 19$). HL, hindlimbs.

The use of an objective outcome measure like the PSW for medium- to long-term outcome has not been done in the previous study of TTA implants.

The data from the PSW in this study were obtained at medium- to long-term term follow-up (median: 72 weeks). Preoperative PSW measurement was not obtained in any of the dogs included in this study mainly due to the severity of lameness at presentation; instead a healthy group of small dogs were used as reference data.

All the dogs showed a symmetry in the hind- and frontlimbs with no difference compared with the control group ($p > 0.05$). For the group of bilaterally operated dogs, no weight was shifted to the frontlimbs, which is often the case with pain in the hindlimbs or lower back. These PSW results show that after a TTA procedure in small dogs a good long-term function of the operated hindlimbs can be achieved. The rate of major complications of the TTA Tiny procedure was low. No postoperative infection was noted, which is interesting because no peri- or postoperative antibiotic prophylaxis was used. This result further validates the low infection rate reported by Dyall and Schmökel performing the original TTA Rapid in small breed dogs without antibiotic prophylaxis.[3] In our study, one dog (3%) had an intraoperative fracture of the distal tibial tuberosity attachment with complete detachment and required additional fixation. Fifteen dogs (52%) had subperiosteal cranial cortical fissures, at the distal end of the osteotomy, which were left to successfully heal with no further treatment.

Previous studies have shown that small breed dogs often have a high TPA, ranging from 25 ± 3 to 37 ± 5 degrees, which corresponds to the mean TPA of 27.3 degrees (range: 18–35 degrees) in our study.[28–34]

A large TPA makes a large TTA advancement necessary to correct the cranial tibial thrust and achieve a PTA of 90 degrees. The geometry of the TTA Rapid cage defines the length of the necessary osteotomy to fit the cage correctly and provide a buttress support for the tuberosity. In small breed dogs with a large TPA, a relatively longer osteotomy is necessary compared to larger dogs. The osteotomy, therefore, reaches the diaphysis of the tibia distal to the tibial tuberosity. In the case study from Dyall and Schmökel, two tibial fractures were reported after a TTA using the original TTA Rapid cage in small dogs. Such observations have prompted the development of the new geometry of the TTA Tiny cages,

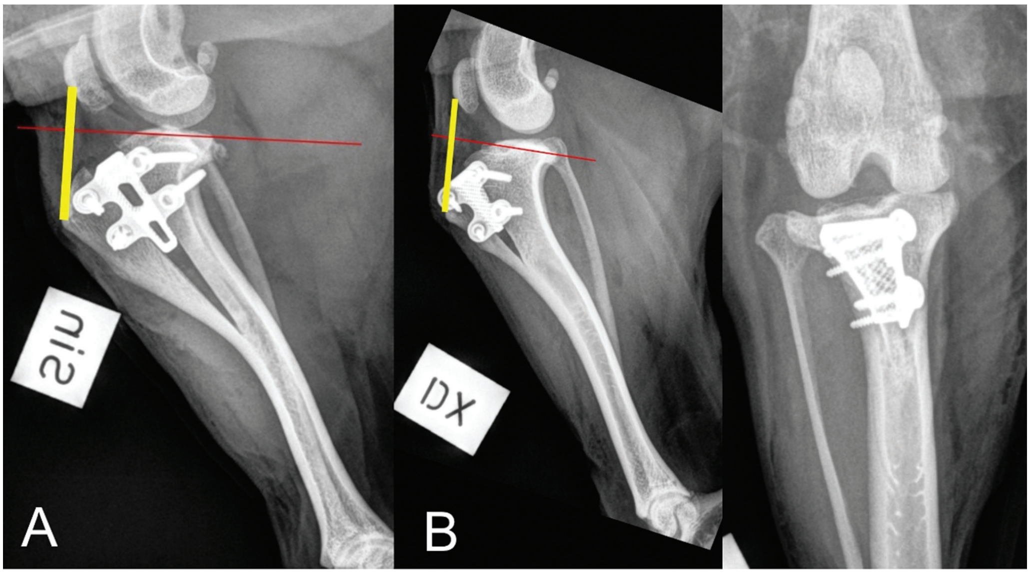

Fig. 3 Postoperative lateral radiographs showing successful TTA in Bichon Frisé of the same bodyweight and same cage size. Notice the longer osteotomy necessary for the (**A**) TTA Rapid compared to the (**B**) TTA Tiny. The postoperative patellar tendon angle (PTA) is indicated with the *red* and *yellow lines*.

allowing the cage to fit with a significantly shorter osteotomy. No fracture of the tibia is reported in this series (**►Figs. 3** and **4**), suggesting that the goal of avoiding a longer osteotomy causing potential tibial fractures.

The owners of all the included dogs, except two who were lost to follow-up, also filled in the standardized LOAD questionnaire. The mean LOAD score at medium- to long-term follow-up was 3.6 (range: 0–13) and the average lameness score was 0, indicating a considerable improvement. Ten of these dogs did not come to a follow-up visit and although the LOAD score is not as reliable as a clinical examination and PSW, it showed that the clients saw a great

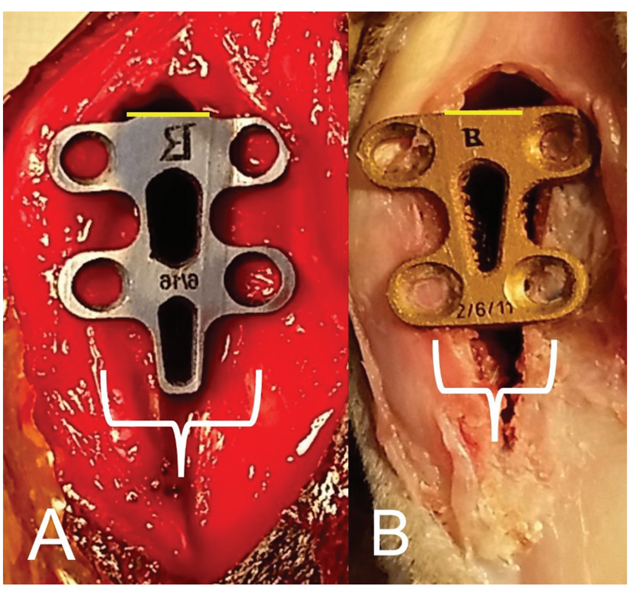

Fig. 4 (**A**) Original TTA Rapid cage and (**B**) the new TTA Tiny cage. The distal screw holes are closer together, and the cage geometry of the TTA Tiny is shorter and narrower, leading to a shorter necessary osteotomy to fit the cage. The *yellow bars* indicate 6 mm.

improvement in their dogs after surgery and they all expressed satisfaction with the procedure. Both series with the TTA Rapid and the TTA Tiny cages achieved a similar postoperative PTA with 90.8 ± 2.9 and 92.2 ± 4.06 degrees, respectively. In four dogs the preoperative planning suggested a 7.5 mm cage rather than a 6 mm cage, but the 7.5 mm TTA Rapid cage with the original design could not be fitted into the small tibias without an osteotomy considered too long. A 6-mm TTA Tiny cage was used giving undercorrection of the PTA (102.7–105.2 degrees). Clinically the dogs improved to a good result and no subsequent meniscal tears occurred. These dogs, with a tibia size and individual TPA falling between a 6- and a 7.5-mm advancement, demonstrate the need for a 7.5-mm short osteotomy TTA Tiny cage.

Our study reports a medial meniscal injury rate of 20% at the time of surgery. This is like previous studies that report an incidence of meniscal injury of 15 to 48% in small breed dogs.[1,3,31,33,34] Similar to the study of Dyall and Schmökel, we found neither a correlation between a high TPA and meniscal injury nor an increased incidence of meniscal injury with a longer duration of lameness, which was the finding in the study of Hayes and colleagues.[3,35] Dyall and Schmökel reported an occurrence of late meniscal injury of 4.7%, which is similar to the results from studies of late meniscal injuries in large dogs.[3,13,36–38] In this cohort of TTA in small dogs, there were not any cases identified with late meniscal injury. This could be due to the achieved postoperative TPA, within the recommended 90 ± 5 degrees, eliminating substantial subluxation of the tibia.

Limitations of this study include a small sample size and the retrospective nature of the study. Nevertheless, the data from the validated LOAD score and the long-term PSW results of 19 dogs compared with a healthy control group give evidence of a successful treatment based on objective data.

In conclusion, we report the usefulness and safety of the TTA Tiny implant system for treatment of CrCL rupture in small dogs with good long-term outcomes as evidenced by PSW analysis and standardized client reports.

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Conflict of Interest
None declared.

References

1 Harasen G. Canine cranial cruciate ligament rupture in profile. Can Vet J 2003;44(10):845–846
2 Harasen G. Canine cranial cruciate ligament rupture in profile: 2002-2007. Can Vet J 2008;49(02):193–194
3 Dyall B, Schmökel H. Tibial tuberosity advancement in small-breed dogs using TTA Rapid implants: complications and outcome. J Small Anim Pract 2017;58(06):314–322
4 Kowaleski MP, Boudrieau RJ, Pozzi A. Stifle joint. In: Johnston SA, Tobias KM, eds. Veterinary Surgery: Small Animal. 2nd ed. Philadelphia, PA: Elsevier; 2018:1080–1081
5 Roush JK. Canine cranial cruciate disease: updating our knowledge about pathogenesis & diagnosis. Todays Vet Pract 2013
6 Brioschi V, Arthurs GI. Cranial cruciate ligament rupture in small dogs (<15 kg): a narrative literature review. J Small Anim Pract 2021;62(12):1037–1050
7 Comerford E, Forster K, Gorton K, Maddox T. Management of cranial cruciate ligament rupture in small dogs: a questionnaire study. Vet Comp Orthop Traumatol 2013;26(06): 493–497
8 Duerr FM, Martin KW, Rishniw M, Palmer RH, Selmic LE. Treatment of canine cranial cruciate ligament disease. A survey of ACVS diplomates and primary care veterinarians. Vet Comp Orthop Traumatol 2014;27(06):478–483
9 Vasseur PB, Pool RR, Arnoczky SP, Lau RE. Correlative biomechanical and histologic study of the cranial cruciate ligament in dogs. Am J Vet Res 1985;46(09):1842–1854
10 Ferreira AJA, Bom RM, Tavares SO. Tibial tuberosity advancement technique in small breed dogs: study of 30 consecutive dogs (35 stifles). J Small Anim Pract 2019;60(05):305–312
11 Hackett M, St Germaine L, Carno MA, Hoffmann D. Comparison of outcome and complications in dogs weighing less than 12 kg undergoing miniature tibial tuberosity transposition and advancement versus extracapsular stabilization with tibial tuberosity transposition for cranial cruciate ligament disease with concomitant medial patellar luxation. Vet Comp Orthop Traumatol 2021;34(02):99–107
12 Jandi AS, Schulman AJ. Incidence of motion loss of the stifle joint in dogs with naturally occurring cranial cruciate ligament rupture surgically treated with tibial plateau leveling osteotomy: longitudinal clinical study of 412 cases. Vet Surg 2007;36(02): 114–121
13 Lafaver S, Miller NA, Stubbs WP, Taylor RA, Boudrieau RJ. Tibial tuberosity advancement for stabilization of the canine cranial cruciate ligament-deficient stifle joint: surgical technique, early results, and complications in 101 dogs. Vet Surg 2007;36(06): 573–586
14 Boudrieau RJ. Tibial plateau leveling osteotomy or tibial tuberosity advancement? Vet Surg 2009;38(01):1–22
15 Dennler R, Kipfer NM, Tepic S, Hassig M, Montavon PM. Inclination of the patellar ligament in relation to flexion angle in stifle joints of dogs without degenerative joint disease. Am J Vet Res 2006;67(11):1849–1854
16 Cook JL, Evans R, Conzemius MG, et al. Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopedic studies in veterinary medicine. Vet Surg 2010; 39(08):905–908
17 Kowaleski MP, Boudrieau RJ, Pozzi A. Stifle joint. In: Johnston SA, Tobias KM, eds. Veterinary Surgery: Small Animal. Philadelphia, PA: Elsevier; 2018:1121
18 Jerram RM, Walker AM. Cranial cruciate ligament injury in the dog: pathophysiology, diagnosis and treatment. N Z Vet J 2003;51 (04):149–158
19 Johnson JM, Johnson AL. Cranial cruciate ligament rupture. Pathogenesis, diagnosis, and postoperative rehabilitation. Vet Clin North Am Small Anim Pract 1993;23(04):717–733
20 Evans R, Horstman C, Conzemius M. Accuracy and optimization of force platform gait analysis in Labradors with cranial cruciate disease evaluated at a walking gait. Vet Surg 2005;34(05): 445–449
21 Bertram JE, Lee DV, Case HN, Todhunter RJ. Comparison of the trotting gaits of Labrador Retrievers and Greyhounds. Am J Vet Res 2000;61(07):832–838
22 Mölsä SH, Hielm-Björkman AK, Laitinen-Vapaavuori OM. Force platform analysis in clinically healthy Rottweilers: comparison with Labrador Retrievers. Vet Surg 2010;39(06):701–707
23 Voss K, Wiestner T, Galeandro L, Hässig M, Montavon PM. Effect of dog breed and body conformation on vertical ground reaction forces, impulses, and stance times. Vet Comp Orthop Traumatol 2011;24(02):106–112
24 Budsberg SC, Verstraete MC, Soutas-Little RW, Flo GL, Probst CW. Force plate analyses before and after stabilization of canine stifles for cruciate injury. Am J Vet Res 1988;49(09): 1522–1524
25 Jevens DJ, DeCamp CE, Hauptman J, Braden TD, Richter M, Robinson R. Use of force-plate analysis of gait to compare two surgical techniques for treatment of cranial cruciate ligament rupture in dogs. Am J Vet Res 1996;57(03):389–393
26 Lascelles BD, Roe SC, Smith E, et al. Evaluation of a pressure walkway system for measurement of vertical limb forces in clinically normal dogs. Am J Vet Res 2006;67(02):277–282
27 Brønniche Møller Nielsen M, Pedersen T, Mouritzen A, et al. Kinetic gait analysis in healthy dogs and dogs with osteoarthritis: an evaluation of precision and overlap performance of a pressure-sensitive walkway and the use of symmetry indices. PLoS One 2020;15(12):e0243819
28 Selmi AL, Padilha Filho JG. Rupture of the cranial cruciate ligament associated with deformity of the proximal tibia in five dogs. J Small Anim Pract 2001;42(08):390–393
29 Macias C, Mckee WM, May C. Caudal proximal tibial deformity and cranial cruciate ligament rupture in small-breed dogs. J Small Anim Pract 2002;43(10):433–438
30 Petazzoni M. CCLR in toy breeds. Do we really need locking plates? Paper presented at: 16th ESVOT Congress,. Bologna, Italy on September 12–15, 2012
31 Witte PG, Scott HW. Tibial plateau leveling osteotomy in small breed dogs with high tibial plateau angles using a 4-hole 1.9/2.5 mm locking T-plate. Vet Surg 2014;43(05):549–557
32 Su L, Townsend KL, Au J, Wittum TE. Comparison of tibial plateau angles in small and large breed dogs. Can Vet J 2015;56(06): 610–614
33 Barnes DC, Trinterud T, Owen MR, Bush MA. Short-term outcome and complications of TPLO using anatomically contoured locking compression plates in small/medium-breed dogs with "excessive" tibial plateau angle. J Small Anim Pract 2016;57(06): 305–310
34 Cosenza G, Reif U, Martini FM. Tibial plateau levelling osteotomy in 69 small breed dogs using conically coupled 1.9/2.5. mm locking plates. A clinical and radiographic retrospective assessment. Vet Comp Orthop Traumatol 2015;28(05): 347–354

35 Hayes GM, Langley-Hobbs SJ, Jeffery ND. Risk factors for medial meniscal injury in association with cranial cruciate ligament rupture. J Small Anim Pract 2010;51(12):630–634
36 Stein S, Schmoekel H. Short-term and eight to 12 months results of a tibial tuberosity advancement as treatment of canine cranial cruciate ligament damage. J Small Anim Pract 2008;49(08):398–404
37 Hoffmann DE, Miller JM, Ober CP, Lanz OI, Martin RA, Shires PK. Tibial tuberosity advancement in 65 canine stifles. Vet Comp Orthop Traumatol 2006;19(04):219–227
38 Dymond NL, Goldsmid SE, Simpson DJ. Tibial tuberosity advancement in 92 canine stifles: initial results, clinical outcome and owner evaluation. Aust Vet J 2010;88(10):381–385