



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

Jessica Entoft<sup>1</sup> Ditte Skytte<sup>2</sup> Hugo Schmökel<sup>3</sup> Barbara Dyal<sup>4</sup>

<sup>1</sup>Evidensia Specialistdjursjukhuset Strömsholm, Strömsholm, Västmanland, Sweden

<sup>2</sup>Surgical Department, Specialistdjursjukhuset, Strömsholm, Sweden

<sup>3</sup>Specialistdjursjukhuset – Ryggcenter, Strömsholm, Sweden

<sup>4</sup>Awake Djursjukhus, Stockholm, Sweden

**Address for correspondence** Jessica Entoft, DVM, Evidensia Specialistdjursjukhuset Strömsholm, Djursjukhusvägen 11, Strömsholm, Västmanland 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.<sup>1–5</sup> The condition is described as a degenerative and progressive weakening of the ligament and the pathology behind the degeneration is not yet fully understood.<sup>4</sup>

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.<sup>2,3</sup> Treatment options for cranial cruciate ligament (CrCL) insufficiency in small breed dogs include conservative management, extracapsular stabilization, cranial closing wedge osteotomy, tibial plateau levelling osteotomy, center of rotation of angulation (CORA) based levelling osteotomy (CBLO), and tibial tuberosity advancement.<sup>4,6</sup>

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.<sup>7,8</sup> Studies have shown that conservative management is likely to result in prolonged average recovery time of approximately 4 months.<sup>6,9</sup>

Dyall and Schmökel reported good to excellent midterm outcome using the TTA Rapid implants in 48 stifles in small breed dogs.<sup>3</sup> 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.<sup>3,10,11</sup> 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,<sup>12</sup> 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

Cranio-caudal 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.<sup>13</sup> In stifles with clear tibial subluxation, additional measurements were made on the contralateral healthy stifle using the anatomical landmark method.<sup>14,15</sup>

## 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<sub>2</sub> 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.<sup>16</sup> 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.<sup>17</sup> They were also advised to start formal rehabilitation including water treadmill after 2 weeks to enhance limb function and muscle circumference.<sup>18,19</sup>

## 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.<sup>3</sup>

### 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  $92.2 \pm 4.06$  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.<sup>16</sup> 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  $1.04 \pm 0.08$  in the control group,  $1.02 \pm 0.12$  in TTA unilateral, and  $1.10 \pm 0.15$  in TTA bilateral. The SI maximum force of the hindlimbs was  $1.02 \pm 0.07$  in the control group,  $1.02 \pm 0.09$  in TTA unilateral, and  $1.08 \pm 0.14$  in TTA bilateral. The SI maximum force of the frontlimbs was  $1.05 \pm 0.06$  in the control group (–Table 1),  $1.03 \pm 0.10$  in TTA unilateral, and  $1.01 \pm 0.09$  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 ( $\text{kg}^*\text{sec}$ )	$1.04 \pm 0.08$	$1.02 \pm 0.12$	$1.10 \pm 0.15$
SI maximum force of the hindlimbs	$1.02 \pm 0.07$	$1.02 \pm 0.09$	$1.08 \pm 0.14$
SI maximum force of the frontlimbs	$1.05 \pm 0.06$	$1.03 \pm 0.10$	$1.01 \pm 0.09$
SI maximum force of the frontlimbs/hindlimbs	$1.68 \pm 0.13$	$1.77 \pm 0.2$	$1.85 \pm 0.31$

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

$1.68 \pm 0.13$  in the control group,  $1.77 \pm 0.2$  in TTA unilateral, and  $1.85 \pm 0.31$  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<sup>3</sup> 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.<sup>20–26</sup>

Brønniche Møller Nielsen and colleagues questioned the reliability of the SI in their study, which showed an insuffi-

cient overlap performance, indicating lack of ability for the SI to clearly distinguish healthy from lame dogs.<sup>27</sup> Despite this, SI is currently one of the most utilized modalities.

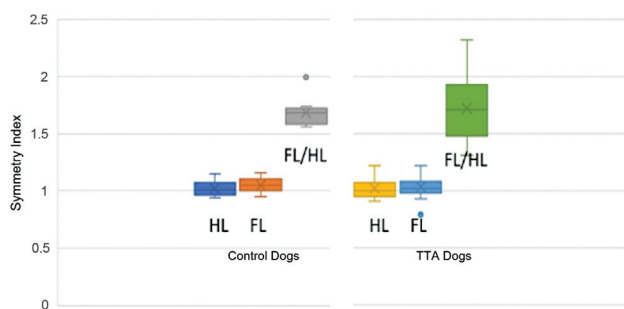
The use of an objective outcome measure like the PSW for medium- to long-term outcome has not been done in the previous study of TTA implants.

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.

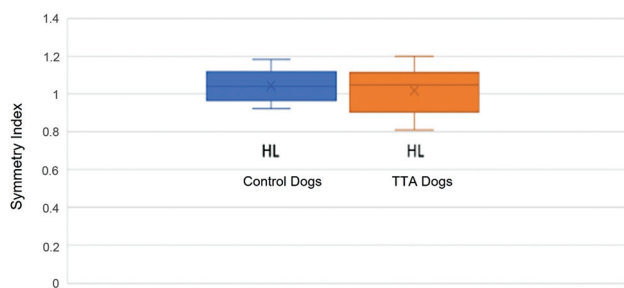
All the dogs showed a symmetry in the hind- and frontlimbs with no difference compared with the control group ( $p > 0.05$ ). For the group of bilaterally operated dogs, no weight was shifted to the frontlimbs, which is often the case with pain in the hindlimbs or lower back. These PSW results show that 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.<sup>3</sup> 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  $25 \pm 3$  to  $37 \pm 5$  degrees, which corresponds to the mean TPA of 27.3 degrees (range: 18–35 degrees) in our study.<sup>28–34</sup>

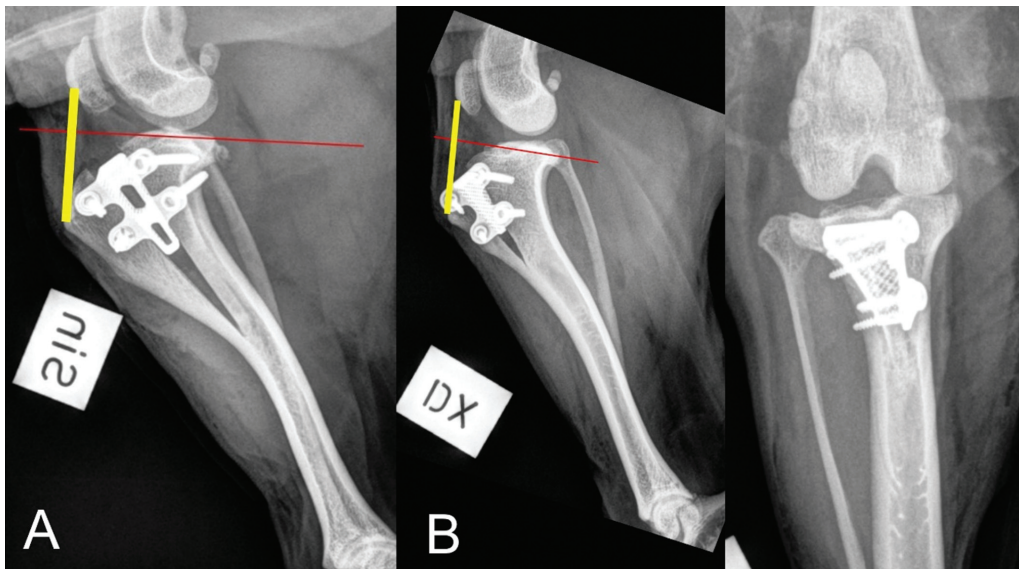
A large TPA makes a large TTA advancement necessary to correct the cranial tibial thrust and achieve a PTA of 90 degrees. The geometry of the TTA Rapid cage defines the length of the necessary osteotomy to fit the cage correctly and provide a buttress support for the tuberosity. In small breed dogs with 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. 1** Symmetry index (SI) maximum force ( $\text{kg}$ ) 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 ( $\text{kg}^*\text{sec}$ ) of control dogs and unilaterally TTA treated dogs 6 to 48 months postoperatively ( $n = 19$ ). HL, hindlimbs.



**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.

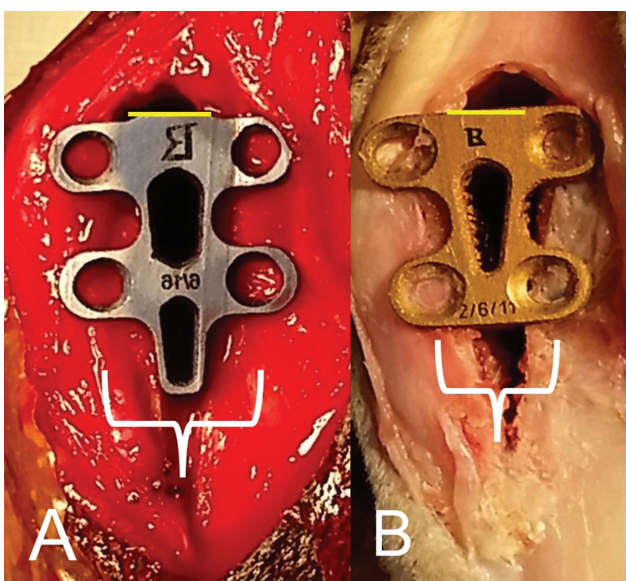
allowing the cage to fit with a significantly shorter osteotomy. No fracture of the tibia is reported in this series (→ **Figs. 3 and 4**), suggesting that the goal of avoiding a longer osteotomy causing potential tibial fractures.

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

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  $90.8 \pm 2.9$  and  $92.2 \pm 4.06$  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 under-correction 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.<sup>1,3,31,33,34</sup> 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.<sup>3,35</sup> 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.<sup>3,13,36–38</sup> 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  $90 \pm 5$  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.



**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.

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.

#### Funding

None.

#### Conflict of Interest

None declared.

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