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

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Keywords
Complications, small breed dogs, stifle, retrospective study, TPLO, tibial plateau levelling osteotomy

Summary
Objective: To report clinical experiences with the tibial plateau levelling osteotomy (TPLO) procedure in small breed dogs with cranial cruciate ligament (CCL) disease using specific, conically coupled, 1.9/2.5 mm locking plates and evaluating short-term complications and outcome.

Methods: Medical records of small breed dogs (<15 kg) that underwent TPLO using 1.9/2.5 mm locking plates were reviewed retrospectively. The preoperative, postoperative and six to eight weeks postoperative tibial plateau angle (TPA) measurements were determined from the radiographic images. Lameness evaluation was assessed subjectively preoperatively and six to eight weeks postoperatively.

Results: Sixty-nine small breed dogs (n = 79 stifles) were included in the study. Mean (± SD) preoperative TPA was 29.0 ± 3.4°, postoperative TPA was 5.8 ± 2.5°, and six to eight weeks postoperative TPA was 7.3 ± 4.1°. Sixteen complications occurred in 12 out of 79 TPLO procedures: three were intraoperative (intra-articular screw placement) and 13 were postoperative complications, of which nine were identified as minor complications not requiring surgical intervention and four as major complications requiring additional surgical intervention, including tibial tuberosity fracture (n = 1), osteomyelitis (n = 1), screw failure (n = 1), and plate breakage (n = 1). Lameness scores by clinical assessment reduced from a median value of 3/4 preoperatively to 1/4 at six to eight weeks postoperatively.

Clinical significance: 1.9/2.5 mm locking plates appear to be a valid choice of implant for the stabilization of unilateral TPLO in small breed dogs.

Introduction
Cranial cruciate ligament disease has been recognized as a cause of hindlimb lameness in both small and large breed dogs since 1926 (1). Cranial tibial thrust is the cranially directed shear force on the tibia with respect to the femur generated during weight bearing (2). The cranial cruciate ligament contributes to passive opposition of cranial tibial thrust. Deficiency of the cranial cruciate ligament permits cranial tibial translation during weight bearing, resulting in degradation of the hyaline cartilage matrix, inflammation, and osteoarthritis (3–5). Slocum and Slocum proposed that cranial tibial thrust magnitude is directly proportional to the tibial plateau angle (TPA) (6). It has been suggested that small breed dogs may have a higher TPA than large breed dogs, with TPA ranging from 21° to 34° (mean: 27.4°) and 27° to 40° (mean TPA not reported) (7, 8). A high TPA in small breed dogs has been associated with caudal deformity of the proximal tibia (9, 10).

Concern about body weight as a variable in the management of dogs with cranial cruciate ligament rupture was first expressed in 1984 (11). In that study, conservative management resulted in acceptable hindlimb function in up to 85% of small breed dogs (<15 kg) with cranial cruciate ligament disease (11, 12). However, recovery time was prolonged (mean: 4 months) and 14.3% of dogs remained lame (12). Extra-capsular stabilization consists of placing one or more extracapsular sutures across the joint to neutralize the cranial tibial thrust statically. Extra-capsular stabilization improves stability and hindlimb function during the postoperative period (13–15). However, long-term stifle stability relies on periarthritic fibrosis, and suture failure resulting in joint instability does occur more commonly than one may expect, especially in dogs with a high activity level (15–20).
A greater TPA in smaller dogs may produce a greater cranial tibial thrust and could theoretically contribute to early failure of extra-capsular stabilization techniques. Therefore, performance of a tibial osteotomy with the aim of levelling the tibial slope may be more appropriate in this population of dogs. Tibial plateau levelling osteotomy provides stifle stability by neutralizing tibiofemoral shear forces dynamically (6, 21).

Increased tibial plateau rotation associated with a high TPA may result in a lack of buttress support of the tibial tuberosity. It has been suggested that rotation beyond the point of patellar ligament insertion would make the tibial tuberosity more susceptible to fracture (22, 23). To obviate this problem, a combination of tibial plateau levelling osteotomy and cranial tibial closing wedge osteotomy has been proposed in dogs with a steep TPA, however this may be technically demanding in small breed dogs due to the small bone (22). Tibial plateau levelling osteotomy in small breed dogs with a high TPA (>30°) has been reported previously without encountering tibial tuberosity fracture (24).

Both conventional and locking plates are available for small breed dogs. Locking screws help maintain the tibial plateau position during plate application (25). Small plate contouring discrepancies and subtle shifts in alignment when tightening conventional screws can have a great impact on both osteotomy compression and corrected tibial plateau angle (24–27).

Tibial plateau levelling osteotomy using a 4-hole 1.9/2.5 mm conically-coupled locking T-plate in small breed dogs with a steep TPA has been reported previously without encountering tibial tuberosity fracture (24).

Material and methods

Medical records of dogs that underwent tibial plateau levelling osteotomy utilizing 1.9/2.5 mm conically-coupled locking plates at a referral centre (Tierklinik in Böbingen) between January 2008 and November 2014 were reviewed. Inclusion criteria included a body weight of less than 15 kg, cranial cruciate ligament disease confirmed by mini-arthroscopy, complete medical records including preoperative and six to eight week postoperative subjective lameness scoring (0 = no lameness, 1 = mild, 2 = moderate, 3 = severe, 4 = non weight-bearing) by a board-certified surgeon (UR), and preoperative, postoperative and six to eight week postoperative radiographs.

Excluded from the study were dogs with incomplete medical records that could not be returned for follow-up examination six to eight weeks after surgery, dogs with neurological diseases, severe systemic diseases, or any other injuries or diseases such as patellar luxation, hip dysplasia, Legg-Calvé-Perthes disease in the limb being treated for cranial cruciate ligament disease, and dogs that underwent surgery on the limb being treated for cranial cruciate ligament disease for conditions other than cranial cruciate ligament disease. Information obtained included breed, sex, age, body weight, pre-, postoperative and six to eight week postoperative TPA, meniscal damage and treatment, saw blade size, implants applied, and complications.

All osteotomies were secured with tibial plateau levelling osteotomy plates of the mini-implant series (1.9/2.5 mm system) which were able to accommodate both 1.9 mm and 2.5 mm screws. The locking plate consisted of a stainless steel plate with titanium alloy bushing inserts and titanium self-tapping screws with a conical head that lock into the bushing inserts of the plate by conical coupling (28).

Using a standard anaesthesia protocol, dogs were premedicated with levomethadone, and anaesthesia was induced with propofol and maintained with isoflurane in oxygen. All dogs received a single administration of cefazolin (22 mg/kg IV) and ciprofloxacin or tolfenamic acid preoperatively. The dogs were positioned in dorsal recumbency with the pelvic limb suspended for surgery.

All dogs underwent a cranio-medial parapatellar mini-arthrothry for stifle exploration, and inspection of both cruciate ligaments and menisci. Meniscal injuries were treated by partial meniscectomy. After fascial incision and reflection of the sartorius muscle, no additional dissection of musculature cranial or caudal to the proximal segment was performed. A semicylindrical osteotomy of 12 or 15 mm radius was made without use of a jig. Rotation of the proximal fragment was temporarily maintained with an anti-rotational Kirschner wire and pointed reduction forceps.

The locking plate was then contoured such that the proximal two screws would converge to avoid invasion of the osteotomy gap and to improve fixation of the caudal part of the proximal tibial bone fragment. The plate was positioned on the medial surface of the tibia in a matter that best fitted the bone contour and osteotomy. Whenever possible, the plate was oriented such that the caudal margin was placed parallel to and adjacent to the caudal cortex of the tibial shaft. The type of implant was subjectively chosen by the surgeon preoperatively, considering body weight, the size and conformation of the tibia, and the amount of rotation of the proximal fragment. In every case, the plate was secured with 2.5 mm locking screws in both the proximal fragment and the tibial diaphysis. The anti-rotational Kirschner wire was removed and the surgical site closed in layers.

Radiographs were reviewed by one author (UR), with the observer blinded to all data. All measurements were made on digital radiographs using the built-in tool on a standard diagnostic imaging software system. The TPA was measured using the tangential and conventional methods.

Postoperative mediolateral radiographs were also used to determine whether rotation of the proximal fragment was beyond the point of patellar ligament insertion. Osteotomy healing was assessed on the six to eight weeks postoperative radiographs using a modified version of a previously developed grading system (International Society of Limb Salvage) (23, 30, 31, 32).
Surgery

Seventy-nine tibial plateau levelling osteotomy procedures were performed in 69 dogs by one board-certified surgeon. Bilateral simultaneous tibial plateau levelling osteotomy procedures were not performed. Meniscal injuries were apparent in 22 stifles and all were treated by partial meniscectomy. Osteotomy radius was 12 mm in 20 stifles (mean body weight: 6.1 ± 1.2 kg) and 15 mm in 59 stifles (mean body weight 9.7 ± 1.7 kg) (Figure 1). The most common plate used was the 1.2 mm thick and 25 mm long L-plate (n = 38, Figure 2), followed by the 1.9/2.5 mm Fixin® plates. Breeds were as follows: Jack Russell Terrier (n = 11), West Highland White Terrier (n = 6), Australian Terrier (n = 4), Havanese (n = 3), Yorkshire Terrier (n = 3), Bichon Frise (n = 2), Bolonka Zvetna (n = 2), Cairn Terrier (n = 2), Norwich Terrier (n = 2), Shetland Sheepdog (n = 2), Beagle (n = 1), Chihuahua (n = 1), Coton de Tulear (n = 1), Fox Terrier (n = 1), Lhasa Apso (n = 1), Miniature Schnauzer (n = 1), Patterdale Terrier (n = 1), Pug (n = 1), Shi Tzu (n = 1), Toy Poodle (n = 1), Welsh Corg (n = 1). Twenty-one dogs were mixed-breed. There were 26 spayed and 16 entire females, and 11 castrated and 16 entire males. Mean age was 8.5 ± 2.8 years and mean body weight was 8.8 ± 2.2 kg. Median preoperative subjective lameness score was 3 (range: 2–4).

Statistical analysis

Data were reported as mean ± SD for normally distributed data, or median and range for non-parametric data. Distributions of categorical and continuous variables associated with surgical procedure and were classified depending on severity as major (surgical intervention required) or minor (managed nonsurgically).

Results

Signalement

Eighty dogs (96 stifles) fulfilled the initial criteria for inclusion: all were less than 15 kg in bodyweight and treated by tibial plateau levelling osteotomy using 1.9/2.5 mm Fixin® plates. However, 11 dogs (17 stifles) were excluded from the study; five dogs (7 stifles) had medial patellar luxation or were treated surgically for patellar luxation and six dogs (10 stifles) were lost to follow-up. Thus, 69 dogs (79 stifles) were included.

Statistical analysis

Dogs were typically discharged six to 24 hours after surgery with instructions to the owner to administer carprofen (2 mg/kg daily) for 10 days. No routine postoperative antimicrobial therapy was administered. Patients were re-examined five to 10 days after surgery. Postoperative care consisted of six week confinement to a cage or a single room except for leash walks of 10–15 minutes two to three times daily.

Complications were defined as any undesirable outcome associated with the surgical procedure and were classified depending on severity as major (surgical intervention required) or minor (managed nonsurgically).

Statistical analysis

Data were reported as mean ± SD for normally distributed data, or median and range for non-parametric data. Distributions of categorical and continuous variables associated with complications were compared by use of a two-tailed Fisher’s exact test and independent t test, respectively. The two methods of TPA measurement were compared by linear regression analysis with non-normal errors. For all analyses, a value of p <0.05 was considered significant.

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Figure 1  Relationship between body weight and the saw blade used to perform the osteotomy.

Figure 2  A) Preoperative mediolateral and caudocranial views of a right tibia and stifle of a dog with a high tibial plateau angle (34°) and great subluxation of the tibia. B) Immediate postoperative mediolateral and caudocranial views showing rotation of the proximal fragment to level the tibial plateau and fixation with a locking L-plate and four screws.

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followed by the 1.5 mm thick and 32 mm long T-plates\textsuperscript{f} (n = 27), and the 1.2 mm thick and 25 mm long T-plate\textsuperscript{g} (n = 14, Figure 3, Figure 4). Seven dogs were treated with cephalexin (22–30 mg/kg PO) for 10 days postoperatively.

**Radiographic assessment**

No significant difference between the two methods of TPA measurement was observed. Mean (± SD) preoperative TPA was 29.0 ± 3.4°, postoperative TPA, 5.8 ± 2.5° and six to eight weeks postoperative TPA 7.3 ± 4.1°. The mean change in TPA between postoperative and six to eight weeks postoperative radiographs was 1.4 ± 1.6°. The proximal fragment was rotated beyond the point of patellar ligament insertion in 38 stifles (48.1%). Median osteotomy healing grade was 3 (range: 3–4).

**Complications**

Sixteen complications were recorded in 12 out of 79 tibial plateau levelling osteotomy procedures. Intra-operative complications (intra-articular screw placement) occurred in three dogs. The malpositioned screws were replaced with a shorter screw immediately after surgery and radiographs showing proper screw length and orientation were obtained.

Thirteen postoperative complications occurred: four major complications required an additional surgical intervention and the remainder nine were minor complications. Major complications included one tibial tuberosity fracture, one osteomyelitis, one screw failure, and one plate breakage.

Tibial tuberosity fracture was apparent four weeks after surgery (Figure 5) as the owner noticed the dog becoming acutely lame. This was treated with Kirschner wire fixation and tension band placement. Eight weeks after revision surgery, osteomyelitis caused by a multi-resistant Staphylococcus aureus was diagnosed, thus plate removal as part of infection treatment was performed. Outcome in terms of radiographic healing and lameness evaluation after eight weeks was assessed as good.

Failure of the caudal screw in the proximal fragment occurred in one stifle. The dog had a persistent lameness and a local infection of the incision site. Radiographs taken 16 weeks following tibial plateau levelling osteotomy procedure demonstrated good osteotomy healing and no implant loosening. However, implant removal led to the detection of the broken screw just below the screw head. At the six weeks follow-up examination, the lameness had resolved.

Plate breakage was apparent three weeks postoperatively in the stifle of a 12 kg mixed breed dog treated by tibial plateau levelling osteotomy using the 1.2 mm L-plate. The owners reported excessive activity within 10 days of surgery. The plate was removed and the osteotomy re-stabilized by a 3.0/3.5 mm locking T-plate\textsuperscript{h}. Healing was progressing at six to eight weeks with active callus formation and no lameness was noted.

Minor complications included surgical site infection (n = 6) and seroma (n = 3).
All surgical site infections resolved after antimicrobial therapy with oral cephalixin (22–30 mg/kg) for 10 days.

Short-term complications were not significantly associated with sex (p = 0.95), age (p = 0.67), body weight (p = 0.75), meniscal injury (p = 0.45), preoperative TPA (p = 0.79), postoperative TPA (p = 1), six to eight weeks postoperative TPA (p = 1), change in TPA from postoperatively to six to eight weeks postoperatively (p = 0.28), rotation of the proximal fragment beyond the point of patellar tendon insertion (p = 0.38), saw blade size (p = 0.67), or type of implant (p = 1).

Subjectively assessed median lameness scores six to eight weeks postoperatively were between 0 (n = 39) and 1 (n = 40).

Discussion

In our study tibial plateau levelling osteotomy procedures utilizing 1.9/2.5 mm conically-coupled locking TPLO plates in 79 stifles of small breed dogs were evaluated. Mean (± SD) preoperative TPA was 29.0 ± 3.4°, postoperative TPA was 5.8 ± 2.5°, and six to eight weeks postoperative TPA was 7.3 ± 4.1°. We observed an overall complication rate of 15.2% (12/79 stifles), but no predisposing factor for postoperative complications was found. The locking plates in our study resulted in a stable fixation of 77 out of 79 osteotomies. Lameness scores by clinical assessment reduced from median 3/4 preoperatively to 1/4 at six to eight weeks postoperatively.

Preoperative TPA of 29.0 ± 3.4° is consistent with the findings of similar studies in small breed dogs, reporting a higher TPA compared to other dogs (7, 8, 26). Possible explanations are that small breed dogs have a physiologically steeper TPA, or that small breed dogs with cranial cruciate ligament disease and a lower TPA respond well to other treatment options and therefore referral is not sought (7). Moreover, what in the past has been referred to as a caudal deformity of the proximal tibia, has to be considered the physiological tibia conformation in small breed dogs (9, 10). Caudal bowing of the proximal tibia associated with caudal sloping of the tibial plateau is a common finding in small breed dogs, and it results in a higher TPA compared to medium- and large breed dogs.

Meniscal injuries were found in 27.8% of stifles, which is similar to the ranges of 10–70% in large breed dogs (32–37). Late meniscal tears have been reported as frequently occurring complications, but were not observed in our study (33). This may be in part attributable to the short follow-up time in our dogs (33–38). Nevertheless, thorough evaluation of the meniscus using a probe should be performed in order to diagnose latent tears, which may result in persistent lameness after tibial plateau levelling osteotomy (39, 40).

Intra-articular screw placement occurred in three stifles. The occurrence of this complication is more of a technical error (41). Greater experience with tibial plateau levelling osteotomy using this plate system in small breed dogs may influence the type and incidence of complications over time (42). Since screw direction is imposed in locking plates, contouring of the plate may redirect the angle of the locking screws.

Depending on plate availability and subjective choice of the surgeon, different 1.9/2.5 mm locking plates were used to secure the osteotomy. Special features of these implants include the plate head that is specifically designed to facilitate adequate screw purchase in the proximal bone segment. High TPA resulting in great rotation causes the caudal portion of the proximal fragment to protrude beyond the caudal cortex of the tibial shaft, as a result the osteotomy fixation becomes technically.
challenging. For this reason, the L-shaped plate was designed to ensure appropriate osteotomy fixation and plate placement parallel to the caudal cortex of the tibial diaphysis. Furthermore, temporary stabilization prior to plate fixation is possible in some plates by inserting Kirschner wires through additional plate holes, but was never performed in our study.

Tables reporting the saw blade size and the implant used in relation to the body weight can be used as guidelines when performing tibial plateau levelling osteotomy in small breed dogs using these plates. Care must be taken not to undersize the implant, as it happened in one of our cases. A 1.2 mm L-plate broke three weeks after surgery in a 12 kg mixed breed dog. This finding suggests that the use of the 1.2 mm L-plate should be limited to dogs weighing less than 12 kg. Finally, factors other than weight, such as bone size, bone quality, age, conformation of the tibia, and osteotomy placement have to be considered when choosing the type of implant.

High TPA need increased rotation of the proximal fragment that may result in tibial tuberosity fractures. Risk factors for this include a thin postoperative tibial crest, a postoperative increase in TPA, a gap in the cranial aspect of the osteotomy after fixation, a single-session bilateral tibial plateau levelling osteotomy procedure, and lack of osteotomy planning (43–46). Also, a lack of caudal buttress support due to rotation beyond the point of patellar ligament insertion was proposed as a risk factor, but this was not confirmed by another study (22, 43).

Postoperative tibial tuberosity width greater than 10 mm has been suggested to be critical in avoiding tibial tuberosity fractures in large breed dogs, but not in small breed dogs (24, 43). The tibial crest in dogs in our study population was usually prominent, but rarely fractured, even in extreme rotations (maximum TPA: 38.00°) of the tibial plateau. Rotation beyond the patellar ligament insertion was performed in 38/79 stifles without major complications, suggesting that this condition is not a risk factor for tibial tuberosity fracture in small breed dogs. An inappropriately placed osteotomy resulting in a narrow tibial crest was considered to be the cause of a tibial tuberosity fracture in one dog in our study.

Mean postoperative change in TPA was 1.4 ± 1.6°, which supported previous evidence that use of a locking plate results in improved maintenance of TPA compared with non-locking systems (24–26). A minimum of two bicortical locking screws per fragment are typically recommended (47). The locking plates used in our study allowed two screws in each fragment, except in one stifle, as the caudal screw in the proximal fragment was found to be broken at 16 weeks. This complication occurred three times in another study and has been attributed to the steep TPA in small breed dogs and the increased degree of rotation causing the proximal fragment to displace more caudally (24). The caudal part of the construct has been suggested to be initially non-load sharing, potentially explaining the propensity for failure of the screw at this point (24).

Plate removal was performed in two stifles, because of infection, which has been reported as a complication in 3.6% to 8.4% of tibial plateau levelling osteotomies (48–50). A multi-resistant Staphylococcus aureus was isolated in one stifle following surgical correction of a tibial tuberosity fracture. The other stifle had an infection that was associated with implant failure.

While complication rates in previous studies reported 14.8% to 28% for tibial plateau levelling osteotomies using conventional plates in large breed dogs, 9.7% to 11.4% for tibial plateau levelling osteotomies using both conventional and locking plates in large breed dogs, and 36% in small- and medium-sized dogs, we observed an overall complication rate of 15.2% (12/79 dogs presented complications) (26, 33, 41, 45, 51–53). The use of different definitions and classification of complications could certainly explain complication rate differences between retrospective studies, making it difficult to directly compare results of each study. Nevertheless, unlike comparable retrospective studies, no predisposing factor for postoperative complications was found (33, 41, 45, 51–53). Previously reported risk factors include breed, sex, body weight, arthrotomy, complete ligament ruptures and a TPA greater than 30°.

Other types of locking plates for small breed dog tibial plateau levelling osteotomy have been developed recently. The Synthes plates stabilize the osteotomy with three screws in each fragment and have combi-holes that may be used to provide interfragmentary compression. Thus, Synthes TPL0 locking plates theoretically offer improved stability of the fixation. Because of the often small size of the proximal tibial fragment, placement of three screws can be technically demanding. The plates used in our study provided adequate stability with just two screws in each fragment, which resulted in healing of all the osteotomies, except for two stifles.

In our opinion, advantages of the Fixin® TPLO plates include the plate thickness. Due to the presence of a bushing insert, the thickness required for adequate conical coupling is not related to the plate thickness. This allows implants to be thin. Compared to the 2.0/2.4 Synthes® TPLO plates (2.3 mm thickness), Fixin® plates have a plate thickness of 1.2 mm or 1.5 mm. Thin implants are less stiff and much easier to contour and are ideal for distal extremities where there is less soft tissue coverage. However this could predispose to plate breakage.

Several limitations should be considered when interpreting the data of this study. The retrospective nature of our study represents a main limitation. Furthermore, clinical outcome assessment methods were limited to physical and radiographic examinations that were performed by one surgeon. Limited data on outcome was tolerated, as the focus of our study was on the technical feasibility of 1.9/2.5 mm Fixin® TPLO plates in small breed dogs, rather than on the clinical outcome. No objective assessments of limb use, such as force-plate analyses and kinematic gait evaluations, were obtained. Therefore, these findings have to be interpreted in light of this lack of objective data.

In summary, the tibial plateau levelling osteotomy procedure was performed in small breed dogs using 1.9/2.5 mm Fixin® plates. Short-term complications included a tibial tuberosity fracture associated with an inadequate osteotomy placement and a plate breakage. Plate removal as part of an infection treatment was performed in two
cases, one of which was associated with screw failure. Complication rate is comparable to large breed dogs, but no predisposing factor for postoperative complications was found. The Fixin® locking plates used in this study resulted in successful osteotomy healing of 77 out of 79 osteotomies, and were considered to be a valid choice for the stabilization of tibial plateau levelling osteotomy in small breed dogs.

Conflict of interest
The authors declare no conflict of interest related to this report.

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