Article published online: 2024-11-21

Outcome and Complications Following Medial Patellar Luxation Corrective Surgery with Tibial Tuberosity Transposition Using a Locking Plate and a Pin Fixation: 45 Unilateral and 20 Single-Session Bilateral Procedures

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Vet Comp Orthop Traumatol

Abstract

Objectives To evaluate the outcome and complications in dogs with medial patellar luxation (MPL) undergoing tibial tuberosity transposition (TTT) with a locking plate and pin fixation (Plate–Pin).

Methods This retrospective multicenter study included 65 consecutive MPL stifle surgeries using tibial tuberosity (TT) fixation with a 5-hole locking plate and a pin. The median weight of the dogs was 6.2 kg. The grade of luxation was 2/4 in 50 stifles and 3/4 in 15 stifles. Outcomes were assessed during follow-up examinations 33 to 648 days after surgery with clinical examination and radiography. Canine Orthopedic Index questionnaires were sent to owners 6 to 39 months after surgery.

Results Complications were reported in 14/65 stifles, of which 8/14 were minor and 6/14 were major. After treatment of the major complications, lameness was resolved in all cases and the MPL was resolved in 64/65 stifles.

Clinical Significance When the surgery was performed as described in this article, Plate–Pin fixation for TT during MPL surgery is a feasible technique with a lower incidence of luxation recurrence, TT avulsion, and fractures compared with recent retrospective studies with pin and tension band wire TT fixation. Further development of the locking plate TT fixation is indicated to resolve pin-related complications and to determine if fixation including a pin is necessary.

Keywords
- medial patellar luxation
- tibial tuberosity transposition
- locking plate fixation
- unilateral surgery
- single-session bilateral surgery

Introduction

Medial patellar luxation (MPL) is a common cause of pelvic limb lameness in small breed dogs.[1–4] Medial patellar luxation (MPL) is usually a developmental abnormality but can also be induced traumatically. Surgery is recommended for symptomatic dogs with MPL classified as grade 2, 3, or 4.[1,2] Tibial tuberosity transposition (TTT) is a surgical procedure to realign the quadriceps mechanism with the trochlear groove. The transposed tibial tuberosity (TT) can be fixated

received
December 15, 2023
accepted after revision
October 3, 2024

DOI https://doi.org/10.1055/s-0044-1795087.
ISSN 0932-0814.

with one or two pins with or without a tension band wire (TBW) with reported 11 to 43.1% overall complication rate.[3,5–9] It would be desirable to have a reliable TT fixation method with a lower complication rate. Alternative TT fixation methods have been developed including a pin or screw placed medial to the transposed TT,[10,11] an "impact plate" and a curved plate with locking screws,[12] a trapezoid plate and nonlocking screws,[13] and a hemicerclage.[14]

Locking plates and screws are commonly used for fracture or osteotomy stable fixation.[15,16] The use of a locking plate and pin TT fixation (Plate–Pin) in a cadaveric in vitro mechanical study was reported showing a higher load at failure values compared with Pin–TBW fixation.[17] Mechanical testing does not replicate physiologic loading or cyclic fatigue encountered during the postoperative convalescent period. Hence testing with clinical cases is needed to evaluate different methods of TT fixation. The use of locking plates has not been reported for TT fixation during MPL surgery in dogs or cats.

The objectives of this study were to assess outcome and complication rate in dogs with MPL undergoing TTT surgery using a Plate–Pin fixation.

Materials and Methods

Case Selection

This multicenter study included all dogs with grade 2 to 4 MPL treated surgically with TTT Plate–Pin fixation between December 2019 and May 2023. The operations were performed in three veterinary hospitals by three surgeons: Esa Eskelinen ($n = 26$), Ari Suhonen ($n = 21$), and Johanna Makitaipale ($n = 18$) MPL Plate–Pin procedures. The surgeons were nonboarded with over 30 years, over 10 years, and over 15 years of experience, respectively. Anesthesia, surgical technique, postoperative care, and follow-up examination were described in written format to maintain consistency among surgeons and centers and agreed upon by participating surgeons.

The inclusion and exclusion criteria are presented in ►**Supplementary Appendix Table A1** [available in online version only].[18–20] The femoral neck anteversion angle and the depth of the patellar groove were not considered relevant as inclusion or exclusion criteria. The owners were preoperatively informed of the results of the cadaveric study of the Plate–Pin fixation[17] and the experimental nature of the use of the locking plate fixation in clinical cases.[21] If an owner did not want to participate in Plate–Pin study, two pins and a TBW were used for TT fixation.

Perioperative Care

All dogs included in the study received perioperative cephazolin as per inclusion criteria.[22] The first dose was given 30 minutes before the skin incision, at 90-minute intervals, and was discontinued immediately after surgery. All dogs were given bupivacaine (1 mg/kg) and morphine (0.1 mg/kg) epidurally. Either carprofen (2.0 mg/kg twice daily [b.i.d.] orally [p.o.]) or meloxicam (0.1 mg/kg once daily p.o.) was given for 14 to 21 days postoperatively. Anesthesia and perioperative medications are described in detail in Appendix 1 [online only].

All dogs were discharged from the hospital on the same day within 2 to 8 hours after surgery. At discharge, owners were all given the same written instructions for postoperative care including medications, wound care, possible complications, and a basic at-home rehabilitation program.[23] On-leash-only walks for 6 weeks on a good traction surface was recommended. Vigorous exercise, slippery surfaces, and stairs were to be completely avoided for 6 weeks. Trazadone (10 mg/kg b.i.d.) was dispensed on an as needed basis to help control activity at home for 6 weeks. Owners were instructed to return for a follow-up examination and radiographs 10 weeks after surgery. Normal activity was allowed after the follow-up examination with radiographic evidence of bone healing and stability of the transposed TT.

Surgery

All Plate–Pin procedures included a parapatellar approach to the stifle starting with a craniolateral skin incision. The incision extended distal to the femorotibial joint on the medial side to expose the proximal medial tibia. The tibialis cranialis muscle was left intact on the lateral aspect of the tibia. The joint was opened through a lateral retinaculum incision and the patella was luxated medially. The cranial cruciate ligament and menisci were evaluated. A trochlear wedge recession[1] was performed if the femoral trochlear groove was subjectively considered to be of inadequate depth. Templates were preoperatively superimposed on the mediolateral radiographs to select the optimum plate size, and sizing was confirmed during surgery with the plate placed on the tibia (►**Fig. 1**). The largest plate that fitted perfectly on the TT and tibial diaphysis was chosen. The proximal end of the osteotomy was located cranial to the long digital extensor tendon groove. The distal end of the osteotomy was in the mid-section of the plate that is void of screw holes. At the distal end of the osteotomy, the craniocaudal width of the osteotomized TT was less than one-third of the entire craniocaudal dimension of the tibia to minimize the risk of tibial diaphyseal fracture.[24] The desired and intended TT osteotomy line was marked with electrocautery with the plate laying in its intended location. Optionally, the distal end of the TT osteotomy was marked with a 1.1 to 1.5 mm diameter drill hole. The markers helped to identify and localize the distal end point of the TT osteotomy and to create a precise fit for the plate. The TT osteotomy was made using an oscillating saw perpendicular to the sagittal plane of the proximal tibia. With the osteotomy completed, the TT was transposed carefully and slowly. If only a small amount of transposition was needed, the bone at the distal end of the TT osteotomy was bent during TT positioning. If more transposition was needed, a hinged osteotomy was created at the distal end of the TT osteotomy. It was at surgeon's discretion to drill two or three 1.1 to 1.5 mm diameter partial or full thickness holes on the medial aspect of the tibia at the distal end of the intended TT osteotomy (►**Fig. 1B**). This facilitated the hinged fracture to occur at the intended location at the distal end of the TT osteotomy and minimized

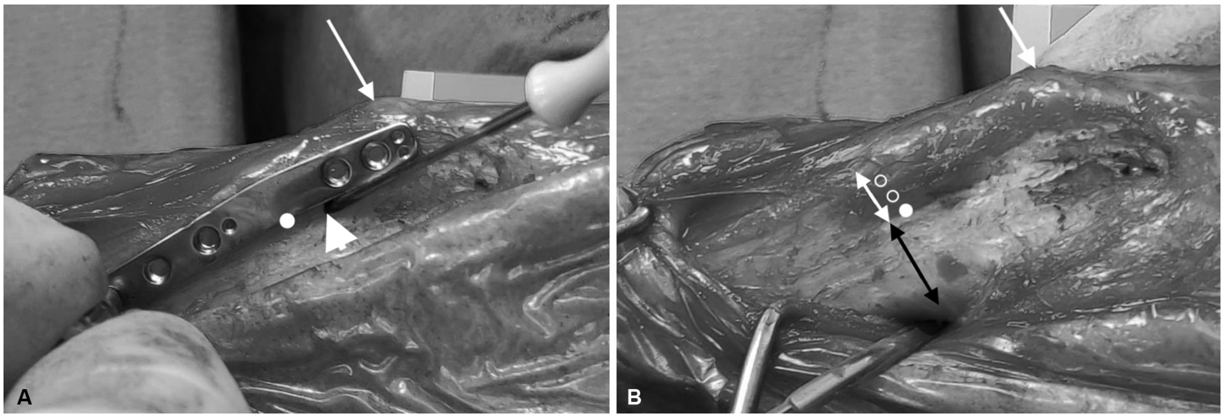

Fig. 1 The medial aspect of the right proximal tibia of a 7-year-old 5.7 kg Miniature Poodle with a grade 2 medial patellar luxation (**A**). The insertion of the patellar ligament is shown (white arrow). The distal end of the osteotomy is shown (white dot). A 2.0/1.5 mm locking plate is in place in its intended location. The tibial tuberosity transposition osteotomy line was marked with monopolar electrocautery (white arrowhead) on the tibia. Optionally, a 1.5 mm diameter hole can be drilled at the distal end of the intended osteotomy. It was at surgeon's discretion to drill two or three 1.1–1.5 mm diameter partial or full thickness holes (**B**, white circles) on the medial aspect of the tibia at the distal end of the intended TT osteotomy. The distance from the osteotomy to the caudal cortex of the tibia (black double arrow) should be as wide as possible to minimize the risk of tibial diaphyseal fracture. The distance from the osteotomy to the cranial cortex of the tibia is shown (white double arrow).

the risk of an inadvertent fracture of the more proximal TT during transposition.

The TT was initially stabilized with a single pin (►**Fig. 2A–C**). Patellar alignment in the trochlear groove was then evaluated. If necessary, the pin was removed, and the TT was repositioned into a more perfect alignment. The transposed TT was cranially-caudally compressed against the tibia with pointed bone holding reduction forceps to close the gap between the osteotomy and the proximal tibia. The straight locking plate (Veterinary Orthopedics Scandinavia Ltd, Helsinki, Finland) was contoured in the sagittal plane and mediolaterally using plate bending pliers to match to the medial surface of the TT and proximal tibia. The most proximal screw (Veterinary Orthopedics Scandinavia Ltd, Helsinki, Finland) was applied first. The most distal screw was applied second taking care to position it near the center of the tibial diaphysis. Locking screws were used. The screws were bicortical except the most distal screw, which was monocortical. The pins, plates, and locking screws were 316L stainless steel alloy. Capsulorrhaphy was performed along the retinacular incision to imbricate the joint capsule and

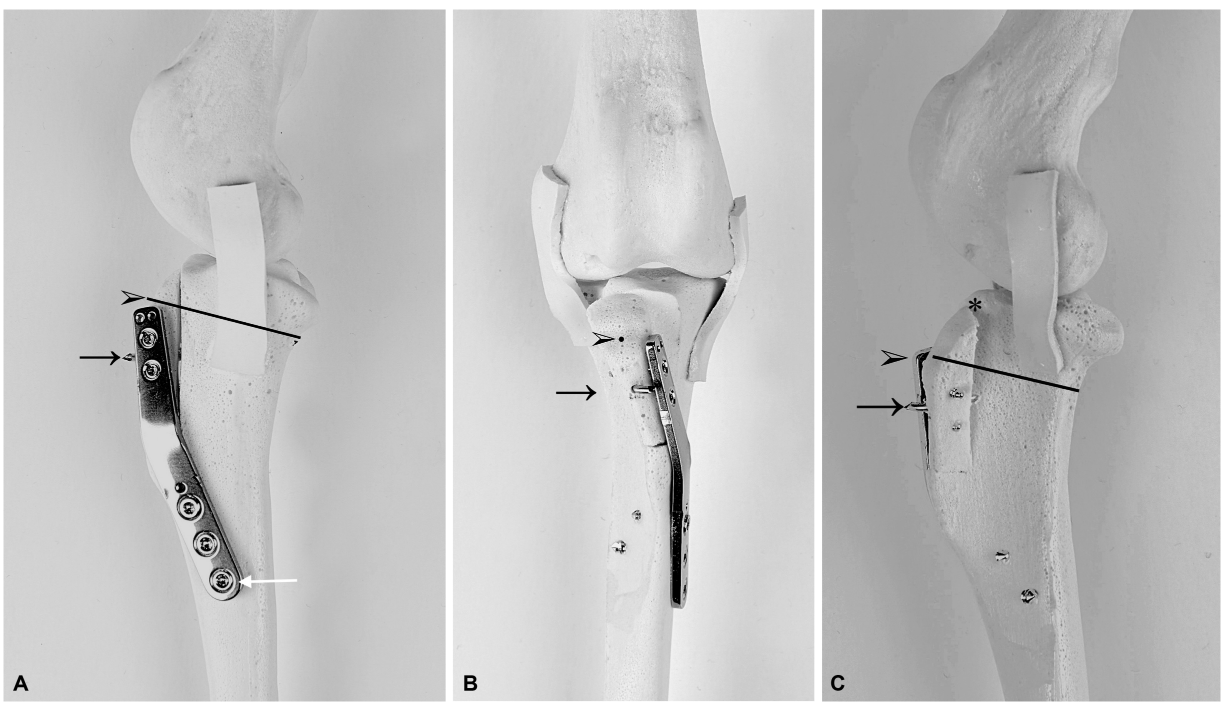

Fig. 2 Plastic bone model after tibial tuberosity transposition. Tibial tuberosity fixation was with a locking plate and a pin (black arrow) (**A** medial view, **B** cranial view, **C** lateral view). An alternative positioning of the pin is shown by a black arrowhead and black line (A– C). The cranial aspect of the long digital extensor tendon groove is shown (C, black asterisk). The most distal locking screw through the plate is monocortical and should be positioned near the center of the tibial diaphysis (A, white arrow) to minimize fracture at the stress riser.

lateral parapatellar fascia as subjectively deemed necessary. The joint capsule and deep fascia were closed with monofilament cruciate pattern sutures of absorbable polydioxanone (MonoPlus, B. Braun AG, Melsungen, Germany). Subcutaneous closure was a continuous pattern with the same material or with absorbable monofilament suture (Monosyn, B. Braun AG, Melsungen, Germany). The skin was closed with monofilament antibacterial absorbable sutures (Monocryl Plus 4–0, Ethicon, Johnson & Johnson, New Brunswick, New Jersey, United States), in a continuous intracutaneous suture pattern. A sterile adhesive bandage was applied over the wound. Mediolateral and craniocaudal radiographs were acquired to document the Plate–Pin fixation construct.

Complications

Minor complications were defined as those that resolved without surgery including seroma, superficial incisional surgical site infection (SSI), pin breakage, or pin migration. Major complications were defined as those that required surgical intervention, including deep incisional SSI and pin migration with seroma requiring pin removal.[25] Tibial tuberosity fixation failures were defined as those major complications in which the TT fractured or avulsed. Surgical site infections were defined based on the criteria adapted from the Centers for Disease Control and Prevention.[26]

Follow-Up

Outcome and complications were assessed during the follow-up examinations. Lameness was assessed by observation during ambulation and by questioning the owner if there were gait abnormalities observed or if the gait had returned to normal. Lameness was classified into five grades (►**Supplementary Appendix Table A2** [available in online version only]).[27] Patellar alignment was assessed during physical examination with no analgesia or sedation and was classified into four grades.[28] Craniocaudal and mediolateral radiographs were acquired to evaluate implant fixation, stability, and osteotomy healing. The radiographs were compared with the immediate postoperative radiographs to evaluate bone healing, integrity of the implants, and TT position.

Mid-term or long-term[25] outcome was assessed using the ACVS COI (American College of Veterinary Surgeons Canine Orthopedic Index) questionnaire,[19] which was translated to the client's native language. Each question was answered with points awarded 0 to 4. The best possible outcome score of 16 questions was 0 points and worst 64 points. The owners were also asked if they observed any signs of SSI.

Statistical Analysis

Statistical analyses were performed to identify variables associated with increased complication risk. Due to the small number of observations across levels of complication severity, complications were coded as a simple occurrence/nonoccurrence. Separate exact logistic regression[29] models were estimated for each of eight predictors using R statistical software[30] and the "elrm" package.[31] Due to their rare occurrence in the sample, surgical errors and other surgical deviations were combined into a single variable. One control variable was selected for each based on veterinary orthopedic knowledge and statistical comparisons (►**Supplementary Appendix 2** and ►**Table A9** [available in online version only]). The level of statistical significance was set at $p < 0.05$ for two-sided analyses.

Results

Patient Characteristics

All patellar luxation cases were developmental with none being traumatic in origin. At the first presentation, the ages ranged from 9 to 125 months (median: 32 months) and body weight was 2.1 to 15.7 kg (median: 6.2 kg). Additional patient characteristics are presented in ►**Supplementary Appendix Tables A2** and **A4 (available in online version only).**

Surgical Procedures

Details of the surgical procedures are presented in ►**Supplementary Appendix Table A4** (available in online version only). The diameter of the pins used in this study ranged from 0.9 to 1.4 mm. The locking plates were 1.5 mm (TT)/1.5 mm (diaphysis of tibia), 1.5 mm/2.0 mm, and 2.0 mm/2.4 mm (►**Supplementary Appendix Table A5** [available in online version only]). The sizes of the implants were selected based on the size and conformation of the tibia, not the weight of the dog.

Follow-Up

In-clinic follow-up examination and radiography was performed at a median of 68 days (range: 33–648 days) postoperatively (►**Supplementary Appendix Fig. A1** and ►**Supplementary Appendix Table A6** [available in online version only]). In two stifles, a tibial shaft fracture (►**Fig. 3**) and a TT fracture (►**Fig. 4**), the follow-up was performed after the fracture repairs. Lameness resolved in all stifles and patellar luxation in 64/65 stifles. Grade 1 MPL was detected in one stifle. Lameness and grade of patellar luxation are in ►**Supplementary Appendix Table A2** (available in online version only). Orthogonal radiographs confirmed bone bridging of the osteotomy and unchanged position of the TT compared with immediate postoperative radiographs in all stifles. Implants were stable and intact in 57/65 stifles. Minor complications were reported in 8/65 and major complications in 6/65 stifles, adding up to a total of 14/65 stifles with complications. Superficial incisional SSIs were reported in 3/65 stifles.

In 56/65 procedures there were no deviations from the surgical protocol or implant positioning, described in the Surgery section. Minor complications of the surgeries were: seroma at the cranial end of the pin ($n = 1$), pin bending ($n = 1$), pin breakage ($n = 2$), screw breakage ($n = 3$), and superficial incisional SSI ($n = 2$). One stifle had two minor complications: screw breakage and superficial SSI. One stifle had three minor complications: pin bending, screw breakage, and superficial SSI. Major complications were pin migration ($n = 1$) and capsulorrhaphy failure ($n = 1$) in which there was dehiscence of the lateral joint capsule and fascia closure.

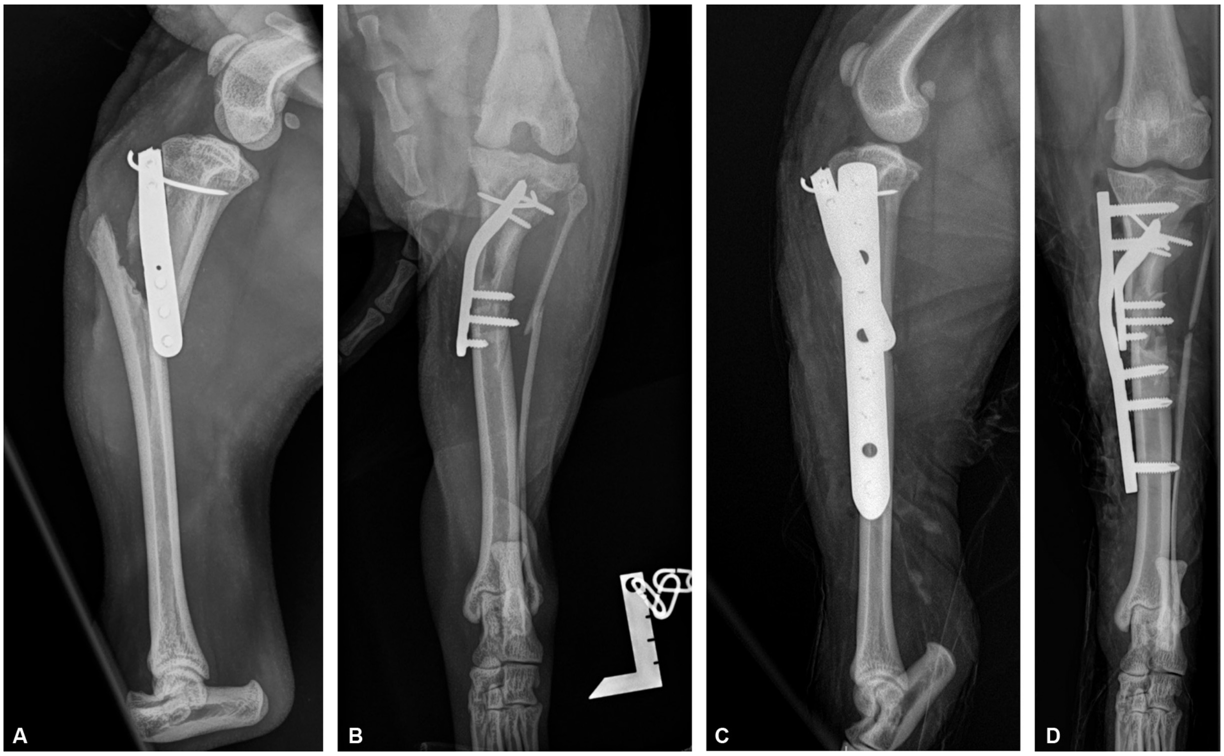

Fig. 3 A medial-lateral radiograph (**A**) of the stifle and fractured left tibia of an 8.3 kg German Spitz Mittel, 5 days after TTT surgery after jumping and falling. TT fixation was with a locking plate, 1.5 and 2.0 mm locking screws, and a 1.0 mm pin. The most distal screw was placed in the caudal cortex of the tibia, which predisposed to the fracture. A cranial-caudal radiograph (**B**) of the same fracture. A medial-lateral radiograph (**C**) and cranial-caudal radiograph (**D**) of the stifle and fractured left tibia 8 weeks after fracture fixation with a 2.7 mm locking plate and screws.

In 9/65 procedures, there were deviations from the surgical protocol or implant positioning. The procedures with deviations and their outcomes are presented in ►**Supplementary Appendix Table A7** (available in online version only). Surgical deviations were found to significantly increase the risk of postoperative complications, odds ratio (OR) = 11.3, $p < 0.05$ (►**Supplementary Appendix Table A8** [available in online version only]). Based on additional exploratory analyses (Appendix 2 [online only]), it is likely that surgical errors contributed considerably more to this effect than did other surgical deviations. The effects of all other predictors were nonsignificant.

The COI questionnaire was acquired at a median of 14 months (range: 6–39 months) postoperatively as detailed in ►**Supplementary Appendix Table A6** (available in online version only). The median COI score was 3 (range: 0–21; ►**Supplementary Appendix Fig. A2** [available in online version only]). One case, a single-session bilateral surgery, had a COI score of 21 for both the left and the right stifle. This dog scored 4 for the question "Jumping up (as in getting into the car or onto the bed)." This 2.1 kg Chihuahua has never been able to jump into the car or onto the bed. The score for question "How often did your dog "pay" for over-activity, with increased pain or stiffness the following day?" was 3. The scores for other COI questions of this dog were 0 to 2.

Discussion

Complications of MPL TTT surgery frequently require additional surgery,[5] and dogs with complications are more likely to have a poor outcome.[32] The complication rates of the Plate–Pin fixation and comparison with other reported TT fixation methods are presented in ►**Supplementary Appendix Table A9** (available in online version only). Direct comparison between different studies is difficult because of different inclusion criteria, different follow-up time frames, potential selection bias and complications classified differently.[1,5]

The incidence of postoperative MPL recurrence in Pin–TBW TTT surgeries ranges from 5 to 12.4% and is reported to be more prevalent in large than small breed dogs.[5–9,33] Insufficient or excessive TT transposition can predispose to luxation recurrence. Transposition distance is based on subjective clinical judgement which is subject to error. Tibial tuberosity fixation failure is another cause of luxation recurrence. In our study, there were no luxation recurrences in 64/65 stifles (►**Supplementary Appendix Table A9** [available in online version only]). This indicates correct alignment of the patella during surgery and that the TT did not displace after surgery in 64/65 stifles. With Plate–Pin TT fixation, the surgeon can achieve marked transposition of the TT, which is necessary in grade 3 and grade 4 MPL surgery.

Bilateral MPL is sometimes treated during single-session bilateral surgery for economic reasons.[7] Recent studies comparing complication rates in dogs undergoing single-session bilateral MPL surgery and unilateral surgery have shown contradictory results.[7,34–36] In our study, complications occurred in 11/55 unilateral and in 3/20 single session bilateral stifle surgeries.

Fig. 4 A medial-lateral radiograph (**A**) of the stifle and left tibia of an 11.2 kg mixed breed dog 8 weeks after TTT surgery with a locking plate, 2.0 and 2.4 mm locking screws, and a 1.2 mm pin. A fracture of the TT occurred when the TT was transposed during the surgery. The most proximal fragment of the TT displaced after surgery causing *patella alta*. A medial-lateral radiograph (**B**) of the stifle 8 weeks after the TT fracture fixation with a locking plate, 2.0 and 2.4 mm locking screws, a 1.2 mm pin, 0.9 mm cerclage wire, and a patellar ligament-circumpatellar loop with 5 metric polyamide suture (Dafilon, B. Braun AG, Melsungen, Germany). The plate has two 1.0 mm holes at the proximal end and one in the middle of the plate. The cerclage wire was anchored through the 1.0 mm holes. In index surgery the plate was shortened through the proximal 1.0 mm holes for better fit.

The incidence of Surgical site infections in dog and cat surgical procedures classified as clean is 2.0 to 4.9%.[37,38] Plate–Pin and TPLO surgery are classified as clean orthopedic procedures in which a locking plate is applied to the proximal tibia. Surgical site infections develop in 8.4 to 11% of dogs following TPLO surgery.[39,40] In our study, SSIs occurred in 3/65 stifles (4.6%).

Implant-associated complications are the most common reported complications following MPL surgery.[1] Pins can cause complications when they migrate or break.[1,3,5–9] In our study, most of the complications (8/65 stifles, 8/20 complications) were problems associated with the pin. We subjectively chose a smaller pin size for Plate–Pin fixation than would be chosen on a Pin–TBW TTT surgery. Despite the small pin size and pin-related complications, all TT osteotomies healed and the TT fixation with the locking plate did not fail in cases performed as described in the Surgery section. It remains equivocal if the pin adds any advantages in TTT surgery with locking plate fixation. A pin could be used only for temporary fixation to hold the TT during patella alignment, before locking plate application (►**Fig. 2**, arrowhead),[10] and then be removed. Alternatively, instead of using a pin for permanent fixation, a cortical screw[10] or an "impact plate"[12] could be placed adjacent to the TT.

In statistical analysis, a lower dog weight was significantly associated with an increased risk of complications in the baseline model (OR = 0.768, $p < 0.05$), wherein a 1 kg increase in weight implied a 23.2% decrease in complication risk. After controlling for surgical deviations, however, this association became nonsignificant. This suggests that the impact of weight on complication risk might be partially mediated through increased incidence of surgical deviations: smaller screws are used on smaller dogs and smaller screws also break more easily (►**Supplementary Appendix Table A8** [available in online version only]). In 3/65 stifles (3/20 complications), one of the two 1.5 mm screws holding the transposed TT were broken at follow-up. This indicates that at least three screws are needed for a more secure TT fixation. Further development of the locking plate TT fixation is needed to overcome the pin-related complications and breakage of the TT fixation screws.

Our study has limitations. It was retrospective, there was no control group, and no randomization.[41] A significant limitation regarding the statistical analyses of complication risk was small sample size, which resulted in estimates with poor stability and limited statistical power to reveal small to moderate effects. Consequently, the results should be interpreted with caution. The outcome measures including lameness, degree of luxation, assessment of healing of the TT osteotomy, and COI questionnaire answers were subjective, which is an inherent problem with this kind of study. These factors could have caused a variation in examination and documentation reporting among authors as has been reported elsewhere.[11] The follow-up period varied and COI questionnaires from the preoperative period were not available. Mid- or long-term outcome was assessed in most cases with the COI questionnaire only (►**Supplementary Appendix Table A6** [available in online version only]). Regardless, it is improbable that the TT fixation would fail if bone bridging of the osteotomy is confirmed radiographically after surgery.

The Plate–Pin is a promising new fixation technique for TTT that is suitable for patients with MPL. There were 9/65 stifle surgeries with deviations from the surgical protocol with increased complication rate (►**Supplementary Appendix Tables A7–A9** [available in online version only]). We refined the surgical technique after every complication we encountered and we described the procedure in the Surgery section with special emphasis on preventing the complications.[21] It does not mean that complications or surgical errors will be completely eliminated in the future by every surgeon including the authors. Also new types of complications that were not seen in our study may occur.

There were no TT avulsions, fractures, or luxation recurrences in 56/65 stifles where the Plate–Pin surgery was performed as described. This indicates that the fixation method could prevent complications and therefore, significant postoperative morbidity and costs. A prospective, randomized, and preferably multicenter study is needed to confirm if the complication rate of Plate–Pin TT fixation is significantly lower than the complication rate of the traditional TT fixation with pins and TBW or with other fixation techniques.[10–14]

Authors' Contribution

All authors contributed to the study conception, design, acquisition of data, data analysis and interpretation, drafting and manuscript revision, and approved the submitted manuscript.

Funding

A grant from Finnish Foundation of Veterinary Research, Helsinki, Finland. Evidensia Eläinlääkäripalvelut Ltd, Helsinki, Finland and Vireä Group Ltd, Helsinki, Finland paid the expenses of the follow-up visits. Veterinary Orthopedics Scandinavia Ltd, Helsinki, Finland paid the article processing charge of Open Access publication.

Conflict of Interest

J.V.V. and A.P.S. are shareholders of Veterinary Orthopedics Scandinavia Ltd. The authors have no other conflicts of interest connected to this study.

Acknowledgment

The authors acknowledge the contribution of Ville Junttila, MSc in performing the statistical analysis and Johanna Mäkitaipale, DVM, PhD in the development of the manuscript and performing 18 surgeries of this study. The authors acknowledge the contribution of Juha Junttila, DVM in the development of the manuscript.

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