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Evaluation of Surgical Technique and Clinical Results of a Procedure-Specific Fixation Method for Tibial Tuberosity Transposition in Dogs: 37 Cases

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Abstract

Objective The aim of this study was to describe the use of a procedure-specific fixation method for tibial tuberosity transposition and report clinical outcome.

Study Design This is a multi-institutional case series, evaluating 37 cases that were treated surgically for medial patellar luxation (MPL) and in which the tibial tuberosity transposition (TTT) was performed using the Rapid Luxation Plating System (RLPS). Surgical technique, implants, clinical outcome, and complications are reported.

Results Surgery was successfully performed in dogs weighing 2.5 to 36.2 kg. Postoperative minor complications occurred in 13 cases (35%) and major complications occurred in 3 cases (8%). No implant-related complications or tibial tuberosity avulsions or fractures were seen. Outcome related to surgery was good or excellent in all cases.

Conclusion The RLPS for TTT provides a feasible technique in a large range of patients with MPL and lowers the occurrence of implant-related complications and tibial tuberosity avulsion or fracture.

Keywords
- rapid luxation plating system
- tibial tuberosity transposition
- medial patellar luxation
- dog
- implant

Introduction

Medial patellar luxation (MPL) is a common problem in dogs, accounting for a significant proportion of dogs presented with orthopaedic problems.[1,2] Affected dogs typically show skeletal abnormalities of the femur, tibia, or both combined, resulting in malalignment of the quadriceps mechanism.[3,4] Surgical treatment aims to realign the quadriceps mechanism and stabilize the patella within the femoral trochlea, using a combination of techniques including tibial tuberosity transposition (TTT), trochleoplasty, lateral imbrication, and medial retinacular release.[5,6] In selected cases, corrective osteotomies or use of a patellar groove replacement is indicated.[7–9] Postoperative complications are reported in 13 to 45% of cases, with an incidence of major complications of 6 to 25%, most commonly reluxation, implant-related complications, and tibial tuberosity avulsion or fracture.[6,10–14] In these publications, fixation of the tibial tuberosity was performed with Kirschner wires with or without a tension band wire. As noted in a recent review, data on alternative fixation methods are sparse.[3] This study aims to evaluate the outcome of treating MPL using a procedure-

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specific plating system (Rapid Luxation Plating System [RLPS], Rita Leibinger GmbH & Co. KG., Mühlheim an der Donau) to laterally transpose and fixate the osteotomized tibial tuberosity.

Materials and Methods

Study Design and Case Inclusion

This was a descriptive multicenter study including two cohorts of dogs with MPL treated surgically with the RLPS TTT plating system. Cohort A was enrolled at AniCura Dierenziekenhuis Drechtstreek between April 2020 and July 2021. Cohort B included all dogs treated at Evidensia Specialistdjursjukhuset Strömsholm between December 2019 and August 2021. The inclusion criteria were presence of clinically apparent MPL and age >9 months. The exclusion criteria were grade 4 MPL,[15] use of a patellar groove replacement or corrective osteotomy, previous surgery on the same stifle, trauma, and comorbidities causing clinical signs. The owners were informed about the nature of the study and those that chose to participate signed an informed consent form. Full physical and orthopaedic examinations were performed. Patellar luxation was graded according to Roush.[15] Lameness was graded as reported previously, with grade 0 = no lameness; grade 1 = normal at walk and mild/intermittent lameness at trot; grade 2 = mild/intermittent lameness at walk and increased lameness at trot; grade 3 = severe lameness with regular nonweight bearing; and grade 4 = continuous non-weight-bearing lameness.[16] Lameness was also scored as grade 1 when owners reported regular (i.e., daily) skipping lameness, which was not identified in the clinic. Preoperative imaging consisted of a ventrodorsal hip-extended radiograph[17] extending from the pelvis to the proximal tibia plus a mediolateral stifle radiograph in cohort A and computed tomography (CT) in cohort B.

Implants

The RLPS consists of titanium plates, spacers and self-tapping cortical screws, and tappet (►**Fig. 1**). The plates have four or six gliding holes, depending on plate size, which accommodate two or three screws in both the tibial metaphysis and the tibial crest. The tappet can be locked into the holes of the plate and is rotated to gradually transpose the tibial crest laterally using a screw mechanism. A spacer is inserted between the tibial crest and the plate to maintain lateral transposition. Three sizes of plates are available for use with screw size 1.5 or 2.0 mm (small plates) or 2.4 mm (medium and large plates). Spacers range in width from 1 to 6 mm.

Perioperative Care

Anesthetic and analgesic protocols varied, based on patient characteristics and preference of the attending clinician. In cohort A only, cefazolin sodium (22 mg/kg) was administered intravenously 30 to 60 minutes before surgery and repeated every 90 minutes until surgery was completed. All dogs were discharged the day of or the day after surgery, receiving methadone intravenously (0.2–0.3 mg/kg every 4–6 hours intravenously) until discharge and oral meloxicam (0.1 mg/kg once daily per os) or robenacoxib (1–2 mg/kg once daily per os) for 2 to 4 weeks. In cohort A only, a soft padded bandage was applied for two weeks postoperatively. All owners were instructed to restrict exercise until radiographical follow-up showed healing of the osteotomy.

Surgical Procedure

Surgery was performed by a board-certified or board-eligible surgeon. Intra-articular structures were inspected through a lateral parapatellar arthrotomy. A medial release,[15] block recession trochleoplasty,[18] or a combination of both was performed as deemed necessary. Subsequently, the medial side of the proximal tibia was approached by extending the skin incision distally. The osteotomy was created using an oscillating saw, aiming just cranial to the long digital extensor groove proximally and ending in or directly caudal to the cranial tibial cortex at the distal end of the tibial crest, and the RLPS was applied according to the manufacturer's instructions.[19] After attaching the plate to the tibial shaft by placing the caudal screws, the tappet was inserted in the cranial plate holes. By rotating the tappet, the tibial crest was transposed laterally (►**Fig. 1C**) until appropriate alignment was reached, as indicated by visual assessment and a stable patella during stifle flexion and internal rotation of the tibia. The amount of lateralization was read from the indicator on the tappet, the corresponding spacer was placed, and the cranial screws were inserted (►**Fig. 1D**). Lateral joint capsule imbrication and closure were routine.[15] Mediolateral and craniocaudal radiographs were obtained postoperatively to confirm correct execution of the osteotomy and placement of the implants. Duration of surgery, details of the surgical techniques and implants, and occurrence of complications were recorded.

Follow-Up

In-clinic physical and radiological examinations were scheduled 6 to 8 weeks postoperatively, plus, in cohort A, 3 months after surgery. At the time of data acquisition, cases were invited for an additional in-clinic physical and radiological evaluation. Telephone interviews were conducted if in-clinic follow-up was declined. Lameness grade, MPL grade, and occurrence of complications were recorded. Complications were defined as any unfavorable and unplanned event, sign, or disease related to treatment, classified by timeframe as either intraoperative, immediately postoperative (between surgery and discharge), short term (between discharge and ≤3 months postoperative) or long term (≥3 months postoperatively) and graded as minor when resolved spontaneously or with medical treatment only or as major when surgical treatment was indicated.[6,12,13] In cohort A, owners were asked to complete the Liverpool Osteoarthritis in Dogs (LOAD) questionnaire before surgery and at 6 weeks and 3 months after surgery.[20] Outcome was categorized as excellent when function at last follow-up was normal, good when function was near normal with infrequent lameness, acceptable with grade 1 lameness and unacceptable with higher-grade lameness or the need for analgesics.

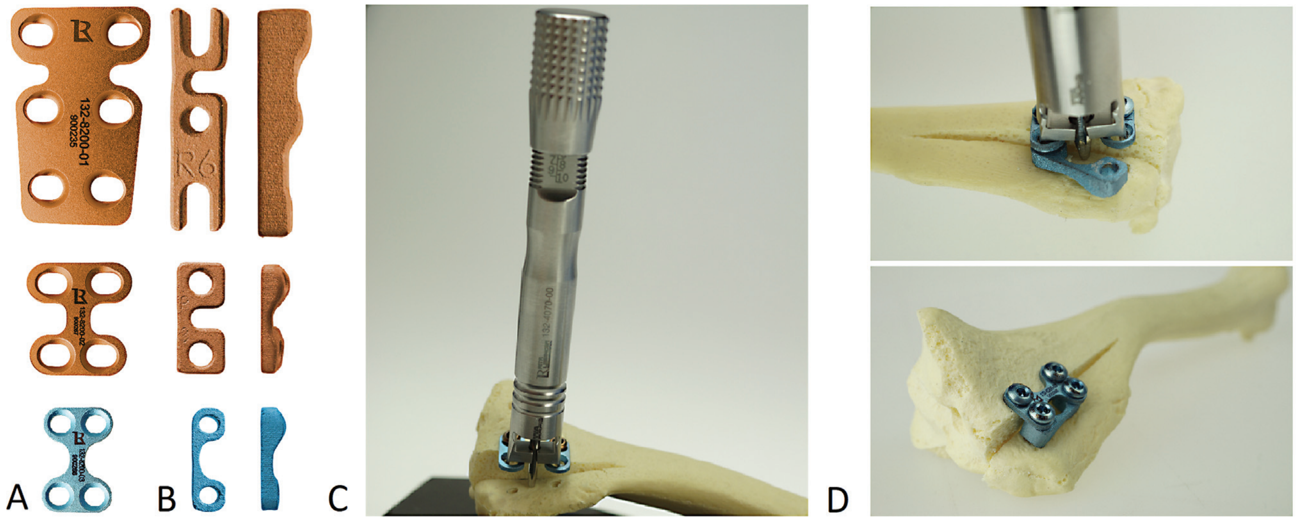

Fig. 1 (**A**) Three sizes of plates accommodating 2.4-mm screws (large six-hole and medium four-hole plates) or 1.5-/2.0-mm screws (small four-hole plate) and (**B**) corresponding spacers are available. Dimensions (length × width) of the large, medium, and small plates are 25 × 16.5 mm, 14 × 13 mm, and 13 × 8.4 mm, respectively. Available spacers have a thickness of 2, 4, and 6 mm for the large plate; 2, 3, and 4 mm for the medium plate; and 1, 2, 3, and 4 mm for the small plate. (**C**) The tappet locks itself in the screw holes and is used to gradually transpose the tibial crest using a screw mechanism. (**D**) After transposition is deemed sufficient, the appropriate spacer is inserted, the tappet is removed, and the remaining screws are inserted. (These images are provided courtesy of Rita Leibinger GmbH & Co. KG, Mühlheim an der Donau.) Note: The small plate is also named tiny/petite by the manufacturer.

Statistical Analysis

The data were entered in MS Excel (Microsoft, Redmond, Washington) and transferred to statistical program R version 4.0.5[21] by library readxl[22] for analysis. We analyzed the within-case difference in LOAD score between time point 0 and 6 weeks and 0 and 12 weeks by Wilcoxon signed-rank test. The level of significance was set at 0.05.

Results

Patient Characteristics

A total of 37 stifles from 33 dogs were included, with 19 stifles in cohort A and 18 stifles in cohort B. No cases were excluded after enrollment. The dogs were mixed breed dogs ($n = 8$), French Bulldog ($n = 5$), Maltese ($n = 3$), Chihuahua ($n = 3$), Pomeranian ($n = 2$), Boston Terrier ($n = 2$), and 1 each of Cavalier King Charles Spaniel, Cairn Terrier, Yorkshire Terrier, Staffordshire Bull Terrier, German Shepherd Dog, Australian Kelpie, Japanese Chin, Lagotto Romagnolo, Griffon Bruxellois, and Bichon Frisé. Ages ranged from 9 to 132 months (median = 36 months) and body weight was 2.5 to 36.2 kg (median = 7.8 kg). At presentation, the median lameness grade was 2 (mean = 1.9; range: 1–4) and the MPL grade was grade 2 in 20 cases, grade 3 in 16 cases, and not recorded in 1 case.

Surgical Procedure

The mean (±SD) duration of surgery was 48 ± 17 minutes (range: 25–79 minutes). All available plate sizes were used with the small plate applied most frequently (►**Table 1**). All screw holes were filled, with enough bone stock to place the cranial screws in even the smallest patient (►**Fig. 2**). In several cases, to allow placement of the spacer between the plate and bone, the distal half of the spacer was cut off ($n = 7$) or a two-hole spacer was combined with a six-hole plate ($n = 3$; ►**Fig. 3**). Block trochleoplasty was performed in 26/37 cases and medial release was performed in 4/37 cases. Lateral imbrication was performed in all cases. There were no intraoperative or immediate postoperative complications. Postoperative radiographs showed adequate positioning of the osteotomy and implants in 36/36 cases. The cranial tibial cortex at the distal end of the tibial crest was intact in 12/36 cases; a fissure or fracture was identified in 24/36 cases. Postoperative radiographs were not available in one case.

Follow-Up

Short-term in-clinic follow-up including radiographic evaluation was available in 35/37 cases, at 4 to 8 weeks ($n = 35$) and at approximately 3 months ($n = 18$) postoperatively. For the remaining two cases, in-clinic follow-up was available at

Table 1 Distribution and characteristics of the Rapid Luxation Plating System for medial patellar luxation

Size plate/screws	No. of cases	Median bodyweight (kg)	Spacer (mm)
Small 4-hole/1.5 mm	7	4.2 (range: 2.8–5.5)	2–4
Small 4-hole/2.0 mm	20	7.5 (range: 2.5–12.3)	2–4[a]
Medium 4-hole/2.4 mm	6	10.6 (range: 7.8–16.1)	3–6
Large 6-hole/2.4 mm	4	16.7 (range: 11.5–37.4)	4–6

[a]One outlier had multiple spacers with a combined thickness of 8 mm.

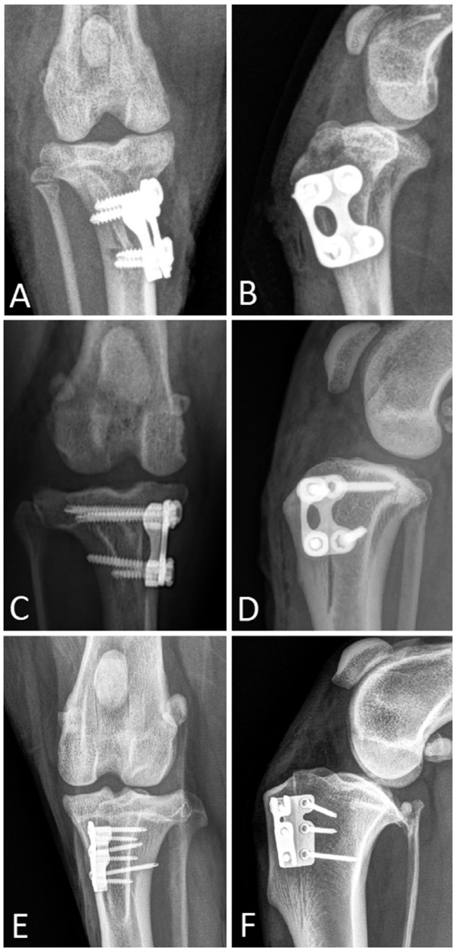

Fig. 2 Postoperative radiographs of cases (**A,B**) weighing 2.45 kg, (**C,D**) 10.8 kg, and (**E,F**) 37.4 kg. Applied implants were the small four-hole plate with 2.0-mm screws in **A–D** and the large six-hole plate with 2.4-mm screws in **E** and **F**.

11 months postoperatively in one case; in the other case, follow-up was by telephone interview only. Long-term follow-up was available in 36/37 cases, for a median of 297 days (range: 105–693 days), either in-clinic ($n=19$) or via telephone interview ($n=17$). One case was lost to follow-up after 6 weeks, at which point the patellar luxation grade and lameness grade were 0 and the osteotomy had healed.

Lameness at last short-term follow-up was grade 0 for 30/35, grade 1 for 2/35, and grade 3 for 1/35. The case with grade 3 lameness had a cranial cruciate ligament rupture (CCLR) that occurred 11 weeks after surgery. As this is presumed to have occurred unrelated to surgery, this event was not included as a major complication. Grade 1 lameness was caused by recurrent grade 2 MPL in one case. In the other case with grade 1 lameness, a cause could not be identified. At physical examination, there was a normal range of motion of the stifle without crepitation, the patella could not be luxated, the cranial drawer test was negative. There was no swelling over the implants and palpation was not painful. Orthogonal radiographs showed bridging of the osteotomy, stable implants, and no soft-tissue swelling, osteolysis, or periosteal reaction surrounding the implants, but mild stifle effusion was noted (►**Fig. 4**). Additional diagnostics were not

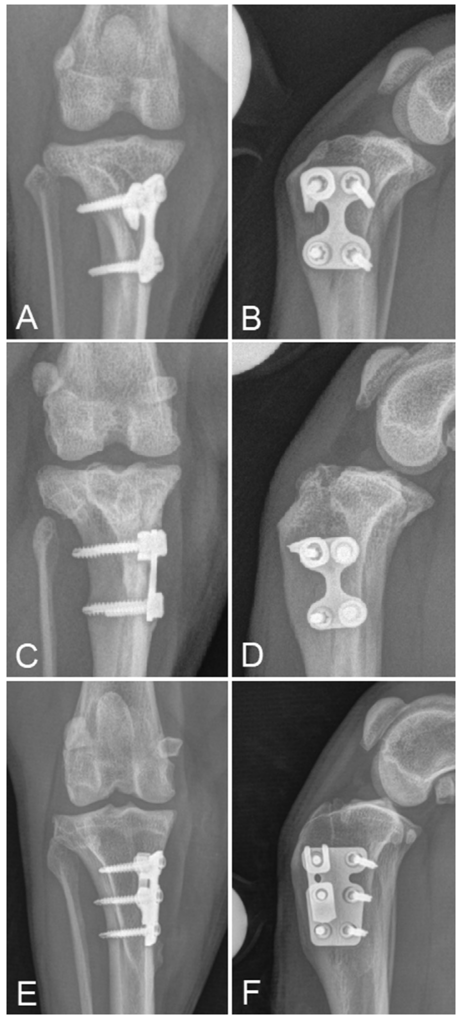

Fig. 3 Craniocaudal and mediolateral radiographs taken 6 weeks postoperation, showing (**A–D**) two cases in which the distal half of the spacer was removed and (**E,F**) a case in which a two-hole spacer was used instead of a three-hole spacer, to facilitate placement of the spacer between the tibial crest and plate.

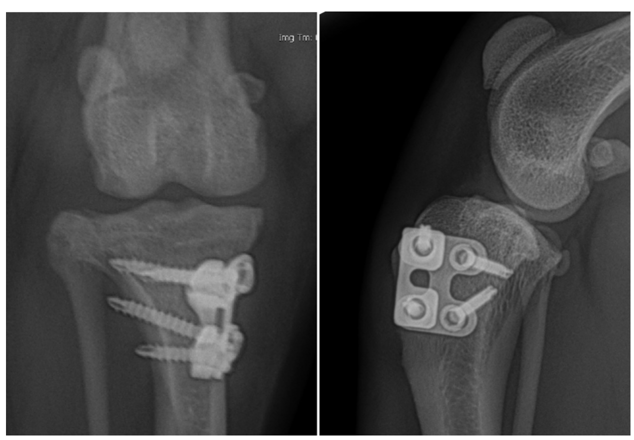

Fig. 4 Craniocaudal and mediolateral radiographs taken 7 months after surgery, immediately before implant removal, in a French bulldog weighing 9.2 kg with intermittent skipping lameness. The osteotomy has healed, the implants are in the correct position, and no implant-related complications were noted. There is mild cranial displacement of the fat pad, indicative of mild joint effusion.

pursued, and no specific therapy was instituted. Seven months after surgery, grade 1 lameness was still present. Since the implants could not be ruled out as a cause, they were removed. Macroscopic signs of infection were not noted during removal, and bacterial culture of the implants was negative. Lameness persisted for 6 more months, after which it gradually resolved. As implant removal did not resolve lameness, this was classified as a non-implant-related major complication. LOAD scores at 6 weeks (median $= 12.5$; $n = 14$) and 3 months (median $= 7$; $n = 10$) were significantly lower compared to preoperative values (median $= 22$; $n = 16$; $p < 0.01$). Radiographic follow-up showed healing of the osteotomy in 35/35 cases.

Minor and major complications were reported in 13 cases (35%) and 3 cases (8%), respectively (►**Table 2**). Two cases had both a minor and a major complication (minor pressure sore and implant removal, major pressure sore, and grade 1 MPL). Infection was suspected in one case, which resolved after a 10-day course of antibiotics. Three cases had major complications. Besides the case in which implants were removed, surgical treatment was performed for one bandage-related pressure sore and one case with a grade 2 MPL. Both cases recovered uneventfully. No implant-related complications or tibial tuberosity avulsions or fractures occurred.

Except for the case with the conservatively treated CCLR, lameness at long-term follow-up was scored as zero and outcome was excellent (32/36) or good (3/36) in all cases.

Discussion

This study describes the use of the RLPS and reports the clinical outcome in dogs treated surgically for MPL using this novel procedure-specific fixation method. Our results suggest this is a feasible technique in dogs with a wide range of body weights.

Minor complications were seen in 13 cases (35%), which is higher than recently reported.[5,6,11–14,23] This should be interpreted cautiously, as there are differences in the type and length of follow-up between studies. Major complications occurred in 8% of cases, compared to reported rates of 6 to 25% in publications using Kirschner wires with or without a tension band wire.[5,6,11–14,23] In these publications, the incidence of major implant-related complications and tibial tuberosity avulsions or fractures were 3 to 17% and 2 to 6%, respectively, whereas implant-related complications or tibial tuberosity avulsions or fractures were not observed in our study.[5,6,11–14,23]

Sparse data on other TTT fixation methods are available. A craniocaudal screw placed through the tibial tuberosity in addition to Kirschner wires was associated with a higher risk of major complications, although the number of cases was low.[23] Placement of a screw adjacent to the tibial tuberosity, to maintain transposition, without implants placed through the tibial tuberosity, resulted in tibial tuberosity avulsions in only 3% of cases.[24] This technique relies on the distal attachment of the tibial crest to resist the tensile forces of the quadriceps muscle. Fissures or fractures of the distal cortex were common in our population, and omitting an implant with purchase of the tibial crest is likely to result in tibial tuberosity avulsions in such cases. TTA plates have been used successfully in large breed dogs undergoing distal transposition of the tibial tuberosity and in dogs undergoing tibial tuberosity advancement and transposition.[25,26] A biomechanical study has shown a higher load to tibial tuberosity avulsion or fracture with a Kirschner wire plus locking plate compared to Kirschner wire plus tension band wire.[27] Clinical results of TTA plates or locking plates for TTT have not been published.

Compared to Kirschner wires, application of the RLPS requires a larger bone stock. To accommodate the two cranial screws, it is imperative to make the osteotomy sufficiently caudal. In all dogs in this study, the two cranial screws were placed without subsequent fractures of the tibial tuberosity. However, the surgeons involved reported that execution was subjectively more difficult in smaller dogs. How large the segment must be to prevent fractures remains to be determined. In dogs undergoing tibial tuberosity advancement, a craniocaudal fragment width <25% of the craniocaudal width of the tibial diaphysis resulted in an increased chance of tuberosity fracture.[28] How to translate this finding to use of the RLPS for TTT remains to be investigated. Other potential disadvantages of RLPS are an increased duration of surgery and risk of infection, and an increased volume of implants, potentially causing soft-tissue irritation. With a mean duration of surgery of 48 minutes, an infection rate of 3% despite limited use of antibiotics and no apparent soft-tissue irritation in our cases, these potential disadvantages seem to be limited.

In 10 cases, the distal part of the spacer was removed, or a two-hole spacer was used instead of a three-hole spacer, because of a mismatch between the taper of the spacer and the angle of the transposed tuberosity. No tibial tuberosity avulsion or fractures occurred, but as this modification reduces bone–implant contact, the risk of complications might be increased. In some of these cases, this mismatch could have been prevented by decreasing the angle of the tuberosity, by ending the osteotomy further distally, or by

Table 2 Incidence of minor and major complications after using the Rapid Luxation Plating System for medial patellar luxation (MPL)

Complication	Minor	Major	Total
Recurrent MPL	6 (16%)	1 (3%)	7 (19%)
Lateral patellar luxation	1 (3%)	0	1 (3%)
Bandage related	4 (11%	1 (3%)	5 (14%)
Persistent lameness	0	1 (3%)	1 (3%)
Surgical site infection	1 (3%)	0	1 (3%)
NSAID side effects	1 (3%)	0	1 (3%)
Total	13 (35%)	3 (8%)	16 (43%)[a]

Abbreviation: NSAID, nonsteroidal anti-inflammatory drugs.
Note: % = percentage of 37 cases.
[a]Two cases had both a minor and a major complication; 16 complications occurred in 14 cases (38%).

placing the implants more proximal, allowing use of a spacer with a greater thickness and a higher taper angle. The cases in which these modifications would not have been possible could benefit from future adaptations to the spacer by the manufacturer.

The most common complication in our study was recurrent MPL. Revision surgery to treat reluxation was required in only one case (3%), while subclinical grade 1 MPL was diagnosed in six cases (16%). In three of six cases diagnosed with grade 1 MPL, the patella could not be luxated at recheck 6 weeks postoperatively, and reluxation was diagnosed only at a later follow-up. Previously identified risk factors for reluxation are higher-grade MPL, not performing a trochleoplasty, not performing a TTT, and not performing a release of the cranial belly of the sartorius muscle.[5,13,16,29] Additionally, failure to correct skeletal deformities has been proposed as a reason for recurrent MPL.[5,30,31] Excellent results have been reported after correction of excessive femoral varus, external femoral torsion, and/or external tibial torsion, with no reluxation observed in three studies including a total of 104 cases.[8,9,32] Cases undergoing a corrective osteotomy were excluded from enrollment in this study. However, a complete preoperative morphometric analysis of the femur and tibia was not performed in the majority of our cases, as this was standard practice only in large breed dogs and dogs with grade 4 MPL. Indeed, retrospective analysis identified multiple cases with a femoral varus angle >12 degrees, which in other publications is considered an indication for a corrective femoral osteotomy.[8,9] The role of these factors as a cause of reluxation in our population is unknown. A risk factor analysis for reluxation was not performed because of the high variability in both treatment regime and available data between cohorts and a relatively low case number.

Recommendations regarding the use of bandages after MPL surgery in the literature are variable, ranging from recommending a padded bandage for 10 to 14 days to stating postoperative bandaging is unnecessary.[15,33] Previous studies found no significant correlation between postoperative bandaging and complications after MPL surgery.[11,23] A postoperative bandage was used in 19 cases in our population. In five of these, bandage-related complications occurred. Most of these were minor and resolved spontaneously after removal of the bandage, but one case underwent surgical treatment of a nonhealing pressure sore. Complications that could have been prevented by a bandage, such as wound complications or tibial tuberosity avulsions or fractures, were not seen in any case without a postoperative bandage. Considering these findings, the use of a postoperative bandage after TTT using the RLPS should be questioned.

Several limitations to this study exist. The multicentric and retrospective nature causes variability in treatment regime and data acquisition. CT was not performed in cohort A, which limits the evaluation of skeletal deformities, and a risk factor analysis was not performed due to previously discussed reasons. Although follow-up of at least 3 months was available in all but one case, this was only by telephone in nine cases. Therefore, it is possible that subclinical complications or complications occurring past the window of follow-up were missed. Objective scoring of clinical results using the LOAD questionnaire was requested, but lack of owner compliance resulted in incomplete records. The number of cases is small and additional case numbers and prospective studies comparing TTT using the RLPS versus Kirschner wires are necessary before drawing definitive conclusions about the advantages or disadvantages of the RLPS.

Conclusion

The RLPS provides a new fixation technique for TTT that is feasible in a large range of patients with MPL. The absence of implant-related complications and tibial tuberosity avulsions or fractures in this study is promising and indicates this fixation method could prevent significant morbidity and costs.

Authors' Contribution

D.O., J.E., E.W. and D.S. contributed to the conception, study design, acquisition of data, data analysis and interpretation. K.B-S. contributed to acquisition of data, data analysis and interpretation. J.C.M.V. contributed to study design, data analysis and interpretation. B.P.M. contributed to conception, study design, data analysis and interpretation. All authors drafted, revised, and approved the submitted manuscript and are publicly responsible for the relevant content.

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Conflict of Interest

None declared.

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