Effect of Plate Type on Tibial Plateau Levelling and Medialization Osteotomy for Treatment of Cranial Cruciate Ligament Rupture and Concomitant Medial Patellar Luxation in Small Breed Dogs: An *In Vitro* Study

Melania Dallago[1,4] Alessandro Boero Baroncelli[2] Caleb Hudson[3] Bruno Peirone[1] Evelien De Bakker[4] Lisa Adele Piras[1]

[1] Department of Veterinary Sciences, University of Turin, Grugliasco, Italy
[2] Clinica Albese per Animali da Compagnia, Alba, Cuneo, Italy
[3] Department of Surgery, Gulf Coast Veterinary Specialists, Houston, Texas, United States
[4] Department of Medical Imaging and Orthopedics, Faculty of Veterinary Medicine, Ghent University, Merelbeke, Belgium

Address for correspondence Lisa Adele Piras, DVM, PHD, DECVS, Department of Veterinary Sciences, University of Turin, Grugliasco 10095, Italy (e-mail: lisa.piras@unito.it).

Vet Comp Orthop Traumatol

Abstract

Objective The main aim of this study was to determine the effective magnitude of proximal tibial segment medialization achievable during tibial plateau levelling and medialization osteotomy (TPLO-M) with Fixin 1.9-2.5 mm pre-contoured T plates with three different offsets.

Methods In this *in vitro* study, 36 tibia bone models reconstructed using stereolithography from hindlimb CT scans of a 5 kg dog and a 10 kg dog without orthopaedic disease were used. TPLO-M was performed using plates with three different offsets (2, 4 and 6 mm). Post-osteotomy radiographic and bone models measurements were performed.

Results Regardless of patient weight, the +4 mm offset plates provided a translation of 2.93mm (± 0.51) while the +6 mm offset plates provided a translation of 5.03mm (± 0.47). In the 5kg dog bone model group limited bone contact at the osteotomy site was documented when using the +6mm offset plate.

Conclusion The +4mm and +6mm offset Fixin plates may be considered for TPLO-M in dogs weighing between 5 and 10 kg. The +6mm offset plate should be used cautiously in dogs weighing less than 10 kg since this plate may result in insufficient postoperative bone apposition at the osteotomy site.

Keywords
- dog cranial cruciate ligament rupture
- tibial plateau levelling osteotomy
- corrective osteotomy
- patellar luxation

Introduction

Medial patellar luxation is a frequent cause of pelvic limb lameness in small breed dogs.[1–5] Dogs affected by medial patellar luxation have an increased risk of developing cranial cruciate ligament disease, with 13 to 25% of dogs diagnosed with medial patellar luxation having concomitant cranial cruciate ligament rupture.[4,6] Surgical treatment of

received
March 23, 2022
accepted after revision
March 9, 2023

Georg Thieme Verlag KG,
Rüdigerstraße 14,
70469 Stuttgart, Germany

DOI https://doi.org/10.1055/s-0043-1768163.
ISSN 0932-0814.

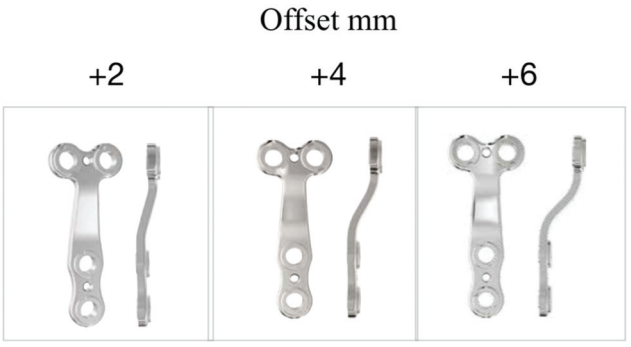


Fig. 1 Fixin 1.9-2.5 mm pre-contoured T plates with three different offsets (2, 4 and 6 mm) for modified tibial plateau levelling osteotomy in patients weighing between 5 and 10 kg.

concomitant cranial cruciate ligament rupture and medial patellar luxation has previously been achieved with a variety of surgical techniques including tibial wedge osteotomy, modified tibial plateau levelling osteotomy (TPLO-M), or modified tibial tuberosity advancement either alone or in combination with other procedures such as tibial tuberosity transposition, trochleoplasty, retinacular release and retinacular imbrication.[5–9] Recently Flesher and colleagues reported on a modified TPLO which is referred to as 'TPLO-M' that simultaneously levels and medializes the tibial plateau using a standard radial osteotomy in the proximal tibia.[10] This TPLO-M technique is designed to negate cranial tibial thrust and improve alignment of the quadriceps mechanism.[10] In Flesher's study, overall complication rates identified were similar to complications reported after traditional medial patellar luxation surgical correction techniques and no differences in patient outcome were identified between the patient group treated with TPLO and the patient group treated with TPLO-M.[10]

Plate contouring to fit the medial aspect of the proximal tibia after TPLO-M is complex and increases the surgical time.[10] Recently, 1.9 to 2.5 mm pre-contoured T plates (Intrauma S.p.A.,Turin, Italy) designed for TPLO-M in dogs weighing between 5 and 10 kg with 3 different offsets (2, 4 and 6 mm) to overcome the difficulties related to plate contouring became available (►**Fig. 1**). Plate offset, measured in mm, refers to the distance between the axes of the proximal and distal portions of the plate in the frontal plane. The 2 mm offset plate was designed for standard TPLO in small dogs without medial patellar luxation. The 4 and 6 mm offset plates were designed to allow medialization of the proximal tibial segment during TPLO. The Fixin system 'mini-implant series' are applied using 1.9 or 2.5 mm diameter screws and are indicated for the treatment of fractures in cats and dogs up to 10 kg.

The objective of this study was to determine the magnitude of proximal tibial segment medialization achievable with Fixin 1.9 to 2.5 mm pre-contoured T plates with three different offsets (2, 4 and 6 mm) in two different tibial model sizes.

We hypothesized that different magnitudes of medialization would be achieved using a plate with the same offset in tibial models from a 5 versus a 10 kg dog (hypothesis 1). We also hypothesized that the magnitude of medialization would not affect the degree of tibial plateau levelling in the sagittal plane and the alignment of the tibia in the frontal plane (hypothesis 2).

Materials and Methods

Specimen Selection

Hindlimb computed tomography (CT) scans were performed on both a 5 kg Yorkshire Terrier and a 10 kg Miniature Pinscher. Body condition score of dogs was 4 and 5 in the 9-point scale body condition score system.[11]

Both dogs had a normal orthopaedic examination and underwent full body CT scan for non-orthopaedic reasons. Informed owner consent was obtained for the use of the CT data to create tibial bone models for this study. The right tibia of each patient was reconstructed as a three-dimensional (3D) model using commercially available software (Rhinoceros 3D, Robert McNeel & Associates, Seattle, Washington, United States, and Magic 3D Print Suite, Materialise NV, Leuven, Belgium) and 18 solid foam polylactic acid bone models were printed of each tibia, resulting in a total of 36 tibial models (3D Printers: Delta Wasp 2040-2070).

Tibial bone models were divided into two groups based on body weight of the model patient and then each weight group was subdivided into three additional groups based on plate offset to be applied for a total of six groups, with each group containing six tibial models. The groups were designated: K5O2, K5O4, K5O6; K10O2, K10O4, K10O6 (K: Kg of the model patient, O: Plate offset). The two groups treated with the standard TPLO plate (2 mm offset plate) were defined as 'control groups' since the 2 mm offset plates are designed for standard TPLO in small dogs without proximal tibial segment medialization. The remaining four groups were termed 'treated.'

Pre- and Post-Osteotomy Radiographs

Orthogonal radiographic views were obtained of each tibial bone model pre- and post-osteotomy. The osteotomy was planned by placing a TPLO saw blade template of appropriate size on the scaled tibial image so that the blade was centred over a point dividing the intercondylar tubercles. The following three reference points were recorded: D1, the distance from the perpendicular cranial straight edge of the tibial crest originating at the most cranioproximal point of the tibial tuberosity to the intended osteotomy; D2, the distance from the most cranioproximal point of the tibial tuberosity and extending to the point where the intended tibial osteotomy transected the cranial tibial subchondral bone; and D3, the distance from the subchondral bone at the most caudal margin of the tibial plateau to the point where the intended tibial osteotomy transected the caudal tibial cortex.

To standardize the radiographic views of each bone, custom-made positioners were fashioned for each model type from commercially available floral foam bricks (Desert FoamÆ Dry Floral Foam bricks: FloraCraftÆ, Ludington, Michigan, United States). A radiopaque lotion made of pure petroleum jelly mixed with barium powder, (Bario Solfato puro A.C.E.F. Spa Fiorenzuola d'Arda, Piacenza, ITA) was applied to the tibial plateau, to the medial tibial cortex of

the bone models and in the middle of the astragalus trochlea to outline those portions of the models and facilitate radiographic measurements and positioning. Digital radiographic views (craniocaudal and mediolateral) were obtained for each model and each view included a magnification correction marker.

Osteotomy Procedure on Bone Models

A jig assisted TPLO was performed on all bone models as described by Slocum and Slocum.[12] In the 'treated groups' the Slocum TPLO technique was modified as described in the subsequent paragraph. The TPLO was performed with a 12 mm blade on the 5 kg tibia models and a 15 mm blade on the 10 kg tibial models. Screw diameters of 1.9 and 2.5 mm were used in the 5 kg and 10 kg tibia bone models respectively. A 1.0 mm Kirschner wire was used for temporary reduction of the tibial segments and 1.5 mm Kirschner wires were used to attach the jig to the tibia. Pin stoppers were applied using 1.5 mm Kirschner wires and 2.0 mm Steinmann pins in the 5 and 10 kg tibia bone models respectively.

An initial osteotomy was performed to disconnect the proximal fibula from the lateral aspect of the proximal tibia to allow caudal rotation and medialization of the proximal tibial segment. Control groups underwent a standard TPLO procedure, without proximal tibial segment medialization. In the 'treated groups,' the tibial plateau was initially rotated to level the TPA and the proximal segment was temporarily stabilized with the temporary reduction Kirschner wire. The TPLO plate was positioned such that the top of the plate was centred in the proximal to the distal centre of the proximal segment while holding the distal part of the plate parallel to the caudal cortex of the tibial diaphysis.[12] Temporary plate fixation was achieved using pin stoppers in the most distal and cranioproximal screw holes.

The plate was secured by inserting the two distal screws to the distal tibial segment (the distal pin stopper was removed to allow screw insertion). The temporary reduction Kirschner wire was then removed. The distal set screw in the jig was loosened and medial translation of the proximal tibial bone segment was obtained by sliding the distal tibia laterally. When the proximal tibial segment was in contact with the plate, the distal set screw in the jig was tightened again and the proximal screws were inserted in the plate. At the end of the procedure, the jig and associated Kirschner wires were removed.

Study Measurements

Measurements were performed by two investigators, different from the investigator who performed the TPLO procedures on the bone models. Digital radiographic software (Horos Project Medical Imaging Viewer version 2.1.1 for Mac Os X) was used for all radiographic measurements and an electronic caliper (FERVI SPA, Vignola, Modena, ITA) was utilized for all measurements performed directly on the bone models.

Electronic caliper measurements included: tibial diaphyseal width (mm) at the level of the osteotomy (WIDTH), plate to bone distance on the proximal (PBDp) and distal (PBDd) tibial segments, plate to joint distance (PJD; ►**Fig. 2**).

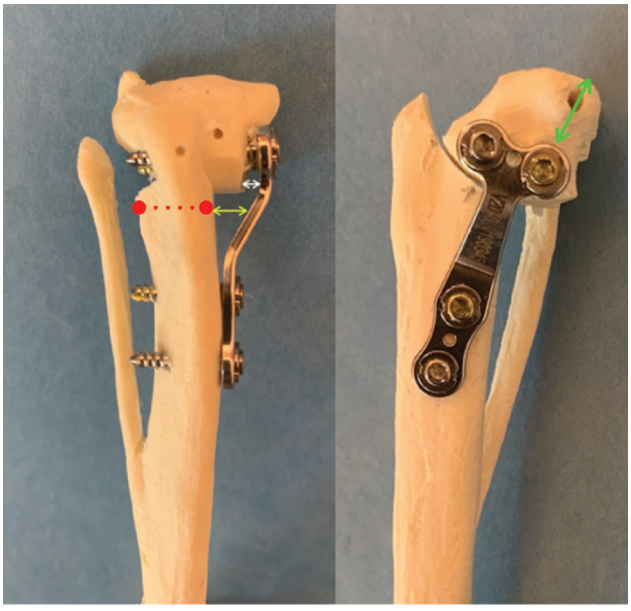


Fig. 2 Cranial aspect of the proximal tibia (**A**) and medial aspect of the proximal tibia (**B**) with the distances measured using an electronic caliper delineated. Measurements performed included: WIDTH (tibial diaphysis width, red dotted line), PBDp (plate to bone distance on the proximal tibial segment, white double arrow line), PBDd (plate to bone distance on the distal tibial segment, yellow double arrow line), and PJD (plate to joint distance, green double arrow line).

Digital radiographic measurements included: tibial plateau angle (TPA), mechanical medial proximal tibial angle (mMPTA) and magnitude of proximal tibial segment medialization (mm) measured at the level of the osteotomy line (MED; ►**Fig. 3**).[13,14]

Using values obtained from caliper and radiographic measurements, two additional values were calculated. These values were: medialization index (MI), calculated as MED/WIDTH, and bone apposition at the level of the osteotomy (APP): calculated as 1–MI.

Statistical Analysis

A statistical software package (GraphPad Prism 7, GraphPad Software, San Diego, California, United States) was used for all statistical calculations. Descriptive statistics including mean and standard deviation were calculated for each measurement value in each group included in this study. A 'Paired sample t test' was used to evaluate for differences in mMPTA and TPA between control and treated groups. An 'Unpaired t test with Welch's correction' was used to assess for the presence of a significant difference in MED between groups. A 'Spearman test' (p-value < 0.05 was considered significant with a confidence interval of 95%) was used to correlate MED with plate offset, PBDp, PBDd and PJD.

Results

Pre-osteotomy Measurements and Planning

The TPA of the tibia from the 5 kg patient was 25 degrees while the mMPTA was 91.1 degrees. For the 10 kg patient, the

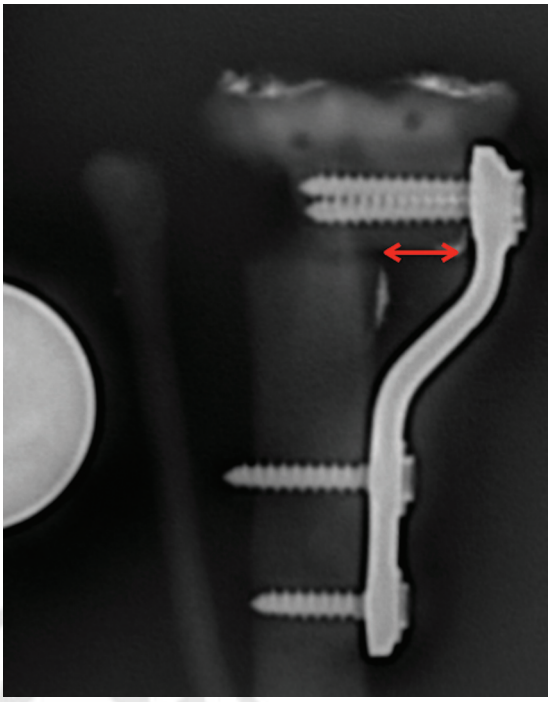
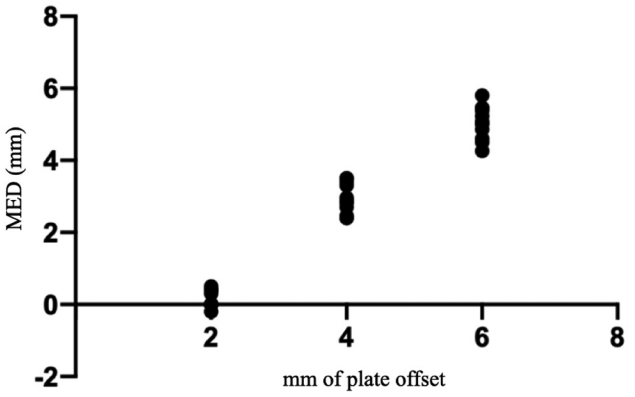


Fig. 3 Craniocaudal radiographic view with the MED (proximal tibial segment medialization) measurement at the level of the tibial osteotomy delineated by the red double arrow line. Note that radiopaque lotion has been applied to the tibial plateau and to the medial cortex of the tibia to outline these portions of the tibia clearly.



Graph 1 Graphic illustration of the positive correlation between mm of plate offset and MED (proximal tibial segment medialization).

TPA was 30 degrees and mMPTA was 92 degrees. Pre-operative TPLO planning was performed using the method described by Slocum and Slocum.[12] The proximal tibial segments were rotated 4.1 mm in the tibia models from the 5 kg dog while the proximal tibial segments were rotated 6.4 mm in the tibia models from the 10 kg dog.

Post-osteotomy Measurements

Mean and standard deviation values are summarized in ►**Table 1** for each group.

Post-osteotomy TPA values did not differ significantly ($p \geq 0.115$) between control and treated groups. Post-osteotomy mMPTA values did not differ between control and treated groups ($p \geq 0.0887$), except in the K5O6 treated group where mMPTA was increased as compared to the K5O2 control group ($p = 0.0204$).

The amount of medialization achieved with the and 6 mm plate offsets did not vary based on patient weight (p-value ≥ 0.232) but the amount of medialization achieved increased in both body weight groups when the mm of plate offset increased from 4 to 6 mm (p-value <0.0001). The correlation between mm of plate offset and MED was positive with a p-value less than 0.0001 (**Graph 1**). No correlation was identified between MED and PJD ($p \geq 0.150$). An inverse relationship between MED and PBDp ($p = 0.001$) and a direct relationship between the MED and DBDd values ($p < 0.0001$) were found. Medialization index and APP values for each group were calculated and are reported in ►**Table 1**. The maximum MI value was 67% (APP = 33%) identified in two cases in group K5O6 while the minimum MI value was −5%, identified in group K5O2.

Magnitude of Proximal Tibial Segment Medialization

Based on the absence of a significant difference in MED values between tibial models from different size dogs when using the same plate offset, MED values from both tibia sizes were pooled into 3 groups based on plate offset (2, 4 or 6 mm) for ease of comparison.

The + 2mm offset plate (control group) resulted in proximal segment medialization of 0.07 ± 0.34 mm, with

Table 1 Values are reported as mean ± standard deviation (SD)

Group	TPA	mMPTA	MED	PBDp	PBDd	PJD	MI	APP
K_5O_2	5.9 ± 1.9	88.4 ± 2.7	−0.1 ± 0.3	2.5 ± 0.8	1.8 ± 0.3	3.8 ± 1.3	−1 ± 3	98 ± 2
K_5O_4	3.7 ± 1.4	91.6 ± 2.8	2.8 ± 0.4	1.6 ± 0.4	3.7 ± 0.3	4.6 ± 0.5	33 ± 4	67 ± 4
K_5O_6	3.4 ± 1.9	93.3 ± 3.0	5.2 ± 0.2	1.6 ± 0.4	5.8 ± 0.3	4.9 ± 0.4	61 ± 6	39 ± 6
$K_{10}O_2$	4.2 ± 1.1	90.5 ± 1.8	0.3 ± 0.3	2.6 ± 0.4	2.9 ± 0.2	5.9 ± 0.4	3 ± 3	97 ± 3
$K_{10}O_4$	5.0 ± 1.2	93.6 ± 2.6	3.1 ± 0.6	2.1 ± 0.6	5.4 ± 0.5	6.6 ± 0.6	33 ± 7	67 ± 7
$K_{10}O_6$	5.2 ± 3.1	93.2 ± 2.8	4.9 ± 0.6	2.1 ± 0.3	6.8 ± 0.5	6.7 ± 0.4	49 ± 7	51 ± 7

Units are mm for TPA (tibial plateau angle), mMPTA (mechanical medial proximal tibial angle), MED (proximal tibial segment medialization), WIDTH (tibial diaphysis width), PBDp (plate to bone distance on the proximal tibial segment), and PBDd (plate to bone distance on the distal tibial segment). Units are % for MI (medialization index) and APP (bone apposition at the level of the osteotomy).

maximum and minimum MED values of 0.65 and −0.50 mm respectively. The +4 mm offset plate resulted in proximal segment medialization of 2.93 ± 0.51 mm with maximum and minimum MED values of 3.70 and 2.35 mm respectively. The + 6mm offset plate resulted in proximal segment medialization of 5.03 ± 0.47 mm with maximum and minimum MED values of 5.75 and 4.25 mm respectively.

Discussion

In this study, the TPLO-M procedure performed with the aid of pre-contoured locking plates on bone models allowed concurrent levelling of the tibial plateau and medialization of the proximal tibial segment. In the previous clinical study by Flesher and colleagues, T style TPLO plates were manually contoured to fit the step in the proximal tibia after proximal segment medialization because the pre-contoured plate utilized in our study had not yet been developed.[10] Manual contouring of TPLO plates to fit the proximal tibia after TPLO-M is somewhat complex and tends to result in an increased in plate to bone distance, which may result in weakening of the bone-plate construct and an increase in surgical time. The pre-contoured implants used in this study allowed subjectively easy plate application to the proximal tibia after TPLO-M without the need for plate contouring. Another difference in the surgical technique utilized in this study as compared to the technique in Flesher's study is that the TPLO procedure in this study was performed with jig assistance.[10] We found that use of the jig allowed medialization of the proximal tibial segment while maintaining tibial angular alignment in the front plane and tibial torsional alignment in the axial plane.

In this study, the magnitude of proximal segment medialization increased as the plate offset increased from 4 to 6 mm. We did not identify any differences in the amount of medialization achievable with a specific plate offset based on body weight of the patient from which the tibial model was obtained. Based on these findings, we rejected the first part of our hypothesis (that patient body weight would affect the amount of medialization achieved with a specific plate offset). Based on our findings, regardless of patient weight the +4 mm offset plates allowed a mean translation of 2.93 mm, while the +6 mm offset plates allowed a translation of 5.03 mm. These values may be useful to keep in mind during the plate selection portion of preoperative surgical planning for TPLO-M.

Plate to joint distance was not correlated with the amount of proximal segment medialization in this study. Since the proximal tibia in the frontal plane is triangular in shape, it stands to reason that the more distally the plate is positioned on the proximal segment, the greater the amount of medialization that should be achievable. In this study, our efforts to standardize plate position on the proximal segment along with the small number of specimens in each group may have hidden any effect that plate positioning on the proximal tibial segment may have on amount of medialization achievable.

Plate to bone distance distal to the osteotomy increases as the magnitude of proximal segment medialization increases. Excessive distance between the bone and the plate together with a decrease in bone segment apposition at the osteotomy site could result in osteotomy instability and delayed bone union. Further clinical studies should be performed to assess any effect these pre-contoured bone plates may have on osteotomy healing time after TPLO-M.

Medialization of the proximal tibial segment results in a direct reduction in bone apposition at the level of the osteotomy site (APP). Based on general orthopaedic principles, the maximum acceptable bone segment translation should leave at least 50% bone segment apposition at the level of the osteotomy line in the frontal plane to facilitate acceptable bone healing.[15] The mean APP value in groups K5O4, K10O4 and K10O6 was higher than 50%, while mean APP in group K5O6 was 39%. The less than 50% apposition documented in group K5O6 represents excessive translation of the proximal segment which might compromise bone healing in a clinical patient. When the +6mm offset plate is selected for use in a patient weighing less than 10 kg, the maximum acceptable proximal segment medialization value should be calculated preoperatively by measuring the width of the tibia on the craniocaudal radiographic view at the level of the planned osteotomy and dividing this width in half. It is recommended that this calculated medialization value not be exceeded during surgery.

In the clinical study by Flesher and colleagues,[10] dogs with grades I, II and III medial patellar luxation were treated with a mean proximal segment medialization (MI) of 20% meaning 80% apposition was retained at the osteotomy site on average.[10] Magnitude of proximal tibial segment medialization in Flesher's study[10] was subjectively determined during surgery, similar to the subjective assessment of how much to move the tibial tuberosity during tibial tuberosity transposition.[5] In most clinical dogs with low to moderate grades of medial patellar luxation, the need for more than 50% medialization of the proximal segment is unlikely, and in the more severe cases of grade IV medial patellar luxation, a corrective osteotomy of the femur is typically recommended.[16,17] Maintaining the centre of the radial osteotomy blade over the centre of the stifle joint to result in a relatively proximally positioned osteotomy may also be useful to help maintain a higher APP after proximal segment medialization, as the tibial width in the frontal plane increases proximally.

Tibial plateau levelling and medialization osteotomy resulted in levelling of the tibial plateau in both control and treated groups without evidence of significant differences in final TPA between groups. Hence, we partially accept the second portion of our hypothesis and conclude that magnitude of proximal segment medialization did not affect final TPA in this bone model study.

Medialization of the tibial plateau resulted in a small but not significant change in mMPTA values in most of the study groups. However, a significant increase in mMPTA was identified in the K5O6 group as compared to the control (K5O2) group (mMPTA control group: 88.9 degrees and mMPTA K5O6: 93.3 degrees). Thus, we partially reject the second portion of our second hypothesis as TPLO-M resulted in an alteration of mMPTA which

was significant in some groups. Medial translation of the proximal tibial segment during the TPLO-M procedure results in a slight medial deviation of the proximal origin of the tibial mechanical tibial axis in the frontal plane and thus tends to increase mMPTA. Given the same amount of proximal tibial segment medialization, the shorter the overall length of the tibia, the greater mechanical tibial axis deviation that will result. This rationale likely explains why given the same amount of MED with the +6mm offset plate, a significant change in the mMPTA was identified only in the smaller (5 kg) and not in the larger (10 kg) patient tibia model. A small shift in mMPTA associated with TPLO-M was previously reported by Flesher and colleagues in a series of clinical dogs treated with TPLO-M.[10] It is important to differentiate between values that are significant and values that are clinically relevant. While in this study an alteration in mMPTA of approximately 4.5 degrees was identified as being significant, the clinical relevance of small shifts in mMPTA has not been determined. The authors' observation has been that small shifts in mMPTA of the magnitude typically observed in association with TPLO-M have no detectable effect on limb function in clinical dogs. Additional studies are needed to determine what effect, if any, small shifts in mMPTA have on joint function in dogs.

This study has several limitations. This study was performed on 3D printed bone models that lacked many anatomical features including muscles, tendons, ligaments and other periarticular structures. Given this limitation, the results of this study should be extrapolated with caution to clinical dogs. We chose to perform this study on bone models to allow sample size optimization and to decrease sample variability (multiple copies of the same tibia). Our results for proximal segment medialization may differ from what other surgeons might achieve, as different surgeons may have different proficiency levels in performing TPLO-M and may position the plate differently on the proximal tibial segment as compared to where the plates were positioned in this study.

In conclusion, the +4mm and +6mm offset pre-contoured locking plates should be considered as a reasonable option for stabilization of TPLO-M in dogs weighing between 5 and 10 kg. The +6mm offset plate should be used cautiously in dogs weighing less than 10 kg since it may allow excessive proximal tibial segment medialization leading to insufficient postoperative bone apposition at the osteotomy site.

Authors' Contributions

M.D, A.B.B contributed to conception of study, design, acquisitions of data, drafting and approval of submitted manuscript. C.H and B.P contributed to conception of study. E.D.B and L.A.P contributed to study design and acquisition of data along with revising of the manuscript. All authors approved and publicly accountable for the relevant content of submitted manuscript.

Financial Support

This study was partially supported by Intrauma S.r.l. who provided all bone plates and financial assistance for manufacturing of the bone models.

Conflict of interest

There are no conflicts of interest to declare.

Acknowledgements

The authors would like to thank the Medical Imaging and Orthopedics Department of Ghent Veterinary Medicine University, for the collaboration in this study.

References

1 Priester WA. Sex, size, and breed as risk factors in canine patellar dislocation. J Am Vet Med Assoc 1972;160(05):740–742
2 Hayes AG, Boudrieau RJ, Hungerford LL. Frequency and distribution of medial and lateral patellar luxation in dogs: 124 cases (1982–1992). J Am Vet Med Assoc 1994;205(05):716–720
3 Ness MG, Abercromby RH, May C, et al. A survey of orthopaedic conditions in small animal veterinary practice in Britain. Vet Comp Orthop Traumatol 1996;9:43–52
4 Campbell CA, Horstman CL, Mason DR, Evans RB. Severity of patellar luxation and frequency of concomitant cranial cruciate ligament rupture in dogs: 162 cases (2004–2007). J Am Vet Med Assoc 2010;236(08):887–891
5 Kowaleski MP, Boudrieau RJ, Pozzi A. The stifle joint. In: Tobias KM, Johnston SA, eds. Veterinary Surgery: Small Animal. vol. 1;St. Louis: Elsevier/Saunders; 2012:906–998
6 Langenbach A, Marcellin-Little DJ. Management of concurrent patellar luxation and cranial cruciate ligament rupture using modified tibial plateau levelling. J Small Anim Pract 2010;51(02):97–103
7 Kergosien DH, Barnhart MD, Kees CE, et al. Radiographic and clinical changes of the tibial tuberosity after tibial plateau leveling osteotomy. Vet Surg 2004;33(05):468–474
8 Arthurs GI, Langley-Hobbs SJ. Complications associated with corrective surgery for patellar luxation in 109 dogs. Vet Surg 2006;35(06):559–566
9 Leonard KC, Kowaleski MP, Saunders WB, McCarthy RJ, Boudrieau RJ. Combined tibial plateau levelling osteotomy and tibial tuberosity transposition for treatment of cranial cruciate ligament insufficiency with concomitant medial patellar luxation. Vet Comp Orthop Traumatol 2016;29(06):536–540
10 Flesher K, Beale BS, Hudson CC. Technique and outcome of a modified tibial plateau levelling osteotomy for treatment of concurrent medial patellar luxation and cranial cruciate ligament rupture in 76 Stifles. Vet Comp Orthop Traumatol 2019;32(01):26–32
11 Laflamme D. Development and validation of a body condition score system for dogs. Canine Pract 1997;22:10–15
12 Slocum B, Slocum TD. Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine. Vet Clin North Am Small Anim Pract 1993;23(04):777–795
13 Cosenza G, Reif U, Martini FM. Tibial plateau levelling osteotomy in 69 small breed dogs using conically coupled 1.9/2.5 mm locking plates. A clinical and radiographic retrospective assessment. Vet Comp Orthop Traumatol 2015;28(05):347–354
14 Reif U, Dejardin LM, Probst CW, DeCamp CE, Flo GL, Johnson AL. Influence of limb positioning and measurement method on the magnitude of the tibial plateau angle. Vet Surg 2004;33(04):368–375
15 Fox DB, Tomlinson JL. Principles of angular limb deformity correction. In: Tobias KM, Johnston SA, eds. Veterinary Surgery: Small Animal. vol. 1;St. Louis: Elsevier/Saunders; 2012:665–668
16 Canapp SO, Campana DM, Fair LM. Orthopedic coaptation devices and small-animal prosthetics. In: Tobias KM, Johnston SA, eds. Veterinary Surgery: Small Animal. vol. 1;St. Louis: Elsevier/Saunders; 2012:628–647
17 Bosio F, Bufalari A, Peirone B, Petazzoni M, Vezzoni A. Prevalence, treatment and outcome of patellar luxation in dogs in Italy. A retrospective multicentric study (2009–2014). Vet Comp Orthop Traumatol 2017;30(05):364–370

