Comparison of Outcome and Complications in Dogs Weighing Less Than 12 kg Undergoing Miniature Tibial Tuberosity Transposition and Advancement versus Extracapsular Stabilization with Tibial Tuberosity Transposition for Cranial Cruciate Ligament Disease with Concomitant Medial Patellar Luxation

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Abstract

Objective The aim of this study was to describe a technique for performing miniature tibial tuberosity transposition and advancement (mTTTA). The secondary objective of this study was to compare the short-term outcome and complications in small breed dogs weighing less than 12 kg undergoing surgical correction of cranial cruciate ligament disease with concurrent medial patellar luxation via either extracapsular stabilization with tibial tuberosity transposition (ECS + TTT) or mTTTA.

Study Design This is a retrospective case comparison study.

Results There was no significant difference in overall outcome between the ECS + TTT group and the mTTTA group when comparing 8-week postoperative radiographic healing scores as well as 2- and 8-week postoperative lameness scores.

Conclusion This study concluded that the mTTTA procedure was feasible and the overall outcome and complications for the dogs that underwent ECS + TTT and those that underwent mTTTA were comparable.

Keywords
- cruciate ligament disease
- orthopaedic surgery
- dog
- tibial tuberosity advancement
- patellar luxation

Introduction

Cranial cruciate ligament disease and medial patellar luxation are two of the most common orthopaedic conditions affecting canine patients.[1] It has been theorized that dogs with patellar luxation may actually be predisposed to cranial cruciate ligament disease.[2] This is likely caused by abnormal forces being placed on the cruciate ligament from excessive internal rotation due to the malalignment of the quadriceps mechanism.[2] Small breed dogs, in particular, have been commonly found to have cranial cruciate ligament disease with concomitant medial patellar luxation with an incidence of 6 to 20%.[2–6] Extracapsular stabilization (ECS) has been routinely performed in small breed dogs with cranial cruciate ligament disease.[7,8] This procedure relies on fibrous tissue to form along the suture line to provide long-term stability.[9,10] There are two main concerns with this procedure: loosening of the suture and placement of the suture at non-isometric points.[9–12] Previous studies have reported suture failure more commonly than anticipated.[7,13–15] Tibial plateau levelling osteotomy has been researched in small dogs with favourable results; however, little data are reported on tibial tuberosity advancement in similar sized dogs.[16,17]

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Traditionally, small dogs have been treated with extracapsular stabilization + tibial tuberosity transposition (ECS + TTT) for their cranial cruciate ligament disease and medial patellar luxation when lateralization of the tibial crest is necessary.[7,8] One study compared the results of ECS + TTT treated dogs versus dogs treated with a tibial tuberosity transposition (TTT) and advancement.[18] The results of this study showed a 2.7× increase in complications within the ECS + TTT group over the tibial tuberosity transposition and advancement group.[18] The average weight in their study population was 23.4 kg.[18] While ECS is a feasible method of repair of cranial cruciate ligament disease in those dogs, it may not be the best choice for dogs with concurrent medial patellar luxation.[18] To the author's knowledge, there are no reports on TTT and advancement performed in small breed dogs. The purpose of this study was to describe a technique for performing miniature tibial tuberosity transposition and advancement (mTTTA). The secondary purpose of this study was to compare the short-term outcome and complications of dogs less than 12 kg with cranial cruciate ligament disease and medial patellar luxation treated with ECS + TTT versus those treated with mTTTA. Our primary hypothesis was that the mTTTA would be feasible to perform in dogs less than 12 kg. Our secondary hypothesis was that the mTTTA cases would have equivalent outcome and complications when compared with those undergoing the standard ECS + TTT.

Materials and Methods

Medical records from July 2016 to December 2018 of dogs less than12 kg that underwent mTTTA for cranial cruciate ligament disease and medial patellar luxation were collected and reviewed. Inclusion criteria were dogs less than 12 kg, a complete cranial cruciate ligament tear and medial patellar luxation diagnosis, miniature forkless titanium tibial tuberosity advancement plates used (Mini number 1 or Mini number 2 tibial tuberosity advancement plates Everost Surgical, Everost Inc., Sturbridge, Massachusetts, United States), 2-week follow-up examination with lameness evaluation and 8-week follow-up examination with lameness evaluation and radiographs. Medical records from December 2007 to November 2018 of dogs less than 12 kg that underwent ECS + TTT for cranial cruciate ligament disease and medial patellar luxation were collected and reviewed. Inclusion criteria were dogs less than 12 kg, a complete cranial cruciate ligament tear and medial patellar luxation diagnosis, 2-week follow-up examination with lameness evaluation and 8-week follow-up examination with lameness evaluation with or without radiographs. Exclusion criteria included those with incomplete surgical reports, dogs with partial cranial cruciate ligament tears, follow-up examinations without lameness scores provided and the need for a distal femoral corrective osteotomy or any other orthopaedic procedures.

Data obtained included breed, sex, age, weight, affected limb, medial patellar luxation grade, lameness score (graded 0–4), pre- and postoperative radiographs, trochleoplasty, medial meniscus status and treatment, implants used and complications. Lameness was graded at the 2-and 8-week follow-ups on a 0 to 4 scale with 0 being no lameness, 1 subtle lameness, 2 weight-bearing lameness, 3 toe touching lameness and 4 non-weight-bearing lameness.[19] Medial patellar luxation was graded on a scale of 1 to 4 as previously reported.[20]

Anaesthetic protocol included premedication with either hydromorphone (West-Ward, West-Ward Pharmaceutical Corp, Eatontown, New Jersey, United States) at 0.1 mg/kg intramuscular (IM) and midazolam (Akorn, Akorn Pharmaceuticals, Lake Forest, Illinois, United States) at 0.2 mg/kg IM or hydromorphone 0.1 mg/kg IM and dexmedetomidine (Zoetis, Orion Pharmaceutical Corp, Kalamazoo, Michigan, United States) 3 to 5 µg/kg IM per surgeon discretion and induction with propofol (Actavis, Actavis Pharma Inc, Parsippany, New Jersey, United States) at 2 to 6 mg/kg IV to effect. General anaesthesia was maintained with isoflurane (VetOne, MWI Animal Health, Boise, Idaho, United States) and continuous infusions of analgesics. Cefazolin (Pfizer, Pfizer Inc., New York, New York, United States) was administered at 22 mg/kg IV every 90 minutes. Surgery was performed by a board-certified surgeon or by a surgery resident under direct supervision of a board-certified surgeon. A standard medial skin incision and approach to the stifle joint was performed.[3] Either a caudomedial or mini craniomedial arthrotomy was performed for joint evaluation based on surgeon preference. The medial menisci were released, removed via a caudal pole hemimeniscectomy or left intact. A wedge or block trochleoplasty was performed based on surgeon preference if needed due to a shallow trochlear groove.[21,22] Beginning just cranial to the extensor groove, an osteotomy of the tibial crest was initiated. This was ended at the level of the distal crest preserving the trans cortex in the proximal half.[23,24] In all cases, the tibial crest was not robust so the osteotomy was notched at the distal aspect to both increase tuberosity bone stock to accommodate the cranial aspect of the tibial tuberosity advancement plate and to decrease the risk of creating a stress riser with the distal plate screw holes according to the original surgical method (►**Fig. 1**).[23] Each plate was also contoured laterally to allow for realignment of the quadriceps mechanism. A Mini number 1 or Mini number 2 plate was affixed to the osteotomy using two 1.5 mm self tapping titanium screws (Everost Surgical, Everost Inc.). The osteotomy was then completed.[24] A 3.0 or 4.5 mm titanium tibial tuberosity advancement cage (Everost Surgical, Everost Inc.) was then placed in the osteotomy site for cranial translation of the tibial crest.[23,24] The caudal 2.0 mm self-tapping titanium cage screw (Everost Surgical, Everost Inc.) was placed. The distal portion of the osteotomy was then reduced with pointed reduction forceps so that it came into contact with the tibial diaphysis allowing 2 to 3 mm of proximal translation of the crest.[23] The distal 2.0 mm self-tapping titanium plate screws were placed. The final 2.0mm self tapping titanium cranial cage screw was placed. Based on intraoperative visual assessment of the alignment of the trochlear groove and tibial tuberosity, a 2, 4, or 6 mm spacer (Everost Surgical, Everost Inc.) was placed under the cranial cage screw to further lateralize the tibial tuberosity to correct alignment prior to affixing the last screw. Modifications due to small bone size were necessary in the smallest of patients

Fig. 1 Intraoperative image showing a craniomedial approach to the left stifle having been performed revealing the left tibia and tibial tuberosity. Notching of the tibial crest has been performed at the distal aspect of the tuberosity osteotomy (arrow); this is done to both increase tuberosity bone stock to accommodate the cranial aspect of the tibial tuberosity transposition and advancement plate as well as to decrease the risk of creating a stress riser with the distal plate screw holes.

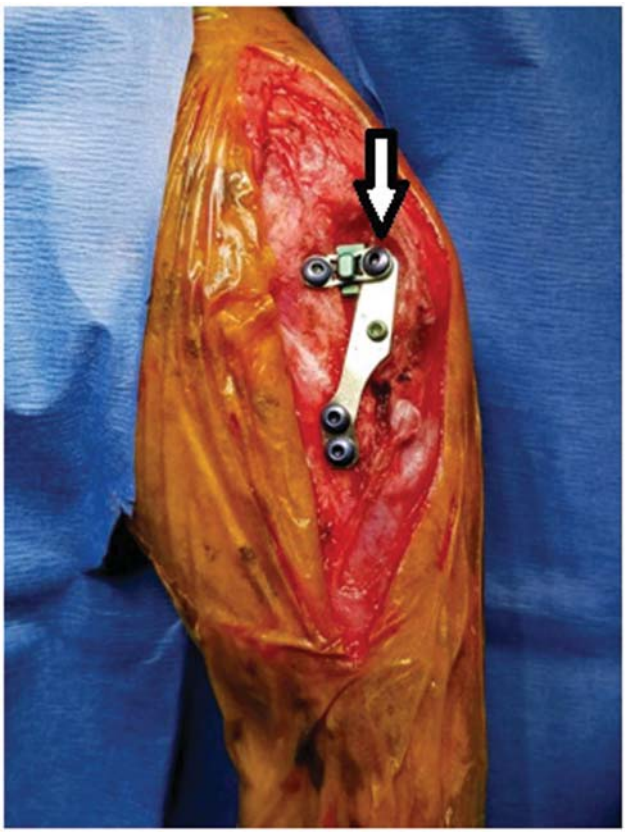

Fig. 2 Intraoperative image showing a craniomedial approach to the left stifle having been performed as well as a completed miniature tibial tuberosity transposition and advancement procedure with a modification, the proximal plate screw and cranial cage ear screw are combined(arrow). This was performed in cases with limited bone stock on the tibial tuberosity osteotomy.

within the study. In these cases, the cranial cage ear was placed over the proximal plate screw hole and both were filled with one 2.0mm self tapping titanium screw with or without the addition of a spacer (►**Fig. 2**). The osteotomy site was either filled with bioactive ceramic synthetic bone graft particulate (Consil Dental, Nutramax, Nutramax Laboratories Veterinary Sciences, Inc., Lancaster, South Carolina, United States), or autogenous cancellous graft, or otherwise left empty. The site was lavaged and closed routinely.[24]

For the ECS + TTT group, a medial skin incision was again performed combined with a lateral parapatellar approach to the stifle joint.[3] The joint was explored in a similar fashion and medial meniscal status was identified and treatment was performed as previously stated. Trochleoplasty was performed if needed at surgeon discretion.[21,22] The ECS + TTT were performed using either polypropylene, braided polyethylene or monofilament polyamide and 22-gauge wire or 0.89/1.14 mm Kirschner wires respectively.[5,6,13,20,25]

Orthogonal radiographs were made preoperatively, immediately postoperatively and 8 weeks postoperatively for all mTTTA included in this study and a portion of the ECS + TTT (►**Figs. 3–6**). Measurements for mTTTA implants were performed on the preoperative lateral radiograph with the stifle at 135 ± 5 degrees flexion (eFILM Software, IBM Watson Health, Merge Healthcare, Chicago, Illinois, United States) which is the approximate weight-bearing angle of the stifle.[26,27] Radiographs at 8 weeks postoperatively were made with the stifle again at 135 ± 5 degrees flexion for the mTTTA. Radiographs were evaluated for the extent of healing, implant failure and any other complications. A modified Lane and Sandhu scale was utilized for both groups to assess radiographic healing (►**Table 1**) (►**Figs. 7–10**).[28]

Post-operative complications were defined as either major or minor.[29] Major complications included implant failure, patellar reluxation requiring revision or any other that required a second surgery.[29] Minor complications were those treated without the need for surgical intervention.[29]

Owners were mailed a survey (►**Appendix A** [available in online version]) to determine their assessment of the mTTTA procedure and outcome.[19] Owners were asked how often their dog limped prior to and after surgery as well as whether or not their dog required long-term medications for discomfort. They were finally asked if they would recommend the surgery.

Data were analysed using a computer software program for statistical analysis (SPSS, IBM Corporation, Armonk, New York, United States). Normality of age, weight, medial patellar luxation grade, lameness scores and Lane and Sandhu

Fig. 3 Immediate postoperative cranial–caudal radiographic projection of a left-sided miniature tibial tuberosity transposition and advancement.

Fig. 4 Immediate postoperative lateral radiographic projection of a left-sided miniature tibial tuberosity transposition and advancement.

Fig. 5 Immediate postoperative cranial–caudal radiographic projection of a left-sided extracapsular stabilization with tibial tuberosity transposition.

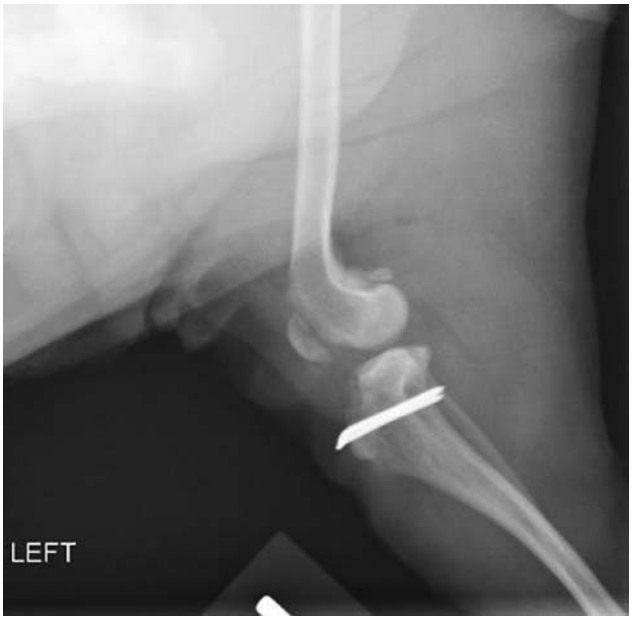

Fig. 6 Immediate postoperative lateral radiographic projection of a left-sided extracapsular stabilization with tibial tuberosity transposition.

radiographic healing scores were evaluated using a Shapiro–Wilk test. Based on normality, data were then described as mean with standard deviation for parametric data or median with interquartile range (IQR) for non-parametric data. In the results section, the IQR is expressed in parentheses as the IQR after each median value. Due to the nonparametric nature of the outcome data, a Kruskal–Wallis test was performed on the numerical outcome data between the two study groups, including Lane and Sandhu scores and lameness score at 2 and 8 weeks postoperatively. A p-value of <0.05 was determined to be significant. A Kappa measure of agreement was performed to determine interobserver agreement between each surgeon's scoring of the radiographs using the scoring system. A value less than 0 was determined to be

Table 1 Modified Lane and Sandhu radiological scoring system[17]

Bone formation	Score
No bone formation	0
25% formation	1
50% formation	2
75% formation	3
100% formation	4
Union (proximal and distal separately)	
No union	0
Possible union	1
Radiographic union	2
Remodelling	
No remodelling	0
Medullary canal remodelling	1
Full cortex remodelling	2
Total point/category	
Bone formation	4
Proximal union	2
Distal union	2
Remodelling	2
Maximum score	10

Fig. 7 Cranial–caudal radiographic projection of the same dog as in ►**Figs. 3** and **4**, 8 weeks postoperatively.

poor agreement, 0.01 to 0.2 was slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 for moderate agreement, 0.61 to 0.80 for substantial agreement and 0.81 to 0.99 for perfect agreement.[30] Multiple Kruskal–Wallis tests were used to determine significance of confounding factors, such as, whether or not a trochleoplasty was performed and meniscal status and treatment had an effect on the outcome.

Results

Thirty-one client owned dogs underwent the mTTTA surgery during the study time frame. Four of those dogs were excluded with two being excluded due to a lack of a medial patellar luxation and two being excluded due to a lack of 8-week postoperative radiographs. Ultimately, 27 client owned dogs satisfied the inclusion criteria for the mTTTA. Fifteen females and 12 males ranging from 1 to 13 years old with a median of 7 years (IQR = 2.5) were included. A Shapiro–Wilk test performed on the age data revealed that the ages were not normally distributed. Weights ranged from 2.4 to 12 kg with a mean of 7.6 ± 2 kg. Normality of the weight data was confirmed using a Shapiro–Wilk test. Breeds included Maltese ($n = 8$), Yorkshire Terriers ($n = 3$), Lhasa Apsos ($n = 3$), Scottish Terriers ($n = 3$), Mini/Toy Poodles ($n = 2$), Boston Terriers ($n = 2$), Havanese ($n = 2$) and 1 each of Shih Tzu, Coton de Tulear, Jack Russell Terrier and Cairn Terrier. Seventeen had left cranial cruciate ligament disease and 10 had right. One dog had bilateral cranial cruciate ligament disease and underwent single session bilateral mTTTA with each side evaluated separately. Medial patellar luxation grade was not normally distributed and ranged from 1 to 3/4 with a median of 3 (IQR = 1). 17/27 dogs had a torn medial meniscus. 15/27 had a caudal pole hemimeniscectomy, while 11/27 had a medial meniscal release. One case had a normal meniscus which was left intact. Sixteen had a trochleoplasty performed with nine being wedges and seven blocks. Eighteen received a cage spacer to further lateralize the tibial tuberosity. Plate size included 15 Mini number 1 and 12 Mini number 2 plates. Cage sizes included 3 ($n = 16$) and 4.5 mm ($n = 11$). Spacer sizes included 2 ($n = 9$), 4 ($n = 5$), 6 mm ($n = 2$) with nine patients not receiving a spacer.

Twenty-six client owned dogs fit the inclusion criteria for the ECS + TTT with no cases being excluded. Sixteen females and ten males ranging from 1 to 14 years old with a median of 7 years (IQR = 2.75) underwent surgery. A Shapiro–Wilk test performed on the age data revealed that the ages were not normally distributed. Weights ranged from 1.7 to 11.5 kg with a mean of 5.8 ± 2.25 kg. Normality of the weight data was confirmed using a Shapiro–Wilk test. Breeds included were Yorkshire Terriers ($n = 12$), Maltese ($n = 4$), Pomeranians ($n = 2$), Toy Poodles ($n = 2$), Shih Tzus ($n = 2$), Chihuahuas ($n = 2$) and 1 each of Cocker Spaniel and Bichon. Fourteen were diagnosed with left cranial cruciate ligament disease and 12 with right. One dog had bilateral cranial cruciate ligament disease and underwent a single session bilateral ECS + TTT with each sided evaluated separately. Medial patellar luxation grade was not normally distributed and ranged from grade 1 to 3/4 with a median of 3 (IQR = 1). Six of 26 dogs had a torn medial meniscus. Six of 26 had a caudal pole hemimeniscectomy, while 8/26 had a medial meniscal release and 8 had no meniscal treatment performed. Nineteen dogs underwent a trochleoplasty with 10 being wedges and 9 blocks. The ECS was performed using

Fig. 8 Lateral radiographic projection of the same dog as in ►**Figs. 3** and **4**, 8 weeks postoperatively. In scoring this radiograph with themodified Lane and Sandhu system, the white and grey arrows dictate the proximal and distal osteotomy segments, respectively, which are graded separately for evidence of bone union. Complete bone union of the distal segment is noted, while possible union of the proximal segment is present so a score of 3 is given. Complete union and full cortical remodelling are present giving a score of 4 and 2, respectively, giving this radiograph a total score of 9.[28]

polypropylene in 5 cases, braided polyethylene in 7 cases and monofilament polyamide in 14 cases. Tibial tuberosity transposition was secured using either Kirschner wires or cerclage wire in 20 and 6 cases respectively.

Multiple confounding factors were analysed to determine their effect on overall outcome. These factors were age, whether or not a trochleoplasty was performed, meniscal status and what type of meniscal treatment was performed. Analysis via Kruskal–Wallis test determined that none of these factors had a significant impact on overall outcome between each of the study populations. A *p*-value of 0.766 was calculated for ages between groups, 0.393 for whether or not a trochleoplasty was performed between groups, 0.668 for whether a meniscal tear was present or not between groups and 0.737 for treatment performed on the meniscus between groups. Due to the lack of significant associations within these factors, data correction for multiple variables was not performed on the outcome measures.

On preoperative radiographs, tibial plateau angles were measured according to Slocum's original research for each of the groups.[31] Tibial plateau angles for the mTTTA were not normally distributed and ranged from 23 to 39 degrees with

Fig. 9 Cranial–caudal radiographic projection of the same dog as in ►**Figs. 5** and **6**, 8 weeks postoperatively.

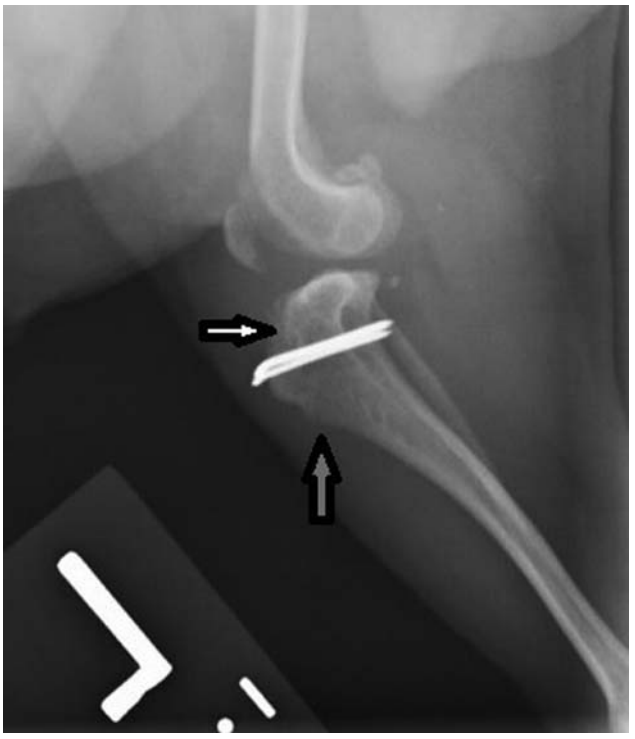

Fig. 10 Lateral radiographic projection of the same dog as in ►**Figs. 5** and **6**, 8 weeks postoperatively. In scoring this radiograph with the modified Lane and Sandhu system, the white and grey arrows dictate the proximal and distal osteotomy segments, respectively, which are graded separately for evidence of bone union. Complete union of each is noted giving a score of 4. Complete bone union and full cortical remodelling are present giving a score of 4 and 2, respectively, giving this radiograph a total score of 10.[28]

a median of 28 degrees (IQR = 7.5 degrees). For the ECS + TTT, preoperative tibial plateau angles were not normally distributed and ranged from 28 to 37 degrees with a median of 29 degrees (IQR = 3.5 degrees). No significant difference was noted between groups with a *p*-value of 0.493. On postoperative radiographs for the mTTTA, the patellar ligament ('tendon') angle was measured as previously described and recorded.[16,32] The patellar ligament ('tendon') angles were not normally distributed and ranged from 75 to 99 degrees with a median of 90 degrees (IQR = 6 degrees).

Two-week postoperative lameness scores were not normally distributed and ranged from 1 to 3/4 for the mTTTA with a median of 2 (IQR = 0). At the 8-week follow-up, lameness scores were also not normally distributed and ranged from 0 to 3/4 with a median of 0 (IQR = 1). Values for the ECS + TTT ranged from 1 to 3/4 with a median of 2 (IQR = 1) for the 2-week follow-up and 0 to 3/4 with a median of 1 (IQR = 0) for the 8-week follow-up. No significant difference was noted between the 2- and 8-week lameness scores between groups with a *p*-value of 0.299 for the 2-week lameness scores and a *p*-value of 0.202 for the 8-week lameness scores.

Eight-week postoperative radiographs were available for review in all mTTTA and 17/26 of the ECS + TTT. Each analyser evaluated the radiographs separately. The data were not normally distributed as determine via Shapiro–Wilk test. For the modified Lane and Sandhu scale, observer 1 scores for the mTTTA group ranged from 2 to 10 with a median of 8 (IQR = 4) and 4 to 10 with a median of 8 (IQR = 2) for the ECS + TTT group. Observer 2 scores ranged from 2 to 9 with a median of 6 (IQR = 3) for the mTTTA group and 4 to 9 with a median of 8 (IQR = 2) for the ECS + TTT group. No significant difference was noted when comparing the radiographic scoring scale between the two groups. A *p*-value of 0.35 was calculated for observer 1 and 0.18 for observer 2. Interobserver agreement was slight between the two observers with a Kappa value of 0.11. In subjectively comparing immediately postoperative radiographs to the 8-week radiographs, there was no evidence of implant failure, loosening or infection in any of the cases in either study group. The overall prevalence of complications for the mTTTA was 4/27 (1/27 major, 3/27 minor). The overall prevalence of complications for the ECS + TTT was 10/26 (5/26 major, 5/26 minor). There was no significant difference in the overall prevalence of complications or the prevalence of major complications between groups, at 0.06 and 0.08, respectively. For the mTTTA, one of the first cases performed had the only major complication which was patellar reluxation that required surgical revision. Ultimately, that dog passed from unrelated disease prior to revision. Minor complications for the mTTTA included superficial incisional infections (3/27). For the ECS + TTT, 3/26 ECS failed and revision surgery was recommended. These three cases had amongst the highest tibial plateau angles within the ECS + TTT group, ranging from 30 to 33 degrees. Two of twenty-six cases required implant removal due to irritation of the Kirschner wires from the tibial tuberosity transposition. No recurrent medial patellar luxation was reported. Minor complications included occasional lameness (1/26), suture reaction (2/26) and incisional infection (2/26).

Surveys were sent to owners of dogs with mTTTA performed between 4 and 6 months postoperatively with 14/25 returned. Of the surveys returned, 14/14 noted that their dog limped all of the time prior to surgery. Eleven of fourteen noted that their dog no longer limps, while 2/14 noted limping after exercise, and 1/14 limping after rest. Twelve of fourteen owners noted that their dog no longer needed a non-steroidal anti-inflammatory drug (NSAID), 1/14 required an NSAID as needed and 1/14 required an NSAID once monthly. Thirteen of fourteen owners believed surgery gave their dog an excellent outcome, while 1/14 noted a good outcome. All responders noted that they would recommend mTTTA surgery.

Discussion

Our study revealed that the mTTTA procedure was both feasible and resulted in a subjectively assessed outcome as being good, and comparable complication prevalence to the ECS + TTT procedure.

The one case in the mTTTA group with a major complication of patellar reluxation required revision surgery. It is difficult to say if the recurrent medial patellar luxation was a direct result of inadequate tuberosity lateralization or decreased retropatellar forces. Theoretically, decreased retropatellar forces which occur with tibial tuberosity advancement could increase laxity of the patellar ligament and increase the risk of patellar reluxation.[33,34] The surgeons that were performing the mTTTA procedures within this study also noted a subjectively steep learning curve in performing the surgery itself. It is possible that this major complication that occurred in this one case may have been avoided had it been one of the later performed surgeries instead of one of the first.

Previous reports have noted that a tibial plateau angle above 30 degrees may be a contraindication in performing the tibial tuberosity advancement.[35] The only case within this study that experienced a major complication had a tibial plateau angle of 27 degrees. It is, therefore, possible that tibial plateau angles above 30 degrees may not be a contraindication to perform mTTTA surgery; however, a larger study with a wider range of tibial plateau angles will be necessary to determine this.[35]

Similar to previous studies, not every case in this study resulted in a patellar ligament ('tendon') angle of exactly 90 degrees.[19,36] Despite this, gross over- or underadvancing of the tibial crest did not lead to any major or minor postoperative complications. Gross over- or underadvancement of the tibial crest may have been due, in part, to the lack of a broad selection in cage sizes as well as radiographic measuring variability or poor radiographic positioning due to varus and torsion deformity.

Previous studies have reported difficulties in implant sizes and plate contouring for small sized dogs with limited bone stock.[36,37] Implant sizes and over contouring of the tibial tuberosity advancement plates were not complications encountered in this study. The tibial tuberosity advancement plates utilized in this study were specifically designed for

small dogs. A big challenge with small and toy breed dogs was the limited bone stock associated with the tibial crest. A modification was performed when necessary, where the proximal tibial tuberosity advancement plate screw and cranial tibial tuberosity advancement cage ear screw were combined and filled with one screw. This was found to be a valid modification that did not lead to any observed complications in those cases.

Interobserver agreement for the modified Lane and Sandhu radiographic scoring system was only slight between the two surgeons. This may be due to the small sample size of the study population. It is important to note that, individually, each observer's scoring revealed no significant difference between to the two study populations, but this might be a type II statistical error. This scoring system is one that is used in human medicine specifically for assessing healing of tibia fractures and has been used in a study on rats.[28] Subjectively, this system was easy to use and was helpful as a way to obtain objective data on radiographic healing. It is important to also note that no complications were observed within this study with regard to bone healing.

Although subjective, owner perception of outcome is an important component when analysing surgical procedures. In this study, owners were asked whether or not they would recommend the mTTTA surgery to another owner. Of those that answered the survey, all recommended the surgery. Limitations of this study include the small sample size and inherent nature of a retrospective study. It is important to note that the mTTTA cases were being collected prospectively. While they were being evaluated retrospectively, medical records were meticulously kept for these cases as it was known that they would eventually be in this study. Records collected for the ECS + TTT cases were collected retrospectively and not as complete. Outcomes were mainly evaluated subjectively based on follow-up examination and owner assessment. The main objective data in this study were the 8-week postoperative radiographic evaluations, level of osteotomy healing grades and lameness scores. Future studies are necessary that include force plate and kinematic analysis with pelvic muscle mass measurements pre- and postoperative compared between groups.

In conclusion, the outcome and prevalence of complications of the mTTTA were comparable to the ECS + TTT. The mTTTA was performed successfully in 27 cases with minimal postoperative complications. Patellar reluxation was infrequently seen. Further research is necessary to assess more objective data in small breed dogs undergoing mTTTA.

Authors' Contributions

All authors contributed to conception of study, study design, acquisition of data, and data analysis and interpretation. They drafted, revised and approved the submitted manuscript and are publically accountable for relevant content.

Conflict of interest

None declared.

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