Tibial tuberosity transposition-advancement for treatment of medial patellar luxation and concomitant cranial cruciate ligament disease in the dog

Surgical technique, radiographic and clinical outcomes

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Keywords
Cruciate, patella, stifle, tibial tuberosity advancement, osteotomy

Summary
Objective: To report surgical technique, morphometric effects and clinical outcomes for tibial tuberosity transposition-advancement (TTTA), sulcoplasty and para-patellar fascial imbrication for management of concomitant medial patellar luxation (MPL) and cranial cruciate ligament (CCL) disease in 32 dogs.

Study design: Case series.

Methods: A previous technique for tibial tuberosity advancement was modified to incorporate lateral and distal tibial tuberosity transposition. Preoperative, immediate, and six to eight week postoperative radiographs were reviewed with morphometry of a range of tibial and stifle anatomic parameters. Findings of sequential clinical examinations to six months postoperatively were recorded.

Results: Thirty-nine stifles were treated by surgery. Medial patellar luxation grade ranged from II to IV/V. The CCL rupture was complete in 17/39 stifles, and incomplete in 22/39. Complications occurred in 11/39 stifles including MPL recurrence (n = 4). Resolution of subjectively-assessed lameness occurred in 29/39 stifles at the six to eight week assessment. Resolution of lameness was eventually documented in 35/39 stifles (4/39 lost to follow-up), and was maintained at the six to 20 month reassessment where available. The TTTA induced relative patella baja in 31/39 stifles. Magnitude of actual tibial tuberosity advancement was lower than that predicted by cage size.

Clinical significance: Tibial tuberosity transposition-advancement is a potential treatment modality for concomitant CCL disease and MPL in the dog, but refinement of planning is required, while biomechanical and kinematic effects remain unknown.

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Introduction
Cranial cruciate ligament (CCL) pathology is the most common cause of canine stifle lameness (1). Medial patellar luxation (MPL) is also a common canine stifle condition (1–3). Concomitance of CCL disease and MPL is well recognised with concurrent CCL rupture identified in six to 20% of dogs with patellar luxation (3–7).

Simultaneous treatment of concomitant MPL and CCL disease has been reported in limited numbers of dogs by tibial wedge osteotomy, lateral fabello-tibial suture, fabello-patellar suture, modified tibial plateau levelling and tibial tuberosity advancement (TTTA) either alone or in combination with additional procedures such as trochleoplasty, tibial tuberosity transposition or soft tissue (retinacular) release or imbrication (3, 7–9).

Previously reported techniques for management of MPL usually involve relocation of the tibial tuberosity or the patella in one or two planes (e.g. lateral transposition with or without cranial advancement). The role of vertical patellar height in aetiology and pathogenesis of canine patellar luxation has recently been investigated and an association between patella alta and MPL has been suggested as a possible contributor to high relaxation rates reported in some clinical case series (10, 11).

We proposed that modification of a previously described TTTA technique to include lateral and distal transposition of the tibial tuberosity would allow its controlled relocation in three dimensions, facilitating simultaneous management of MPL and CCL pathology (13, 14). Our objective was to report surgical technique of tibial tuberosity transposition-advancement (TTTA) in conjunction with ancillary procedures (e.g. block recession sulcoplasty, lateral capsulorrhaphy and lateral parapatellar fascial imbrication) in dogs concomitantly...
affected by MPL and CCL disease, to describe the morphometric effects of TTTA measured from pre- and immediate postoperative radiographs, and to report clinical outcome in a cohort of dogs.

We hypothesised that subjectively-assessed lameness would resolve postoperatively, that clinical examination would document resolution of MPL, and that postoperative radiographic morphometric measures would be consistent with both existing reference ranges for appropriate vertical patellar height and technical guidelines for TTA (10–15). Specific ancillary hypotheses based on radiographic morphometry were:

1. That preoperative vertical patellar height would not differ significantly from published reference range for dogs clinically affected by MPL, but that TTTA would result in postoperative effective vertical patellar height within published reference ranges in clinically unaffected dogs (10, 15).
2. That mean actual TTA would be equal to the mean TTA cage size used.
3. That patellar ligament length would not change between preoperative and six-week postoperative measures.

**Materials and methods**

Clinical and radiographic records of all dogs treated between September 2005 and October 2008 by TTTA were retrospectively reviewed. Signalment, orthopaedic history, clinical examination findings, surgical technique and findings at arthrotomy, perioperative management, and postoperative observations (including resolution of lameness and complications) were noted. Preoperative, immediate postoperative and six to eight week postoperative radiographs were evaluated including morphometry of tibial axes and proximal tibial landmarks to establish the effects of TTTA on tibial conformation and the stifle joint.

**Inclusion criteria**

Tibial tuberosity transposition advancement was applied in all dogs presenting to Fitzpatrick Referrals, where clinically significant pelvic limb lameness was attributed to concomitant CCL disease and MPL as the only primary stifle diseases identified. All cases had CCL disease confirmed by visual inspection at arthrotomy, identified either as complete CCL rupture, or as partial tears of the CCL. Medial patellar luxation was identified on clinical examination by stifle palpation and manipulation, and in all cases was subjectively graded using an ordinal scale (16, 17). All cases underwent ancillary block recession sulcoplasty, lateral capsulorrhaphy and lateral parapatellar fascial imbrication. Cases undergoing adjunctive osseous peri-stifle procedures, such as distal femoral osteotomy, were excluded, as were cases with less than six weeks postoperative clinical or radiographic follow-up available.

**Surgical technique**

Dogs were positioned in dorsal recumbency. The affected limb was aseptically prepared and draped to provide full access from the mid-femur to the metatarsus. A medial approach to the proximal tibia was performed prior to plate and fork application to the tibial tuberosity segment, if required, by grasping the plate subcutaneously dissected and excision of CCL remnants were performed in all dogs. Where identified, articular cartilage lesions were documented and scored using a previously described Outerbridge grading scheme (18). Block recession sulcoplasty was performed for all cases using an oscillating saw as previously described (19). Tibial tuberosity osteotomy and preparation for application of securing forks of a titanium tension band plate were performed as previously described (14). Standard TTA implants* and instrumentation† were employed throughout. Plate contour was adjusted such that the tibial tuberosity was transposed laterally and distally (Fig. 1) until patellar tracking was central within the trochlear groove in the frontal plane, as determined by intra-operative palpation and manipulation of the stifle and hock through full range of flexion and extension. Initial plate contouring was performed prior to plate and fork application based on visual estimation of the approximate degree of lateral transposition required based on observation of pre-existing quadriceps-patello-tibial sagittal plane alignment. Plate contouring was subsequently adjusted *in situ* following fork application to the tibial tuberosity segment, if required, by grasping the plate sub-

* TT-Implants, TTA-Instruments: Kyon™, Zurich, Switzerland

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Fig. 1 Schematic representation of medial and cranial views of a right stifle managed by tibial tuberosity transposition advancement. The tibial tuberosity has been transposed laterally and distally to realign the patella with the trochlear sulcus of the distal femur.
adjacent to the osteotomy and applying the Kyon™ plate bender distally.

The medial cortex of the tibia was recessed using a high-speed drill and an appropriately sized burr immediately caudal to the distal extent of the osteotomy to allow unrestrained positioning of the screw in the contoured plate prior to application of the distal plate screws (Fig. 2). Positioning of the screws was determined intraoperatively by the point at which at least half of the proximo-distal patellar length was distal to the proximal extent of the medial trochlear ridge with the limb held in full extension, as assessed by manual palpation and visual examination of the patello-femoral articulation. In all cases, this was at the same level or distal to the equivalent point of screw placement for a standard TTA procedure.

A recessed notch was created at the proximal extent of the tibia caudal to the osteotomy and distal to the tibial articular surface to accept the caudal ‘ear’ of the titanium cage such that the cranial ear of the cage remained in contact with the osteotomised tibial tuberosity following lateral transposition (Fig. 2). The exact proximo-distal position of this notch was determined by the intended position of the distal plate screws, since the cranial ear of the cage was necessarily positioned at the most proximal extent of the osteotomised tibial tuberosity.

The lateralised position of the osteotomised tibial tuberosity was maintained by insertion of a Kirschner-wire (1.1 – 2.0 mm diameter dependent on bone size) cranio-caudally through or immediately distal to the cage and at or immediately proximal to the insertion of the patellar ligament on the tibial tuberosity. The Kirschner-wire was cut flush with the cranial margin of the tuberosity and left in situ following application of the two screws in the cage ‘ears’. Care was taken to hold the caudal cage ‘ear’ tightly against the recessed notch during application of the Kirschner-wire, such that when this screw was placed, the cage had appropriate mechanical anchorage. Autogenous cancellous bone graft collected from the block resection sulcoplasty site was morsellised and packed into the osteotomy site distal to the cage. Lateral capsulorrhaphy and parapatellar fascial imbrication was performed for all cases, and in a minority of cases, release of the medial parapatellar fascia was also required for non-constrained patellar realignment prior to routine closure as previously described (14). Implants used for each case were recorded.

Postoperative care

Cefuroxime at 22 mg/kg was administered intravenously 15–45 minutes prior to the start of surgery. Perioperative analgesia included intramuscular administration of 0.3 mg/kg methadone and epidural injection of 0.1 mg/kg morphine. A self-adhesive wound dressing was applied to the surgical site and a light support dressing was also placed for three days postoperatively. Postoperative analgesia consisted of methadone (0.3 mg/kg intramuscular every 4 hours) or buprenorphine (0.02 mg/kg intramuscular every 8 hours) for one to three days. Carprofen (0.2 mg/kg subcutaneous) was administered at the time of anaesthesia induction, and was continued postoperatively at 2 mg/kg orally twice daily for one week, reducing to 1 mg/kg orally twice daily thereafter and continued until resolution of subjectively-assessed lameness. Cage rest and lead-only walking of progressively increasing duration were recommended until progression of osseous union was radiographically demonstrated.

Clinical assessment

Dogs were clinically assessed preoperatively, and at two weeks and six to eight weeks postoperatively in all cases by one observer, who was also the primary surgeon on all cases (NF). Clinical examination was repeated at six to 20 months postoperatively where possible, or at other time points as clinically indicated if lameness persisted or recurred at any time beyond the six-week reassessment. Findings recorded included subjective assessments of lameness, specific complications, and numerical classification of MPL (16, 17).

Radiographic measurements

Standard preoperative and immediate postoperative (Fig. 3) medio-lateral and caudo-cranial radiographic views of each tibia were assessed by the same observer (RY). Medio-lateral radiographs were positioned such that the femoral condyles were superimposed with a tolerance of <2 mm non-superimposition, and such that the stifle joint angle was within the range 130–140° using the long axes of the tibia.
and femur as reference lines. Direct digital radiography\textsuperscript{e} with diagnostic workstation software\textsuperscript{f} was employed and used for all measurements. A 10 cm radio-opaque marker\textsuperscript{g} was placed immediately adjacent to the tibia during radiographic examination to permit subsequent image calibration for preoperative planning and subsequent measurements (14).

Tibial plateau angle (TPA), patellar ligament length (PLL) along its caudal border, and patellar length (PL) (\textsuperscript{Fig. 4}) were measured as previously described and the PLL:PL ratio was calculated (11, 15). Patellar ligament length was also measured on the six to eight week postoperative radiographs, which were taken following the same protocol as those at other time points.

The position of the most cranial prominence of the tibial tuberosity was mapped relative to the point of intersection of the tibial long axis and tibial plateau axis preoperatively, by measurement of vectors parallel with and perpendicular to the long tibial axis (\textsuperscript{Fig. 5A}). This position was then mapped onto the postoperative radiographs allowing vector analysis of the change in tibial tuberosity location (\textsuperscript{Fig. 5B}). Tibial bone landmarks alone were used to establish these mapping vectors.

The vector of postoperative tibial tuberosity translocation distally (vTTD) parallel to the preoperative patellar ligament angle (e.g. proximo-distal difference between preoperative and postoperative tibial tuberosity location; \textsuperscript{Fig. 5C}) was measured. The vTTD was subtracted from the preoperative PLL allowing calculation of [PLL-vTTD]:PL ratio as a measure of normalised vertical patellar height comparable to preoperative PLL:PL ratio.

The vector of postoperative tibial tuberosity translocation advancement perpendicular to the preoperative patellar ligament angle (e.g. cranio-caudal difference between preoperative and postoperative tibial tuberosity location; \textsuperscript{Fig. 5C}) was calculated as a measure of ‘actual tibial tuberosity advancement’.

Six to eight week postoperative radiographic images, along with any subsequent radiographic images, were subjectively evaluated for osteotomy healing and maintenance of implant position.

Statistical analysis
Statistical analysis was performed using commercially available software\textsuperscript{h}. Descriptive statistics were utilised to depict signalment, clinical, and radiographic data, and the mean and standard deviations were also recorded where appropriate. The PLL:PL ratio was compared for dogs <20 kg with dogs >20 kg, and for dogs <11 kg with dogs >11 kg by Student’s t-test to establish whether the PLL:PL ratio for smaller dogs could be reasonably compared with two published reference ranges for control and (10, 15). The PLL:PL ratio and the [PLL-vTTD]:PL ratio for dogs of appropriate weight ranges were compared with two published reference ranges for control and

\textsuperscript{e} Eklín Medical Systems, Inc., Santa Clara, CA, USA
\textsuperscript{f} eFilm Workstation\textsuperscript{\textregistered} 2.1.2 software: Merge\textsuperscript{\textregistered}, Milwaukee, WI, USA
\textsuperscript{g} 10 cm X-ray Magnification Marker: Zimmer Inc., Warsaw, Indiana, USA
\textsuperscript{h} Minitab \textsuperscript{\textregistered} Release 14.20 software: Minitab Ltd., Coventry, UK
MPL-affected dogs of equivalent body weight groups by Student’s t-test using summarised data (sample size, mean and standard deviation). The PLL:PL ratio versus the [PLL-\( v_{\text{TTD}} \)]:PL ratio, preoperative versus six week postoperative measures of PLL, and true tibial tuberosity advancement versus cage size used were compared by paired t-test. The p-value was set at 0.05 for all analyses (10, 15).

**Results**

Thirty-nine stifles in 32 dogs were treated by surgery. Two dogs underwent single-session bilateral TTTA, while five dogs underwent bilateral staged procedures (staged by 2 months to 2 years). Age at time of surgery ranged from eight months to 141 months (11.75 years) with a median of 28 months (2.33 years). Body weight ranged from 6.3 – 51 kg (median 22.3 kg). Breeds included Staffordshire Bull Terrier (n = 7), West Highland White Terrier (n = 4), Jack Russell Terrier (n = 3), Labrador Retriever (n = 2), Bulldog (n = 2) and 14 other breeds. Six stifles had undergone previous surgical management (range 6 weeks to 9 years previously), three for CCL disease (lateral fabellotibial suture placement) and three for MPL (2 by retinacular release/imbrication alone, 1 by tibial tuberosity transposition and retinacular release/imbrication).

**Preoperative clinical findings and surgical details**

Grade of preoperative MPL was II/IV in 17/39 stifles, III/IV in 19/39 stifles and IV/IV in 3/39 stifles (16, 17). Seventeen of 39 stifles had complete CCL rupture, while 22/39 stifles had partial tears of the CCL. Concomitant medial meniscal injury was identified in 9/39 stifles. All joints manifested significant focal or diffuse cartilage pathology of the caudal articular surface of the patella or medial trochlear ridge of the femur, scored as Outerbridge grade 3 (n = 28) or grade 4 (n = 11).

A three-pronged fork was used most commonly (n = 13) followed by four- and five-pronged forks (n = 8 each), two-pronged fork (n = 6) and a six-pronged fork (n = 4). A 6 mm cage was used in 29 stifles, a 9 mm cage in nine stifles, and a 3 mm cage in one stifle.

**Complications and short-term clinical outcome**

Complications were recorded in 11/39 stifles. Recurrence of MPL occurred two to six weeks postoperatively in four out of 39 stifles, managed by surgical revision of recession sulcoplasty (n = 2/4) and by surgical revision of lateral parapatellar fascial imbrication (n = 4/4). Stifles with recurrent MPL had a preoperative grade of III/IV (n = 3) or IV/IV (n = 1), and at the time of recurrence, all were graded as II/IV. Other complications included implant-associated infection identified three to four weeks postoperatively necessitating eventual implant removal for resolution (n = 2), superficial wound infection managed medically (n = 2), excessive swelling or seroma formation (managed non-surgically) (n = 2).
2) and subsequent medial meniscal injury managed by partial meniscectomy four months postoperatively (n = 1). All complications responded to secondary intervention and subjectively-assessed lameness resolved within six weeks of intervention.

Resolution of subjectively-assessed lameness was documented at six to eight weeks postoperatively at the follow-up examinations in 29/39 stifles while lameness persisted in 10 stifles. In six out of these 10 stifles, lameness was associated with overt short-term complications (specifically recurrent MPL or implant-associated infection) with documented resolution several weeks later after appropriate intervention. In four of 10 stifles with persistent lameness at six to eight weeks postoperative, no overt complication was documented, and all were reported as being mildly lame but improved compared with status preoperatively. Owners were asked to return for reassessment within six weeks if, in their opinion, the lameness did not resolve. None of these four cases was subsequently re-presented although active follow-up was not performed.

**Long-term clinical outcome**

Eighteen dogs (21 stifles) were available for six to 20 months (median 14 months) postoperative clinical reassessment. Three of the 18 dogs were reported to have intermittent low-grade lameness or stiffness following vigorous or prolonged activity. Two of these three dogs with intermittent lameness received occasional doses of non-steroidal anti-inflammatory drugs (NSAID) when lame, but no patient received continuous NSAID or analgesic medication. Neither pelvic limb lameness nor discomfort on stifle manipulation was documented on clinical examination at the time of reassessment for any of the cases. Residual or recurrent MPL was also not detected on stifle manipulation for any of the dogs.

**Radiographic findings**

Mean tibial plateau angle was 26.7° ± 5.04° (range 18–38°). Mean preoperative PLL:PL ratio was 1.61 ± 0.250 (range 1.15 – 2.06). A significant difference was noted in the PLL:PL ratio in dogs <11 kg (mean PLL:PL = 1.45) compared with dogs >11 kg (mean PLL:PL = 1.70) by Student’s t-test (T = –3.27, p = 0.003). On this basis, values for dogs <11 kg were not compared with previously-published reference ranges for dogs >11 kg (10). Values for dogs <11 kg were also excluded from further statistical comparisons since reference ranges for the PLL:PL ratio have not previously been published for small breed dogs, to the best of the authors’ knowledge. No significant difference in the PLL:PL ratio could be determined between dogs in the body weight range 11 – 20 kg (mean PLL:PL = 1.78) and dogs >20 kg (mean PLL:PL = 1.65) by Student’s t-test (T = –1.42, p = 0.173). On this basis, values for dogs >11 kg in our study were considered for comparison with previously-published reference ranges for dogs >20 kg and dogs >11 kg (10, 15).

The preoperative PLL:PL ratio in dogs >11 kg was significantly different from the reference ranges for dogs clinically affected by MPL published by Johnson (T = –3.88, p = 0.001), as well as those published by Mostafa (T = –9.15, p = 0.000). It was also significantly different from the reference range for clinically normal stifles as published by Mostafa (T = –6.00, p = 0.000), but it could not be shown to be significantly different from the reference range for clinically unaffected dogs published by Johnson (T = –1.07, p = 0.300) by the Student’s t-test (10, 15). Preoperatively, only one of 25 stifles >11 kg was found to have definitive patella alta as defined as the PLL:PL ratio >1.97 (or >2.06 in dogs >11 kg) while four of 25 stifles >11 kg were found to have patella baja as defined as the PLL:PL ratio <1.45.

The preoperative PLL:PL and postoperative [PLL-vTTD]:PL ratio were confirmed as significantly different by paired t-test (T = 11.32, p = 0.000). The mean postoperative [PLL-vTTD]:PL ratio was 1.31 ± 0.26 (range 0.75 – 1.75) with 16/25 stifles >11 kg having effective postoperative patella baja under the guidelines reported by Johnson (15). Using summarised data, the postoperative [PLL-vTTD]:PL ratio in dogs >11 kg was significantly lower than the reference ranges for clinically unaffected dogs previously published by Johnson (T = –5.69, p = 0.000) or Mostafa (T = –10.85, p = 0.000) by Student’s t-test (10, 15).

Mean ‘actual TTA’ was 4.7 ± 2.04 mm (range 0 – 9 mm), and was significantly lower that that predicted by cage size by paired t-test (T = –6.91, p = 0.000).

Patellar ligament length could not be shown to have changed six weeks postoperatively compared with preoperative measurements by paired t-test (T = 1.40, p = 0.168). In all cases, evidence of early osteotomy healing was present on the six to eight week follow-up radiographic images, with no evidence of implant failure, loosening or migration. In all cases where subsequent radiographs were available (such as those undergoing implant removal or subsequently operated for contralateral disease in staged procedures) osteotomy healing was considered complete with bridging bone formation across the entire osteotomy line and continuity of trabecular pattern.

**Discussion**

Tibial tuberosity transposition-advancement was applied for the surgical management of concomitant canine CCL disease and MPL in 39 stifles. Technical application required only limited modifications compared with standard TTA procedure (14). Resolution of subjectively-assessed lameness was documented in all stifles with appropriate follow-up, thus supporting our major hypothesis in this regard. However, recurrence of MPL occurred in four of 39 stifles postoperatively requiring secondary surgical intervention in conflict with our major hypothesis. The significant documented reduction in vertical patellar height postoperatively (and effective iatrogenic postoperative patella baja in many stifles) led to rejection of our first ancillary hypothesis. The vector of postoperative tibial tuberosity translocation advancement was significantly lower than that anticipated by cage size, rejecting our second ancillary hypothesis. Patellar ligament length was unchanged between preoperative and six week postoperative assessments, supporting our third ancillary hypothesis.

The relatively low incidence of both concomitant meniscal injury (9/39) and...
subsequent meniscal injury (1/39) reported were consistent with incomplete CCL rupture in the majority of stifles operated (20). The high incidence of cases with partial CCL tears emphasises the importance of direct visual evaluation of the CCL for all cases of MPL.

Recurrent MPL in four of the 39 dogs was considered comparable to or lower than that previously reported for management of uncomplicated MPL (3, 6). None of the four stifles with recurrent MPL were considered to have an exceptionally increased or reduced preoperative PLL:PL ratio or postoperative [PLL-vTTD]:PL ratio compared with other stifles within this case series. Interestingly, all occurred in Terrier breed dogs, the significance of which is unknown, although since 19/32 dogs in this study were Terrier breed dogs, this may be merely coincidental. Relaxation in one stifle two weeks postoperatively was attributed to exuberant fibrous tissue proliferation at the lateral fascial imbrication site (assumed to be associated with suture material) which impinged on the lateral trochlear ridge resulting in MPL. In this case, resection of the fibrous tissue and re-apposition of the lateral para-patellar fascia was sufficient to resolve MPL. In the other three cases affected by relaxation, no specific cause was identified, including unremarkable postoperative [PLL-vTTD]:PL ratios within the context of this study, but the aetiology was considered most likely attributable to technical errors such as inappropriately shallow recession sulcoplasty or inadequate imbrication. In all three cases, revision surgery by sulcoplasty or imbrication alone successfully achieved appropriate patellar tracking (including at the long-term reassessment in two available dogs), and anecdotally, the degree of tibial tuberosity transposition was considered adequate in all cases. Implant failure or migration was not noted in any case, supporting application of standard TTA instrumentation for TTTA.

The mean magnitude of the vector of postoperative tibial tuberosity translocation advancement was significantly lower than mean cage size. In many cases this appeared to be associated with distal transposition of the tibial tuberosity or sub-optimal proximo-distal alignment of the cage within the osteotomy, although the statistical power was insufficient to pursue analysis of this within the study population. This finding raises the concern that femoro-tibial stabilisation may have been sub-optimal in these cases. This may support the contention of Gibbons et al that stabilisation of the patello-femoral joint is clinically more significant than stabilisation of femoro-tibial shear forces, although anecdotally the authors have identified sub-optimal clinical outcomes in a number of other cases where CCL disease has not been directly addressed (3). Further refinement of preoperative planning is warranted to avoid this scenario, particularly where substantial distal transposition of the tibial tuberosity is anticipated to correct for perceived patella alta, and particularly where cranio-caudal obliquity of the osteotomy compared with long tibial axis is required (e.g. due to variation in individual bone conformation). Simple modification of a trigonometric technique previously described may be adequate to allow for more reliable radiographic and mechanical outcomes (21). The effect of the recession sulcoplasty on the change in patellar positioning, and therefore on the patellar ligament angle and stifle biomechanics could theoretically be substantial and warrants further investigation. It is a significant limitation that we could not reliably document patellar ligament angle with reference to TPA postoperatively in this case series due to inability to accurately standardise radiographic positioning between sequential radiographic assessments. Such data would have been a useful adjunct by allowing comparison with existing mechanical data for TTA to determine anticipated femoro-tibial dynamic stability (22, 24). All radiographic measures were made from osseous tibial landmarks which could be more readily standardised.

While clinical outcome within this case series was considered positive, the retrospective nature of the study and the subjective nature of clinical outcome assessments represent a significant limitation. It is of particular note that the clinical assessments were performed in a non-blinded fashion by the primary surgeon in all cases, providing a potential source of bias. Objective outcome measures, such as force platform assessment or a validated owner-directed outcome questionnaire, would have been a valuable addition to this study.

The possibility for TTA to reduce patello-femoral contact pressure although clinical results of application for management of patello-femoral pain have been reported to be unreliable (27, 28). The authors subjectively consider that the clinical benefit in most dogs is unlikely to be a major consideration, at least within this case series, but further investigation is required regarding biomechanics and clinical effects of this phenomenon.

The preoperative PLL:PL ratio was similar to that described for normal, large, and giant breed dogs by Johnson et al, but it was somewhat lower than that described for dogs with MPL by Mostafa et al (10, 11). This may be attributable to the somewhat differing breed populations described, and indicates a potential need for further investigation to establish reference ranges for small breed dogs and chondrodystrophoid breeds, which accounted for the majority of dogs within this study. Another possible reason for the low PLL:PL ratio reported is the possible over-estimation of patellar length where osteophytosis at the proximal or distal pole of the patella was present although care was taken to identify or estimate the location of the patellar margins where osteophytosis was identified (15). Use of these historical reference ranges for statistical comparison introduced a potential source of bias due to the differing study conditions between historic studies and our own. The lack of a contemporary control group for such comparisons represents a further limitation of this study, and therefore this finding should be cautiously interpreted.
The postoperative [PLL-vTDD]:PL ratio was substantially lower than that described for PLL:PL ratios in any previously-reported group of dogs, and was significantly lower than the preoperative PLL:PL ratio by paired t-test. This indicates that within our study, the tibial tuberosity was distally transposed further than might be expected to be required based on published reference ranges, resulting in effective iatrogenic patella baja in a number of cases. This is likely to be attributable to the intraoperative assessment and adjustment of vertical patellar height. Modification of vertical patellar height was performed intra-operatively in this case series, with the target being the point at which at least half of the proximo-distal patellar length was distal to the proximal extent of the medial trochlear ridge with the limb held in full extension. The authors subjectively deemed this to constitute the vertical patellar height position least likely to result in failure by relocation by migration of the patella over the proximal aspect of the medial trochlear ridge.

Modification of preoperative planning in order to achieve a postoperative [PLL-vTDD]:PL ratio closer to the published reference ranges for the PLL:PL ratio would be an alternative, and might avoid the iatrogenic effective patella baja noted postoperatively in this case series. The pathological effects of patella baja recognised in humans include increased patello-femoral contact pressure (which may lead to cartilage wear and arthrosis), and reduction in joint range-of-movement (29). There is some evidence that patella baja is associated with lateral patellar luxation in dogs, but within the authors’ knowledge, there are no other published canine clinical cases documenting clinical disease as a result of patella baja (10). The positive clinical outcomes in this case series intimate that moderate patella baja may be tolerated in dogs and the relatively low recurrence of MPL may imply a beneficial effect in this regard.

However, further investigation is warranted, and such ‘overcorrection’ based on patellar position relative to the proximal trochlear sulcus cannot be reliably recommended in the absence of further definitive supportive data. Furthermore, the difference between the preoperative PLL:PL ratio in this study and previously reported PLL:PL ratio ranges emphasises the importance of individual or breed variations, and further investigation is required to allow detailed refinement of preoperative planning in this regard (10, 15).

Progressive patella baja is a well-recognised problem in humans following tibial osteotomy surgeries or injuries that change the mechanics or location of the patella, and is believed to be associated with contraction or fibrosis of the infra-patellar fat pad and surrounding structures, and may be documented within a matter of weeks postoperatively (29–31). There was no evidence of progressive shortening of the patellar ligament in this case series at the six to eight week radiographic examination by paired t-test, intimating that this may not be a significant feature in most dogs, at least in the short-term. However, longer-term monitoring in this regard may be beneficial, as may observation of further cases.

Summary

Tibial tuberosity transposition-advancement is a viable treatment modality for concomitant CCL disease and MPL in dogs, and is associated with comparable morbidity to existing tibial osteotomy techniques for management of CCL disease or MPL alone. The ability to manipulate the tibial tuberosity in three dimensions may improve versatility of treatment, although refinement of preoperative planning techniques is required to improve reliability in this regard. Further investigation is required to establish the precise effects of three-dimensional manipulation of the tibial tuberosity on stifle biomechanics and kinematics, but based on this case series, TTTA is a potentially useful technique for the clinical management of concomitant CCL disease and MPL.

Acknowledgements

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