# Combined tibial plateau levelling osteotomy and tibial tuberosity transposition for treatment of cranial cruciate ligament insufficiency with concomitant medial patellar luxation

**Katherine C. Leonard[1]; Michael P. Kowaleski[1]; William B. Saunders[2]; Robert J. McCarthy[1]; Randy J. Boudrieau[1]**

[1]Department of Clinical Sciences, Cummings School of Veterinary Medicine at Tufts University, North Grafton, MA, USA; [2]Department of Small Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences at Texas A&M University, College Station, TX, USA

**Keywords**

Tibial tuberosity transposition, tibial plateau levelling osteotomy, patellar luxation, TPLO, cranial cruciate ligament insufficiency, medial patellar luxation

**Summary**

**Objectives:** To describe the surgical technique and report short-term outcome for combined tibial plateau levelling osteotomy and tibial tuberosity transposition (TPLO-TTT) as an option in the treatment of cranial cruciate ligament insufficiency with concomitant medial patellar luxation.

**Methods:** Medical records were reviewed (2011–2013) of dogs that underwent a standard tibial plateau levelling osteotomy followed by a tibial tuberosity transposition in the frontal plane and stabilized with pin and tension-band wire fixation as a component of surgical treatment for combined cranial cruciate ligament insufficiency and medial patellar luxation. Signalment, fixation method together with any ancillary procedures, function at the in-hospital follow-up examinations, and any complications were recorded. Healing was assessed retrospectively based on the grading criteria of the International Society Of Limb Salvage.

**Results:** Fifteen stifle joints in 11 dogs were identified; 13 stifles were available for in-hospital follow-up. All 13 achieved union (3 with grade III/IV and 10 with grade IV/IV radiographic healing scores); mean time to healing was 10.6 (± 2.9) weeks. Patellar ligament thickening was also identified radiographically in seven of the 13 of stifle joints. All dogs were reported to have mild or no lameness at their last follow-up examination. No catastrophic or major postoperative complications occurred that required additional surgery. Patellar re-luxation did not occur in any of the 13 stifles available for in-hospital follow-up.

**Clinical significance:** The TPLO-TTT was found to be a reliable and effective technique when used as a part of the treatment of combined cranial cruciate ligament insufficiency with concomitant medial patellar luxation in this series of dogs.

**Correspondence to:**
Randy J. Boudrieau, DVM, Diplomate ACVS & ECVS
Cummings School of Veterinary Medicine at
Tufts University
Department of Clinical Sciences
200 Westboro Road
N. Grafton, MA 01536
United States
E-mail: randy.boudrieau@tufts.edu

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## Introduction

Cranial cruciate ligament insufficiency is one of the most common causes of hindlimb lameness in dogs, and is a major cause of osteoarthritis of the stifle joint (1–3). Cruciate disease can be complicated by medial patellar luxation (4). Chronic stress and degradation of cranial cruciate ligament fibres associated with medial patellar luxation may also contribute to cranial cruciate ligament rupture (4). Dogs that have chronic medial patellar luxation may have atrophy of hindlimb muscles secondary to chronic lameness; as a consequence, the muscle atrophy may result in increased strain on the cranial cruciate ligament and may predispose to rupture (4). Because many patients have a combination of cranial cruciate ligament insufficiency and medial

patellar luxation, a combination procedure to stabilize the stifle and treat the patellar luxation is often necessary.

There are many skeletal deformities associated with medial patellar luxation, including femoral varus, femoral torsion, tibial torsion, and medial displacement of the tibial tuberosity (5). In cases with medial displacement of the tibial tuberosity, a tibial tuberosity transposition may be necessary to realign the quadriceps mechanism and stabilize the patella (1).

Tibial plateau levelling osteotomy is a common procedure for treating cranial cruciate ligament disease in the dog. The tibial plateau levelling osteotomy procedure involves a proximal tibial radial osteotomy that isolates the tibial tuberosity, potentially leaving the tuberosity vulnerable to fracture after tibial plateau levelling osteotomy, which has been reported in a number of clinical studies (6–9). Therefore, it has been suggested that performing an additional osteotomy of the tibial tuberosity to treat concomitant medial patellar luxation may result in a greater likelihood of tibial tuberosity fracture or avulsion (10). For this reason, combining tibial tuberosity transposition with a tibial plateau levelling osteotomy was not previously recommended, and other procedures such as tibial plateau levelling osteotomy with internal tibial torsion correction, tibial plateau levelling osteotomy with lateral translation of the distal tibial segment, and tibial plateau levelling osteotomy with an additional transverse osteotomy have been described to treat cranial cruciate ligament insufficiency with concomitant medial patellar luxation in cases with medial displacement of the tibial tuberosity (10–13).

The two purposes of this retrospective study were: **1)** to describe the surgical technique in stifle joints in which a combined tibial plateau levelling osteotomy and tibial tuberosity transposition (TPLO-TTT) was used as one of the surgical components to treat cranial cruciate ligament insufficiency combined with medial patellar luxation; and **2)** to report the outcome of this aspect of the overall technique in 11 dogs (15 stifle joints).

# Materials and methods

## Criteria for case selection

Medical records (2011–2013) of dogs diagnosed with cranial cruciate ligament insufficiency in at least one limb with concomitant medial patellar luxation treated with combined TPLO-TTT as part of the surgical treatment at the Cummings School of Veterinary Medicine (Tufts University) and College of Veterinary Medicine and Biomedical Sciences (Texas A&M University) were reviewed. Demographic and surgical data were collected, including patient signalment, method of fixation, and any ancillary procedures performed. All radiographic and clinical findings at the time of in-hospital follow-up re-examinations were also reviewed.

## Surgical technique

Surgery was performed with the dog positioned in dorsal recumbency. The affected limb was aseptically prepared and draped to provide full access to the limb from hip to tarsus (a more proximal access was obtained in cases where a distal femoral corrective osteotomy also was performed). All dogs were administered cefazolin sodium (22 mg/kg IV) at induction and again every two hours for the duration of surgery. Any angular limb malalignment in addition to medial displacement of the tibial tuberosity identified preoperatively was addressed at the discretion of the attending surgeon. The stifle joint was explored by arthroscopy or arthrotomy, and any other ancillary procedures such as trochlear wedge recession, medial release, lateral imbrication, and patellar height correction (patella alta) were performed if needed, as determined at the discretion of the attending surgeon. The tibial plateau levelling osteotomy procedure was performed as described with the osteotomy centred on the intercondylar tubercles, followed by application of a tibial plateau levelling osteotomy bone plate (14). In preparation for the tibial tuberosity transposition, a portion of the cranial tibial muscle was elevated from the proximolateral surface of the tibia. An oscillating saw was used to perform a linear osteotomy of the tibial tuberosity without cutting its distal periosteal attachment. The tibial tuberosity transposition osteotomy was initiated near the most proximal and cranial aspect of the radial osteotomy for the tibial plateau levelling osteotomy, and extended to the distal extent of the tibial crest (▶Figure 1). The tibial tuberosity was then transposed laterally and secured using either two Kirschner wires or two small diameter Steinmann pins. The distance that the tibial tuberosity was translated laterally in each case was determined by the surgeon, with the goal of centring the patella within the trochlear sulcus of the femur. Intra-operative observation of surgical landmarks (radial osteotomy and the tibial plateau levelling osteotomy plate and screw positions) were used to ensure that the Kirschner wires or Steinmann pins used to secure the tibial tuberosity exited the caudal cortex of the proximal tibial bone fragment.

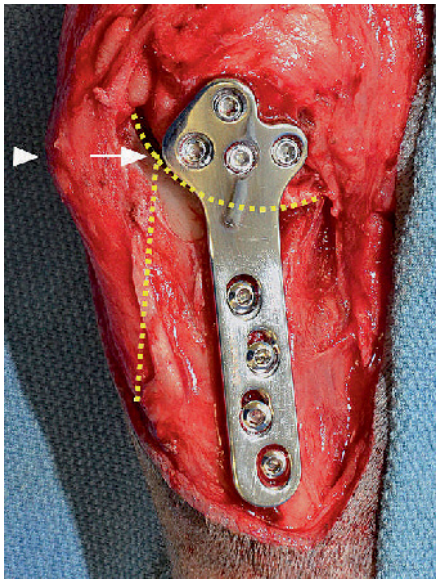

**Figure 1** Gross intra-operative image of the medial surface of the proximal right tibia. A tibial plateau levelling osteotomy has been performed and secured with a 3.5 mm broad tibial plateau levelling osteotomy plate. The radial osteotomy is outlined with the curved dashed line. The proposed location of the linear osteotomy for the tibial tuberosity transposition is shown by the straight dashed line. Note that this osteotomy is to be started proximally (arrow) at approximately the same level as the insertion point of the patellar ligament onto the tibial tuberosity (arrow head). Note that this osteotomy extends distally to include the majority of the tibial crest, thus ensuring a relatively large bone segment that encompasses the tibial tuberosity transposition. Compare to ▶Figure 2.

One or two large gauge, figure-of-eight tension band wires were placed and secured using single or double twists (one or both arms of the figure-of-eight wire) at the discretion of the attending surgeon (▶Figure 2). Closure was routinely performed. A modified Robert Jones bandage was placed on the entire operated limb in all dogs for the first 36 hours.

Postoperative opioid analgesics were administered at the discretion of the primary surgeon. Non-steroidal anti-inflammatory drugs were administered in the early postoperative period, generally for seven to 10 days. Postoperative antibiotic medication (cephalexin: 22 mg/kg orally every 8 hours) was administered at the discretion of the surgeon. Dogs were discharged two to four days after surgery with instructions for strict exercise restriction until re-examination with radiographic assessment of healing eight to 10 weeks later.

## Follow-up

In-hospital re-evaluations were performed, clinical findings (physical examination and limb function) and any complications were recorded, and follow-up radiographs were obtained.

Follow-up radiographs were evaluated and healing of the TPLO-TTT was retrospectively assessed based upon the grading criteria developed by the International Society of Limb Salvage (ISOLS) (15). The following radiographic score defined union as fusion of the osteotomy line, or the presence of bridging callus, or disappearance of the osteotomy lines, as seen on at least one aspect of each radiographic view: 1 = poor union <25% (no evidence of callus); 2 = fair union 25–50% healing; 3 = good union >50–75% healing; and 4 = excellent union >75% healing. Patients with a radiographic healing score of III or IV in conjunction with a recommendation from the attending surgeon to return to normal activity were considered to have reached clinical union. Radiographs were concurrently evaluated for soft tissue abnormalities such as patellar ligament thickening. Patellar ligament thickening was defined as previously described (16).

Complications were defined as has been previously suggested: catastrophic complications were those that caused permanent unacceptable function, death or euthanasia; major complications were those that required either further surgical or medical treatment to resolve; and minor complications were those that were noted on physical examination but required no further surgical or medical treatment (17).

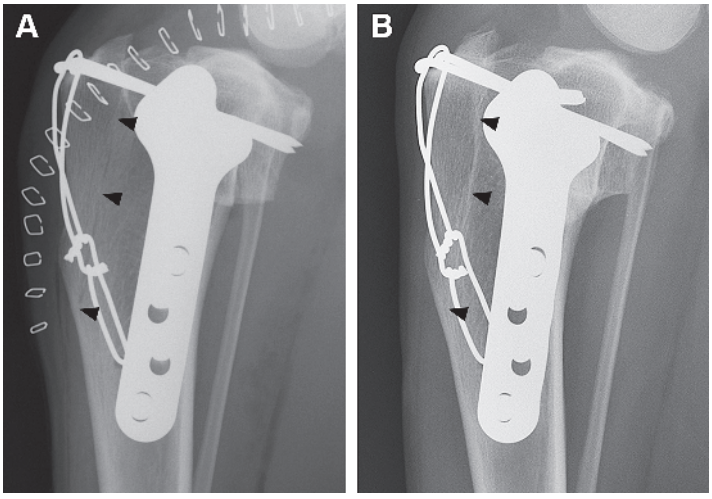


**Figure 2** **A)** Immediate postoperative and **B)** nine weeks postoperative mediolateral radiographs of the proximal tibia after a combined tibial plateau levelling osteotomy and tibial tuberosity transposition (TPLO-TTT) in dog number 5. Notice in **(A)** that both osteotomies have been compressed (black arrow heads outline the TTT): the TPLO by loading one or two screws in the distal portion of the plate to obtain interfragmentary compression; and the TTT with two 2.4 mm Steinmann pins and a 1.25 mm figure-of-eight tension-band wire produces dynamic compression during ambulation. At nine weeks postoperatively, the surgical implants are stable and their position is unchanged. Both osteotomies are healed based on the new bone formation and less defined fracture lines observed.

# Results

Eleven dogs with 15 affected stifles with both cranial cruciate ligament insufficiency and a concurrent medial patellar luxation that had a TPLO-TTT procedure performed as part of their treatment were identified and included for retrospective analysis. Of the 15 TPLO-TTT procedures performed, nine dogs (13 stifles) were available for in-hospital re-evaluation and two dogs (2 stifles) were lost to all follow-up after surgery. Breeds represented included one American Staffordshire Terrier, one Great Pyrenees, one American Bulldog, one Fila Brasileiro, two American Pit Bull Terriers, two Labrador Retrievers, and three mixed breeds. The mean age was 51.3 months (range: 13–96 months). Mean weight was 42.1 kg (range: 23.3–64.1 kg). There were three spayed females, seven castrated males, and one intact male (▶Supplementary Table 1: available online at www.vcot-online.com).

Eight stifles had a grade II/IV medial patellar luxation, five stifles had grade III/IV medial patellar luxation and one stifle had grade IV/IV medial patellar luxation before surgery. The grade of patellar luxation was not noted in the medical record in one stifle joint. Appropriate position of the tibial plateau levelling osteotomy was documented as previously reported, and the tibial tuberosity widths (both actual and relative widths at the level of the patellar tendon insertion) were recorded (9, 18, 19). In six stifles, femoral malformations of femoral varus were present, requiring additional osteotomy of the femur (lateral closing wedge osteotomy of the distal femur) to ensure appropriate stifle alignment. In eight stifles, a trochlear wedge recession was also performed in addition to the tibial tuberosity transposition (▶Supplementary Table 1: available online at www.vcot-online.com).

At the time of the 8 to 10 week follow-up examination, patient medical records documented mild or no lameness in all dogs. One dog (one stifle) was reported to have some signs of pain on pal-

pation of the reconstructed stifle joint; all remaining dogs were reported to be pain free. All stifles were palpably stable in response to the tibial compression test, and all patellae tracked normally within the femoral sulci. In two patients, mild crepitus of the stifle was noted but was non-painful. Radiographs revealed stable implants in all stifles. Ten stifles were assigned an ISOLS healing score of IV and were considered radiographically healed. Three stifles were assigned an ISOLS healing score of III and were considered to have reached clinical union. The mean time to healing for all 13 stifles was 10.6 ± 2.9 weeks (range: 6–15 weeks).

Radiographic evidence of patellar ligament thickening with no clinical signs of discomfort was present in seven stifles. Patellar ligament thickening with clinical discomfort (patellar desmitis) was present in one stifle. None of these cases required further medical or surgical treatment and were therefore considered minor complications. There were no catastrophic or major complications identified in this cohort of patients.

## Discussion

In this case series, we report TPLO-TTT to be a successful and repeatable surgical option for treating cranial cruciate ligament rupture with concomitant medial patellar luxation as a result of medialization of the tibial tuberosity. All dogs available for follow-up examination exhibited clinical union and stable implants with healing consistent with that observed with tibial plateau levelling osteotomy or tibial tuberosity transposition alone. All dogs were also reported to have a pronounced improvement in weight bearing and limb function at the time of re-evaluation. Although the follow-up re-evaluation and radiographs were recommended at 8 to 10 weeks after surgery, the time of re-evaluation was inconsistent in many of these patients. This makes it difficult to accurately compare healing at a specific time point after surgery. The time to radiographic healing was probably shorter than that reported, as the first radiographic evaluation occurred as long as 15 weeks postoperatively. As such, it is also reasonable to presume that clinical union was achieved at an earlier time frame than reported.

The most common complication at the time of the re-evaluations was patellar ligament thickening in over half of the stifles. Patellar ligament thickening is not an unusual clinical finding after the tibial plateau levelling osteotomy or tibial tuberosity transposition procedures performed in isolation, and in all but one stifle in this study, it was not clinically significant. Long-term follow-up would be needed to comment on the significance of these short-term findings. Based upon the improved clinical function observed short-term, and similar findings with a tibial plateau levelling osteotomy or tibial tuberosity transposition when performed alone, we would expect to similarly find resolution of the patellar ligament thickening with time.

In cases where lateralization of the tibial tuberosity is necessary to realign the quadriceps mechanism, it has been suggested that a tibial plateau levelling osteotomy may not be the ideal procedure to correct cranial cruciate ligament rupture with concomitant medial patellar luxation, as the tibial tuberosity is isolated as a result of the osteotomy, which may predispose it to fracture, delayed or complicated healing, or a combination of all (1, 13). This was a rationale presented by Weh and colleagues, to perform a double osteotomy (tibial plateau levelling osteotomy and transverse osteotomy) to avoid isolating a small tibial tuberosity bone fragment (13). This is, however, a relatively complex procedure and requires considerable additional fixation of the tibial tuberosity (13).

Previously, TPLO-TTT has not been performed as a component of cranial cruciate ligament insufficiency and medial patellar luxation surgery because of the concern that the small tuberosity segment might be difficult to secure, or that the tibial tuberosity transposition would weaken the tuberosity and predispose it to fracture. As such, an alternate method has been advocated, combining the tibial tuberosity advancement with a simultaneous transposition of the tibial tuberosity to address a combined medial patellar luxation with cranial cruciate ligament insufficiency (10, 20). We do not believe that a tibial tuberosity advancement and tibial tuberosity transposition is the best solution based upon our experience of a limited translation of the tibial tuberosity transposition, and the high rate of complications reported (28%, including a reluxation rate of 10% and patellar baja reported in 79%) (20). The results of the present study demonstrate that a tibial tuberosity transposition in the frontal plane is an effective solution to transpose the tibial tuberosity when combined with an appropriately positioned tibial plateau levelling osteotomy.

Correct positioning of the tibial plateau levelling osteotomy centred on the intercondylar tubercles, whereby a centred osteotomy with ample width to the tibial tuberosity cranial to the proximal tibial segment is performed, is likely to be the most important factor in this combined technique to ensure that the tibial tuberosity segment is of sufficient size and shape to mitigate the possibility of a fracture and allow for application of adequate fixation (18, 19). A large tibial tuberosity bone segment, as described with a coincident proximal origin with the tibial plateau levelling osteotomy osteotomy at the tibial plateau, and extending to the distal extent of the tibial crest, probably facilitates the placement of appreciably robust and secure fixation to this bone fragment. An adequate width of the tibial tuberosity segment when performing the tibial plateau levelling osteotomy is therefore necessary, and has been previously recommended along with the most appropriate osteotomy position (9, 18, 19, 21). For these reported cases, we demonstrated that all tibial plateau levelling osteotomy positions were appropriate based upon a minimum tibial tuberosity width of ≥1 cm and or a relative tibial tuberosity width of ≥25 %.

As noted, uncomplicated healing within the time frame expected for a tibial plateau levelling osteotomy or tibial tuberosity transposition alone was observed in all stifles available for re-examination after surgery. Based upon this series of dogs, we can recommend this procedure as a simple and repeatable technique for tibial tuberosity transposition that is essentially no different from the standard tibial tuberosity transposition routinely described with pin and tension-band wire (1).

The primary limitations to this study include the small number of dogs in which this technique was performed, and the relatively short follow-up period, despite a sufficient time frame to observe successful bone healing. The latter endpoint, healing of both the tibial tuberosity and the proximal tibial rotational osteotomy, was believed to be of sufficient duration to preclude any catastrophic complications and re-luxation of the patella. Furthermore, although the degree of lameness reported in the medical record improved for all dogs available for re-examination, objective measures of the degree of lameness were not used due to the retrospective nature of the study. We also acknowledge that the possibility of patellar re-luxation, implant migration (Kirschner wires), irritation from the tension band wires, or long-term infection might occur with longer term follow-up. All of these complications can be observed independently with tibial plateau levelling osteotomy as well as the various surgical methods of addressing a medial patellar luxation. Nevertheless, our goal was to demonstrate the utility and clinical success of combined TPLO-TTT, as defined by uneventful healing, lack of short-term complications, and complete resolution of the medial patellar luxation in the 13 stifles available for re-examination.

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## Conflicts of interest

None to declare.

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