Complications and outcome of a new modified Maquet technique for treatment of cranial cruciate ligament rupture in 82 dogs

J. Ramirez1; N. Barthélémy2; S. Noël2; S. Claeys2; S. Etchepareborde2; F. Farnir4; M. Balligand2

1Centro Veterinario de Referencia Bahía de Málaga, Málaga, Spain; 2Faculty of Veterinary Medicine, Department of Clinical Sciences, University of Liège, Liège, Belgium; 3Centre Hospitalier Vétérinaire des Cordeliers, Surgery, Meaux, France; 4Faculty of Veterinary Medicine, Biostatistics and Bioinformatic Department, University of Liège, Liège, Belgium

Keywords
Stifle, dog, Maquet, osteotomy, cruciate

Summary
Objectives: To describe the complications, short and long-term outcome and owner satisfaction of dogs with cranial cruciate ligament rupture treated with a recently described new osteotomy for the modified Maquet technique (N-MMT).

Materials and methods: Medical records and radiographs of 82 dogs (84 stifles) were reviewed. Details regarding short-term outcome and complications were recorded from the medical records. Long-term follow-up information was obtained by telephone interview. Historical data and complications were statistically analysed.

Results: Major complications occurred in 34/84 stifles. Intra-operative complications occurred in 26/84 stifles, all of which were fissures or fractures of the cortical hinge. Twenty-one of these fractures or fissures were repaired with a figure-of-eight wire. The second most common major complication was late meniscal tears in 3/84 stifles. One dog sustained a complete tibial fracture. Non-displaced fracture of the cortical hinge was the most common postoperative minor complication, which occurred in 5/84 stifles. The median preoperative lameness score was 3 out of 6. Development of osteotomy related complications was not associated with a significant change in the postoperative lameness score.

Clinical significance: Subjectively assessed clinical outcome with the N-MMT was good to excellent in this cohort of dogs. However, a high rate of intra- and postoperative complications of the N-MMT procedure was also present in these dogs.

Introduction

Complete or partial rupture of the cranial cruciate ligament is the most common disorder of the stifle joint in dogs (1). Disruption of the cranial cruciate ligament leads to progressive stifle joint osteoarthritis, which, along with concurrent meniscal injury, contributes to inflammation, pain, and loss of function (2–6). Numerous surgical techniques have been described to manage cranial cruciate ligament insufficiency, each having proven potential advantages and disadvantages (7). Tibial plateau levelling osteotomy and tibial tuberosity advancement are the most commonly used techniques for dynamic repair (8–10). The modified Maquet technique and tibial tuberosity advancement are derived from a surgical technique that was first introduced by Maquet to relieve pain in osteoarthritic and chondromalacic patellofemoral joints in humans (11). The modified Maquet technique, a modification of the original tibial tuberosity advancement technique, was described by Etchepareborde and colleagues (12). The modified Maquet technique avoids the use of a bone plate as it leaves intact a distal osseous attachment, called the cortical hinge, with the tibial shaft. The modified Maquet technique also preserves soft tissue integrity because reflection of the periosteum along the tibial crest is minimal (12).

Originally, Maquet recommended the placement of a distal drill hole to prevent formation of a fissure (11, 12). However, in our clinical experience with more than 50 cases using the original modified Maquet technique design, we have found that the most common complication was fracture or fissuring of the cortical hinge that always propagated from this drill hole. A biomechanical study found that fracture of the cortical hinge significantly decreased the mechanical strength of the repair, even when it was stabilized using a tension band wire, as previously recom-
mended (13). In 2013, Brunel and colleagues described an ex vivo study of a revised, slightly curvilinear and longer, osteotomy that was created without drilling a distal hole (14). Theoretically, advantages of this modified osteotomy, compared to the previously described modified Maquet technique osteotomy, were tolerance of axial loads to failure up to approximately six times body weight, and that greater tibial tuberosity advancement than clinically required could be reached without fracturing the cortical hinge (11, 14). Since this new modified Maquet technique (N-MMT) osteotomy was described only in a biomechanical, ex vivo study, our purpose was to report the short and long-term outcomes, complications, and owner satisfaction associated with the N-MMT in a large cohort of dogs.

**Materials and methods**

**Inclusion criteria**

Medical records of 82 dogs with cranial cruciate ligament injuries that underwent a N-MMT procedure at the Liege University Veterinary Hospital from December 2011 to April 2014 were reviewed. Signalment data collected included age, gender, weight, and breed. Complications (intra- and post-operative) and outcome were recorded. Intra-operative complications were defined as any unexpected event that occurred during the surgery. Postoperative complications were defined as any unexpected event that occurred after surgery. Complications were considered major if any of the following occurred: implant failure, tibial tuberosity fracture or fissure, tibial fracture, or any other complication requiring surgery or intensive medical therapy. Minor complications were defined as those not requiring additional surgical treatment or intensive medical treatment.

**Preoperative evaluation**

A numerical rating scale of lameness with six levels of severity was utilized (Table 1). Standard medio-lateral and cranio-caudal radiographs of the affected stifles were obtained (11). For the mediolateral view, the limb was positioned with the stifle joint at 135° of extension using the long axis of the femur and tibia as references axes, according to a goniometer placed over the femoral and tibial diaphyses. A standardized tibial tuberosity advancement transparency was used to determine the amount of tibial tuberosity advancement required to position the patellar ligament perpendicular to the tibial plateau in a standing position (135° stifle joint extension).

**Anaesthesia**

All dogs were premedicated with methadone (0.3 mg/kg IM) and acepromazine (0.02 mg/kg IM). General anaesthesia was induced using propofol (4 mg/kg) administered via a peripheral venous catheter and maintained using isoflurane (1.5–2.0%) in 100% oxygen. All dogs received an epidural administration of morphine (0.2 mg/kg) and bupivacaine (1 mg/kg). Intra-operative crystalloid fluid therapy (5–10 ml/kg/hour) was used to maintain systemic blood pressure. Cefazolin (22 mg/kg IV) was administered perioperatively and every 90 minutes thereafter during surgery. Intra-venous carprofen (4 mg/kg) was administered preoperatively for analgesia. A forced warm-air system was used intra- and post-operatively to maintain body temperature.

**Surgical technique**

The N-MMT were performed by seven different surgeons, including five residents under direct supervision of a board certified surgeon or by two different board certified surgeons who were assisted by a first year resident or intern. The previously described N-MMT osteotomy was used in every case (Figure 1) (14). Dogs were positioned in dorsal recumbency. Once the limb was aseptically prepared, it was draped to provide easy access to the limb from mid-thigh to the hock. A curvilinear skin incision was made, centred over the medial aspect of the stifle and extending distally to expose the cranial-medial aspect of the tibial tuberosity and the proximal part of the tibial diaphysis. A medial mini-arthrotomy was performed to determine the degree of damage to the cruciate ligaments and menisci. Remnants of the torn cranial cruciate ligament were debrided and any meniscal tears were sharply excised by removing the injured portion of the meniscus or by performing a complete caudal pole meniscectomy. Meniscal release was not performed in any case. Once the stifle joint exploration was finished, the dog was tilted laterally to provide easier access to the medial aspect of the proximal tibia. The osteotomy was started at a point 5 to 15 mm caudal to the tibial tuberosity.

<table>
<thead>
<tr>
<th>Lameness grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No detectable lameness at a walk or trot and no detectable lateral weight shift at a stance</td>
</tr>
<tr>
<td>1</td>
<td>No detectable lameness at a walk or trot and minor lateral weight shift at a stance</td>
</tr>
<tr>
<td>2</td>
<td>Lameness at a walk or trot without hip hike</td>
</tr>
<tr>
<td>3</td>
<td>Lameness at a walk or trot with hip hike</td>
</tr>
<tr>
<td>4</td>
<td>Non-weight-bearing at a trot</td>
</tr>
<tr>
<td>5</td>
<td>Non-weight-bearing at a stance</td>
</tr>
</tbody>
</table>

Table 1. Clinician’s lameness scores at the pre-operative and post-operative in-hospital evaluation.

---

a Kyon, Zurich, Switzerland  
b Mephenon: Sterop Laboratories, Brussels, Belgium  
c Plavix: Kela Laboratories, Hoogstraten, Belgium  
d Dipitrav 1%: AstraZeneca Laboratories, Brussels, Belgium  
e Morphine Hcl: Sterop Laboratories, Brussels, Belgium  
f Marcaine: AstraZeneca Laboratories, Brussels, Belgium  
g Cefazolin: Sandoz m/va, Vilvoorde, Belgium  
h Rimadyl: Zoetics Belgium SA, Louvain-la-Neuve, Belgium
and the cranial border thereof, according to the dog size, and it was then extended distally over a distance equivalent to at least 150% the length of the tibial crest. In most cases however, the osteotomy was started at a point 10 mm caudal to the tibial tuberosity. The cranio-caudal thickness of the cortical hinge was determined as previously reported (14).

The shape of the osteotomy consisted of a straight proximal part along the whole length of the tibial tuberosity (Figure 1), and then it curved slightly caudally to finish as a straight distal part over a distance equal to 50% of the tibial crest length (Figure 1), using a 30 mm working length, 9.5 mm wide, bone saw.

The saw blade was directed perpendicularly to the sagittal plane of the tibia throughout the entire osteotomy. Once the osteotomy was completed, the tibial tuberosity was displaced cranially with an appropriate spacer for the selected titanium cage width used to maintain the advancement. If an intra-operative fracture or fissure of the cortical hinge occurred, or was suspected by the surgeon, a cerclage wire in a figure-of-eight configuration was placed to stabilize the tibial tuberosity to the tibial shaft. A 1.5 mm diameter cerclage wire was used to stabilize the fissure in a figure-of-eight configuration. A titanium cage was placed into the osteotomy gap at the proximal extent of the osteotomy and secured to the tibia with two 2.4 mm titanium cortical screws. Wound closure was performed by suture apposition of the fascia and subcutaneous tissue with a simple continuous pattern. The skin was closed using a cruciate interrupted pattern.

**Postoperative care**

A Robert-Jones bandage was applied for 10 days after the surgery. Tapered doses of methadone were administered to all dogs during the first 24-hour period postoperatively before being discharged. Cefalexin (20 mg/kg, BID) and carprofen (2 mg/kg, BID) were administered orally for one week. Five to ten minute lead walks, three to four times daily, were the only recommended activity during the initial six to eight weeks after surgery. Based on the amount of bone healing present at the osteotomy gap on follow-up radiographs, controlled activity was slowly increased during the next two to six weeks before uncontrolled activity was allowed.

**Follow-up examination**

In-hospital evaluations were performed at six and 12 weeks postoperatively. In those dogs with no referring veterinarian, wound evaluations, and suture and bandage removal were performed at our institution at 10 days postoperatively. When referring veterinarians did remove the bandage, they were asked to report any bandage sores. All dogs were assessed for lameness as well as any complications recorded. The same lameness grading system as used for the preoperative assessment was used (Table 1).

**Radiographic evaluation**

Radiographs were made for each case immediately following surgery, and at subsequent follow-up examinations. Follow-up radiographs consisted of a cranio-caudal radiograph and a mediolateral radiograph centred on the stifle. On the mediolateral...
radiograph, the angulation of the stifle was set at 135° using a goniometer placed over the shafts of the femur and tibia (Figure 1).

Assessment of postoperative radiographs included the presence of signs of fractures or fissures, implant failure, septic arthritis such as severe joint effusion together with subchondral lytic areas, as well as osteomyelitis.

Follow-up radiographs were examined to evaluate osteotomy healing at three different sites as previously described: proximal to the cage, inside the cage, and between the cage and the cortical hinge. The following grading scale was used: 1 = no or little new bone formation, 2 = bridging at one site, 3 = bridging at two sites, and 4 = bridging at all three sites (Figure 2, Figure 3).

**Owner evaluation**

Further follow-up was obtained by a telephone-based owner questionnaire (Appendix Table 1: Available online at www.vcot-online.com) to determine mid to long-term function (15). The client satisfaction questionnaire was conducted a minimum of six months postoperatively when available. The questionnaire addressed the severity and duration of lameness preoperatively and at the time of survey completion, the current need for nonsteroidal anti-inflammatory drug medication, and overall owner satisfaction.

**Statistical analysis**

The first analysis investigated whether the N-MMT reduced the lameness score. To this aim, lameness scores pre- and postoperatively were analysed by Wilcoxon signed-rank test. Secondly, a case control study was conducted to identify risk factors for intra-operative and postoperative complications. Data were analysed by binary logistic regression to identify which variables increased the odds of suffering each complication. Age, body weight, ratio of tibial tuberosity advancement/body weight (TTA/BW), cage size and preoperative lameness score were included as independent variables in the logistic models. In addition, a Mann-Whitney test was used to compare median age, body weight, TTA/BW ratio, cage size, preoperative lameness score, six weeks postoperative lameness score, and 12 weeks postoperative lameness score in animals suffering or not suffering a complication. For all analyses, a p-value <0.05 was considered significant.

**Results**

Eighty-two dogs (84 stifles) were included. There were 20 crossbreed, 10 Golden Retrievers, nine Labrador Retrievers, seven Bernese Mountain Dogs, six American Staffordshire Bull Terriers, three Bouvier des Flandres, two Boxers, two German Shepherd dogs, two Border Collies, two Jack Russel Terriers, and one each of 19 other different breeds.

Mean body weight and age at the time of surgery were 28 ± 13 kg and 5.1 ± 2.62 years respectively. The median preoperative lameness score for those dogs was 3 (range: 2-5).

Complete cranial cruciate ligament rupture was recorded in 45 stifles and partial cranial cruciate ligament rupture was recorded in 37 stifles. The cranial cruciate ligament status (complete or partial) was not recorded in two dogs.

The menisci appeared normal in 38 stifles. Medial meniscal injuries were treated by partial meniscectomy in 39 stifles. The status of the menisci was not recorded in seven stifles.

The sizes of the cages used for the N-MMT were 15 mm (n = 22), 12 mm (n = 28), 9 mm (n = 13), 6 mm (n = 9), 4.5 mm (n = 7), and 3 mm (n = 5). Mean surgical time was 80 ± 34 minutes.

Complications are summarized in Table 2. The most common major complication was intra-operative fracture (5/84 stifles) or fissure (16/84 stifles) of the cortical hinge. An intra-operative fissure or fracture was suspected by the surgeon, if a sudden loss of resistance was felt, while advancing the tibial tuberosity with the spacer. These fractures or fissures (n = 21) were stabilized with a figure-of-eight wire if they were observed or suspected by the surgeon. All of those dogs recovered uneventfully, and were reported to be clinically sound by the owners. Five more fractures (5/84) were not detected intra-operatively and were only identified on immediate postoperative radiographs. These five fissures did not receive any further surgical treatment. Late meniscal tears occurred in...
three of the 84 stifles. Since partial meniscectomy was performed in 39 stifles and the meniscal status was unknown in seven cases, late meniscal tears actually occurred in three out of 38 stifles, making this the second most common major complication. All three patients that developed a late meniscal tear recovered well after revision surgery for meniscectomy, and the owners’ satisfaction scores were comparable to the rest of the population. Fracture of the tibial diaphysis occurred in one dog in which the osteotomy was clearly too caudal, hence excessively reducing the diaphysis diameter. This fracture was stabilized with a broad 3.5 mm dynamic compression plate and the dog eventually recovered (Figure 4).

The most common minor complication was postoperative fracture of the cortical hinge which occurred in five of the 84 stifles. Those fractures of the cortical hinge were incidental findings on the first postoperative radiographic examination and all of them were minimally displaced fractures (a few millimetres proximally, cranially, or both) showing some degree of osteotomy healing. None of the fractures required extended exercise restriction in these dogs. Lameness scores for four out of five of those dogs was 0 at four to six weeks at the in-hospital clinical examination. One of the dogs had a lameness score grade of 2 at four weeks postoperatively that was resolved (score of 0) at the time of the second in-hospital evaluation. Two dogs with complete skin wound dehiscence were referred again by their treating veterinarians to our institution for further management. Those wounds were managed as an open wound and both dogs recovered uneventfully. Fifty-two sets of radiographs were available for evaluation from the first in-hospital re-examination, with a mean follow-up time of six weeks. Healing of the osteotomy gap at that time was scored as 4 (20/52 stifles), 3 (17/52 stifles), 2 (13/52 stifles), and 1 (2/52 stifles). The median radiographic score at the first re-examination was 3 (range: 0-4).

Thirty sets of radiographs were available for evaluation at the second in-hospital re-examination, with a mean follow-up time of 10 weeks. Healing of the osteotomy gap at that time was scored as 4 (17/32 stifles), 3 (10/32 stifles), and 2 (5/32 stifles). The median radiographic score at the second check-up was 3 (range: 2-4).

Joint effusion was considered as a minor complication in one dog in which the patella was displaced cranially in relation to the femoral trochlea due to the excessive amount of synovial fluid at the six week clinical examination.

**Figure 4** Mediolateral radiograph of a tibial fracture five days postoperatively. The osteotomy was directed too far caudally, splitting the proximal tibial diaphysis into two fragments. A) Immediately postoperative mediolateral radiograph. B) Mediolateral radiograph taken five days postoperatively showing a proximal diaphyseal tibial fracture. C) Fracture and osteotomy repair using two Kirschner wires to stabilize the tibial tuberosity with the tibial shaft and a broad 3.5 mm dynamic compression plate to stabilize the tibial fracture.
In-hospital clinical evaluations were performed in 67/84 stifles at 5.62 ± 1.32 weeks and 58/84 stifles at 11.1 ± 2.43 weeks.

The median postoperative lameness score was 1 (range: 0-4) at 5.62 weeks, which was significantly different from the preoperative lameness score. The median postoperative lameness score was 0 (range: 0-4) at 11.1 weeks, which was significantly different from the preoperative lameness score and from the 5.62 weeks lameness score (p <0.001).

Of the 21 dogs in which a figure-of-eight wire was used, 18 dogs were re-evaluated at our institution at six to 10 weeks postoperatively; 15 of those dogs were judged to be lameness free at the time of the follow-up examination. Three dogs were judged to have a lameness grade of 1.

Age significantly increased the odds of suffering intra-operative fissures, as identified by the binary logistic regression (p <0.05). Age did not increase the odds of suffering intra-operative fractures, immediately postoperative radiographically identified fissures or cortical hinge fractures identified at the six week postoperative follow-up. Body weight, TTA/BW ratio, cage size, or the preoperative lameness score did not increase the odds of suffering any complication. The Mann-Whitney test showed a significant correlation between age and development of intra-operative fissures and between the ratio of TTA/BW and development of intra-operative fractures. The lameness scores at six weeks and 12 weeks postoperatively were not significantly different between dogs that developed any of the analysed complications and dogs that did not. Findings of the owner’s questionnaire are summarized in Appendix Table 2 (Available online at www.vcot-online.com).

Discussion

The signalment of the dogs in our study was comparable to that reported in other cranial cruciate ligament repair studies (15–22). Also, the frequency of other variables such as complete or partial cranial cruciate ligament rupture and meniscal damage at the time of surgery were similar to others reports (15–22). The theoretical potential advantage of the modified Maquet technique is to spare the need for a bone plate for tibial tuberosity stabilization. Major complications in tibial tuberosity advancement cases are usually related to the plate, fork and screws used to fix the plate to the tibial tuberosity and shaft (18). Hence, not using the plate would avoid these complications. However, because of the nature of the osteotomy used for the modified Maquet technique, we encountered a high frequency of cortical hinge fractures or fissures, both intra- and postoperatively, in our cohort of dogs.

It could be argued that tension band wiring of intra-operative fissures was unnecessary, considering that the five dogs with fissures identified on the postoperative radiographs healed uneventfully. However, we recommend stabilization of fissures with a tension band wire as soon as they are identified, even at the immediate postoperative radiographic examination to prevent a tibial tuberosity avulsion.

Age was significantly correlated with development of intra-operative fissures as shown by the binary logistic regression and the Mann-Whitney test. In people, bones typically become more brittle and weaker with age (22). Perhaps the same phenomenon occurs in older dogs, and hence they could be more prone to develop fractures and fissures of the cortical hinge when the tibial tuberosity is advanced whilst performing a N-MMT. The Mann-Whitney analysis also revealed that a high TTA/BW ratio was a significant risk for developing intra-operative fractures, suggesting that in a N-MMT in which the cortical hinge needs to reach higher angles, an intra-operative fracture may occur. Although none of the risk factors seem to influence the final lameness score of our patients, this finding needs to be interpreted with care because of the small sample size of our study. Further studies with a greater number of dogs treated with N-MMT are needed to confirm our results.

A biomechanical study showed that distal tibial tuberosity fractures dramatically decreased the mechanical strength of the fixation, even in the presence of a cerclage wire, which somehow contradicts our clinical observation that no displaced fractures occurred (14). A possible explanation could be the role played by the cage screws, the preserved tibial periosteum, and the early fibrous scar tissue within the osteotomy in preventing the tibial tuberosity from displacing proximally. However,
further studies are needed to support this hypothesis.

The overall complication rate in our study (43/84, 52%) was higher than that reported for the tibial tuberosity advancement or tibial plateau levelling osteotomy procedures, although these complications did not seem to affect the final outcome of our cases (15–22). The different levels of expertise of surgeons who performed the procedures may have produced a high number of technical errors leading to some of the complications encountered. Although not evaluated in this study, increased surgeon experience may diminish the complication rate of N-MMT. The high complication rate could also be attributed to the N-MMT osteotomy design itself, to multiple technical errors, or excessive postoperative patient activity. Further studies of the learning curve of this procedure are hence necessary to determine at what point the complication rate of this procedure becomes acceptable.

The rate of late meniscal tears in our study was similar to that reported for the tibial tuberosity advancement and tibial plateau levelling osteotomy (0 to 13.7%) procedures (15–21, 23–30).

Other common complications such as incisural swelling and bruising were not systematically documented in our records, and also the majority of the patients had their bandage and suture removal performed by their referring veterinarians. The rationale for applying a Robert-Jones bandage for 10 days was to limit postoperative weight bearing, although the benefits of the bandage are unclear. Further studies comparing N-MMT with and without postoperative Robert-Jones bandages are required to evaluate its real benefits and incidence of complications.

Radiographic evaluation at the two time points showed an increased percentage of dogs with an advanced stage of osteotomy healing. It is not known if the osteotomy gap has to be completely filled by new bone to resist physiological loading long-term. According to the theory of functional adaptation of bone, the situation could vary from patient to patient, depending on individual loading patterns (30). Based on our clinical experience relating to fracture healing, we consider that a patient should normally be allowed to resume unrestricted activity after an eight to 10 week postoperative period, or when at least two osteotomy gap sites are filled with new bone.

Some limitations of our study were that only 67/82 dogs could be re-evaluated at our institution for limb function and complications, and that the radiographic follow-up was available only in 54 cases. Another limitation was that the Robert-Jones bandages were removed by the referring veterinarian 10 days postoperatively, which could have resulted in an underestimation of the real frequency of minor complications. In our opinion, sufficient data for an overall assessment of limb function could be obtained despite these limitations.

Despite the high complication rate, follow-up clinical and radiographic findings support the authors’ clinical impression that a long-term outcome of the N-MMT is similar to that of other surgical techniques for treating cranial cruciate ligament rupture in dogs. Prospective and controlled clinical trials are needed to further determine which factors are associated with successful outcome and complications of the N-MMT.

Acknowledgements

We would like to acknowledge Carlos Macias DSAS (Orthopaedics) for his invaluable assistance in the preparation of the final manuscript. This study was not supported by any grants.

Conflict of interest

None declared.

References


© Schattauer 2015