Treatment of tibial diaphyseal fractures following plateless tibial tuberosity advancement to manage cranial cruciate disease

R. De Sousa , P. Egan, K. Parsons, S. Butterworth, I. Calvo , S. Roch and A. P. Moores

Introduction

Cranial cruciate ligament rupture represents one of the most common orthopaedic disorders in dogs (Lapman *et al*. 2013). Numerous techniques have been described to stabilize the cranial cruciate ligament-deficient stifle, but over the past two decades, tibial osteotomies have become increasingly popular surgical options. The aim of all tibial osteotomies is to alter the geometry of the stifle joint to achieve dynamic stabilization (Kim *et al*. 2008, Duerr *et al.* 2014, Aragon *et al.* 2005).

Tibial tuberosity advancement (TTA) was first postulated in 2002 and aims to neutralise cranial tibial thrust by advancing the tibial tuberosity to form an angle of 90 degrees between the tibial plateau and the patellar tendon, when the stifle is at an angle of 135 degrees of extension (Montavon *et al*. 2002). In the original description of the procedure, the advanced tibial tuberosity is stabilised with a plate. More recently tibial tuberosity advancement has been described without plate stabilisation of the advanced tibial crest (Ness 2014, Samoy *et al*. 2015, Ramirez *et al*. 2015, Etchepareborde *et al*. 2010). Although different ways of achieving this have been described, such procedures are collectively known as modified Maquet procedures (MMP) after a procedure performed in human surgery to relieve patellofemoral pain (Maquet 1976, Mendes *et al*. 1987). In the United Kingdom (UK) two proprietary MMPs have gained in popularity; the OrthoFoam-wedge MMP procedure[1] (OF-MMP), (Ness 2014) and the TTA Rapid procedure[2] (Samoy *et al*. 2015). Both techniques are marketed as being quick and easy to perform with a low risk of complications (Orthomed MMP Training Brochure; Leibinger R. Tibial tuberosity advancement rapid. History of TTA). Although based on limited case numbers, an overall complication rate of 34% has been reported for TTA Rapid procedures (Samoy *et al*. 2015). Tibial fractures have been encountered most frequently at the level of the

[1] Orthomed Ltd®, West Yorkshire, United kingdom
[2] Rita Leibinger Medical®, Tuttlingen, Germany

distal cortical hinge of the advanced tibial crest and do not always require surgical revision (Ramirez *et al*. 2015, Samoy et al.2015). To the authors' knowledge, a single clinical case has been reported with tibial diaphyseal fracture following a new modified Maquet technique (Ramirez *et al*. 2015). Complications data are not available for the OF-MMP procedure.

In November 2013 catastrophic fractures of the proximal tibia (fractures of the tibial crest through the distal drill hole combined with tibial diaphyseal fracture) were reported on the British Veterinary Orthopaedic Association (BVOA) discussion forum (https://groups.google.com/forum/#!topic/bvoa/K9pjfiF0F7o). Responses to the initial post indicated that this was a well-recognised complication. The purpose of this study was to report the specific complication and surgical repair of tibial crest fracture combined with proximal tibial diaphyseal fracture in dogs that had undergone tibial tuberosity advancement via either the OF-MMP or TTA Rapid procedures.

Material and Methods

Case selection

Members of the BVOA online discussion forum were invited to participate in the study. Medical records of the revision surgery were collected for dogs that sustained tibial diaphyseal fracture following either OF-MMP or TTA Rapid procedures (henceforth referred to as the index surgery). Inclusion criteria included preoperative, postoperative and follow-up radiographs of the fracture repair surgery (henceforth referred to as the revision surgery) to be available for review as well as a detailed surgical report, postoperative treatment and final clinical assessment (minimum 6 weeks). Cases were excluded when fractures solely involved the tibial tuberosity/crest or when complete medical records and radiographic data were not available.

Medical records review

Individual surgeons were asked to retrieve data on breed, signalment (age, sex, body weight, body condition score and neutering status), history, physical examination findings, imaging investigation, type of fracture configuration, and surgical revision (appendix 1). The qualifications of the revision surgery surgeon, the nature of the surgical revision, intraoperative and postoperative complications and outcome were determined and recorded on an Excel spreadsheet[3].

Radiographic interpretation

[3] Microsoft® Office Excel, 2007, Microsoft Corporation, Redmond, WA

Surgeons were asked to submit all radiographic studies performed for each case. Radiological evaluation was performed independently by two observers (Author XX/XXX) and were reviewed for the type and level of fracture, surgical implants used and positioning and progression of osseous union using a grading system developed by the International Society of Limb Salvage (Glasser *et al.* 1991): Grade (1) poor healing – union <25%; (2) fair-union 25-50%; (3) good-union 50-75%; and (4) excellent-union >75%.

Complications

Complications were recorded as defined by Cook and others (2010). Briefly, minor complications were described as those requiring no additional medical or surgical treatment. (e.g. wound inflammation, seroma formation). Major complications described those associated with morbidity that required further medical treatment or surgery. Catastrophic complications were described as those associated with morbidity that caused permanent unacceptable function. Time frame for complications was defined as “perioperative” (pre, intra, and postoperative to 3 months), “short-term” from 3 to 6 months, “mid-term” as 6-12 months and long-term complications as >12 months (Cook *et al.* 2010).

Follow up and Outcome measurement

Physical examination was performed by veterinary orthopaedic assessment at 6-8 weeks after revision surgery and subsequently as required. Subjective clinical outcome performed by the revision surgeon was classified as “excellent function” when restoration or maintenance of the intended activity level and overall performance was achieved without pain, as “satisfactory function” when restoration or maintenance of the activity level and overall performance was limited in level or duration, and as “poor function” if there was severe lameness and stifle pain.

Revision surgery surgeons were asked to contact owners to obtain verbal consent for their dog's clinical data to be included in the study. Owners were sent the Liverpool Osteoarthritis in Dogs (LOAD)(Walton *et al*. 2013) questionnaire (appendix 2). An aggregate mobility score (LOAD score) was generated for each dog.

Results

A total of 10 veterinary surgeons contributed case material. Data were retrieved for 22 cases that sustained a comminuted tibial shaft fracture (Figures 1 and 2), but only 17 dogs met the inclusion criteria. Surgeon questionnaire data were obtained for 17/17 dogs and owner questionnaire data were obtained for 13/17 cases. All dogs presented with clinical signs including (but not limited to) acute onset of non-weight bearing lameness and pain following the index surgery. The breed of dogs included Springer Spaniel (3), Bichon Frise (3), Beagle (3), Golden Retriever (2), Cocker Spaniel (1), cross-breed (1), Boxer (1), Bearded Collie (1), Miniature Schnauzer (1) and Shetland Sheepdog (1). The mean age was 79 months (SD± 26 months) with a mean body weight of 21kg (range 6.7 - 44 kg) and mean body condition score of 3 (Likert scale from 0 to 5). There were 10 males (8 neutered) and 7 females (6 neutered). The median duration of presentation following the index surgery was 22 days (range, 1-98 days). In two cases, an unsuccessful revision surgery was attempted by the first opinion veterinary surgeon prior to the final revision; case 5, received a double 2.7mm string of pearls plate which failed by screw breakage and case 14, received a single 2.7mm dynamic compression plate which failed by re-fracture at the fracture site. Both cases, had the implants removed prior to final revision.

Surgical procedure

A summary of the surgical information is shown in Table 1. Index surgeries included 11 OF-MMP procedures and 6 TTA Rapid procedures. All but two index surgeries were performed by non-specialist surgeons. Seven dogs had surgery on the right pelvic limb and 10 dogs on the left pelvic limb.

Revision surgeries were performed by 6 European Veterinary Specialists in Small Animal Surgery and/or Royal College of Veterinary Surgery (RCVS) Recognised Specialists and 4

RCVS certificate holders. Index surgery implants were completely removed in 6/17 cases whereas in 7/17 only the distal wire (3 OF-MMP cases) or staple (2 OF-MMP cases) or combination of wire/staple and Kirschner wire (K-wire) (2 cases) were removed. In the remaining 4/17 cases the original implants were maintained, *in situ*. The tibial tuberosity advancement was maintained in 14/17 cases with 3/14 cases having the original TTA Rapid cage replaced by a standard TTA cage[4]. In the 3 cases where the tibial tuberosity advancement was not maintained one (case 1) was deemed stable at subsequent follow ups, one was further stabilised with an extracapsular suture at 6 weeks post revision surgery (case 2) and one was still awaiting second revision at the time of writing the manuscript (case 15).

Radiographic interpretation

Revision surgery post-operative radiographs revealed appropriate implant positioning in all cases with satisfactory reduction and alignment of the tibia. Mean radiographic follow up was 10 weeks (ranging from 6 to 14 weeks). Using the International Society of Limb Salvages radiographic criteria, 7 cases had excellent progression of osseous union, 9 cases had good progression of bone union and 1 case had fair progression of bone union. Incidental implant complications were noted in two cases; case 5, breakage of the 2.7mm LCP medial plate at the level of the 4th screw hole (Figure 3) and case 6, bending of the K-wire with slight cranial tilting of the distal aspect of the tibial tuberosity. Neither case required further treatment.

Complications

Revision surgery complications were encountered in 8/17 cases (complication rate of 47%), Table 1. Minor complications were encountered in 3/17 dogs; case 3, sustained a proximal

[4] Kyon Veterinary Surgical Products®. Zurich, Germany

tibial tuberosity fracture with minimal displacement. This was an incidental radiographic finding at 6 weeks post-surgical repair and subsequent radiographs at 12 weeks showed good bone union at the osteotomy site, (Figure 4). Implant failure was identified in two cases (case 5 and case 6) as an incidental finding and no treatment was subsequently required.

Major complications were encountered in 5/17 dogs. Surgical site infections occurred in 4 cases; In 3 cases where culture was performed, 2 were positive for methicillin-resistant *Staphylococcus pseudintermedius* and 1 was negative. Three of these cases required implant removal (all but the OF-MMP foam wedge) at 9 (case 16), 14 (case 17) and 26 weeks (case 13) post revision surgery. The remaining infection (case 1) resolved with a protracted course of antibiotics (>6 weeks). One case (case 2) in which the original tibial tuberosity advancement was lost, was diagnosed with a late meniscal tear 6 weeks post-surgical repair. Meniscectomy was performed and an extracapsular suture was applied to stabilise the stifle joint. There were no catastrophic complications following the revision surgery.

Follow up and Outcome measurement

Mean time for final veterinary follow up was 23 weeks (ranging from 6 to 106 weeks) with 8/17 dogs deemed to have excellent, 8/17 satisfactory and 1/17 poor surgical outcome.

Thirteen LOAD questionnaires were completed at a mean of 21 months (range 3 - 52 months) after revision surgery. At the time of questionnaire completion, only two owners reported their dog to be receiving some form of non-steroidal anti-inflammatory medication.

The mean LOAD score was 12/52 (range 2 - 28) (0 = normal, 52 = severely disabled). Owner satisfaction with treatment and the final outcome found 6 owners to be very satisfied, 5 owners to be very disappointed, 2 owners to be indifferent and the remaining owners unknown. When asked whether they would undertake the index surgery again, 9/13 said yes, 3/13 said no and 1/13 was unsure.

Discussion

MMPs have increased in popularity for the treatment of dogs with cranial cruciate ligament disease. Despite this, the peer-reviewed literature on complications and outcome is still scarce. (Etchepareborde *et al*. 2011, Ramirez *et al*. 2015, Samoy *et al*. 2015). In this series, we report 17 dogs that sustained tibial diaphyseal fractures following a MMP. Surgical revision resulted in a favorable outcome and owner satisfaction in the majority of cases.

A variety of orthopaedic implants and configurations can be applied to comminuted diaphyseal tibial fractures (Piermattei *et al*. 2006). In the current study, all tibial fractures were repaired using plate and screw fixation. Selection of bone plates included locking and non-locking systems applied as a single medial plate (9 cases), or double medial-cranial (5 cases) or medial-caudal (2 cases) plates. One fracture was repaired with a cranial closing wedge osteotomy combined with a medial Synthes TPLO plate[5] and cranial plate. The failure of the medial plate in case 5 (figure 3), despite double-plating of the fracture in that dog, may be an indication of the large and repetitive stresses that these implants can be subjected to, potentially resulting in fatigue failure of the implant.

Tibial tuberosity advancement was maintained in all but three cases, by preserving the index surgery wedge/cage or by replacing it for a standard TTA cage. Replacing the OF-MMP wedge/TTA Rapid cage with a standard TTA cage was performed in several cases reported here since the smaller size of the standard cage provides greater flexibility for implant placement, particularly if a cranial plate is used. The small number of cases in this series does not allow us to make meaningful comparisons between the different repair techniques employed, or to assess outcome in terms of whether advancement was maintained. Nevertheless, in 2/3 cases in which tibial tuberosity advancement was not maintained, the

[5] Synthesis GmbH®. Zuchwil, Switzerland

stifles were unstable with positive tibial compression tests, at the subsequent re-examinations. While one was successfully managed with application of an extra capsular suture and meniscectomy, the other was still awaiting surgical revision at the time of writing the manuscript.

We report a complication rate for revision surgeries of 47% dogs (8/17). Three dogs were diagnosed with implant failure (case 5 and 6) and proximal tibial tuberosity fracture (case 3) as incidental findings at the 6-8 week radiographic follow up. These three dogs continued to improve over the following months and did not require further medical or surgical treatment. In case 3 the repair was achieved with application of a cranial tibial plate, which did not extend proximally to the tibial tuberosity, and thus the top screw hole together with previous screw holes from the TTA cage may have acted as a stress-riser. The authors suggest that where a cranial plate is used consideration should be given to placing it proximally to incorporate the entire tibial crest (such as in case 5; figure 3) so that an unprotected stress riser is not present distal to the insertion point of the patellar tendon.

The surgical site infection (SSI) rate was 23% (4 cases). This is a high SSI rate compared to elective procedures such as tibial tuberosity advancement (5-7%) or tibial plateau levelling osteotomy (8%) (Yap *et al*. 2015, Wolf *et al*. 2012, Frey *et al*. 2010). Similar to the risk factors identified by Yap et al (2015), we propose that the high rate reflects the increased soft tissue dissection, disruption of local blood supply as a consequence of previous surgery, increased surgical times and large number of implants required for stabilization.

One dog (case 2) was diagnosed with a meniscal injury 6 weeks following revision surgery. Interestingly, tibial tuberosity advancement was not maintained at the time of the revision surgery, which may have predisposed this case to a late meniscal tear. After meniscectomy and extracapsular lateral suture, this dog progressed to full recovery.

At final examination, the majority of dogs (16/17) were classified has having satisfactory to excellent clinical outcome . Clinical outcomes were based on the last veterinary assessment, which in the majority of cases was 6-8 weeks postoperatively, and therefore, results must be interpreted cautiously. It is likely that these cases would have improved further over the following months as shown by Krotscheck and colleagues, in which dogs' peak vertical force and vertical impulse showed continued improvement at 12 month after stabilization via tibial plateau levelling osteotomy, tibial tuberosity advancement or extracapsular repair (Krotscheck *et al*. 2016).

In the present study, LOAD questionnaires were used to assess owner long-term outcome. Results from these questionnaires produced a mean score of 12/52, which is similar to the findings of a previous study in dogs that sustained tibial tuberosity fractures following tibial tuberosity advancement. (Lorenz *et al*. 2014) Further studies are warranted to correlate the level of owner satisfaction and LOAD questionnaire scores.

The OF-MMP and TTA Rapid procedures include drilling a hole at the distal aspect of the tibial crest osteotomy to dissipate stresses when the tibial crest is advanced cranially, and thus avoid fracture of the distal tibial crest. According to Brunel and others (2013), the drill hole does not decrease the risk of fissure and fracture formation, as initially postulated by Maquet (Maquet 1976). This was in agreement with findings from Samoy and others (Samoy *et al* 2015). The drill hole with or without augmentation of the constructs with tension band wires or staples certainly does not prevent fractures; all the tibial diaphyseal fractures we report here occurred through the distal drill hole. We consider it likely that the fractures reported in here were preceded by fracture through the drill hole to the cranial cortex, creating a stress-riser at that level which put the tibia at risk of diaphyseal fracture. The retrospective nature of our study did not allow us to evaluate predisposing factors for these fractures to occur. With access to a larger number of cases than we had, including those with and without fracture, it would be interesting to assess the size and position of the drill hole as a risk factor for fracture. Surgeon experience and expertise is also likely to play a role in the incidence of these complications. A recent study found that it took 22 procedures for a single experienced surgeon to reduce their major complication rate when learning to perform TTA (Proot *et al*. 2013). OF-MMP and the TTA Rapid procedures are marketed towards non-specialist surgeons (Orthomed MMP Training Brochure; Leibinger R. Tibial tuberosity advancement rapid. History of TTA) and although we did not aim to evaluate the expertise of the surgeons who performed the index procedure, the majority of the OF-MMP/TTA Rapid surgeries in this series were performed by general practitioners (15/17). Inappropriate post-operative management and owner non-compliance could also have contributed to the complications.

This study has several limitations. Clearly, the variability introduced by the number of surgeons performing the revision surgeries is not ideal. In addition, the small number of cases limits the strength of any conclusions that can be made. Intraoperative decisions and postoperative owner compliance may have had a role in the occurrence of these fractures. Furthermore, we did not evaluate the incidence for these complications, as we do not know what proportion of all patients these 17 fractures represent. It is also likely that there have been other similar fractures that have been treated by surgeons other than the authors. Further studies are warranted to evaluate the incidence and specific risk factors.

References

Aragon C.L., Budsberg S.C. (2005) Applications of evidence based medicine: cranial cruciate ligament injury repair in the dog. Veterinary Surgery 34, 93-98

Cook J.L., Evans R., Conzemius M.G., *et al*. (2010) Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopaedic studies in veterinary medicine. Veterinary Surgery 39, 905-908

Duerr F.M., Martin K.W., Rishniw M., *et al* (2014) Treatment of canine CCL disease. A survey of ACVS Diplomates and primary care veterinarians. Veterinary and Comparative Orthopaedics and Traumatology 27, 478-483

Etchepareborde S., Brunel L., Bollen G., *et al*. (2011) Preliminary experience of modified Maquet technique for repair of cranial cruciate ligament rupture in dogs. Veterinary and Comparative Orthopaedics and Traumatology 24, 223-227

Frey T.N., Hoelzler M.G., Scavelli T.D., *et al*. (2010) Risk factors for surgical site infection-inflammation in dogs undergoing surgery for rupture of the cranial cruciate ligament: 902 cases (2005–2006). Journal of American Veterinary Medical Association 236, 88–94

Glasser D, Langlais F. (1991) The ISOLS Radiological Implants Evaluation System. In: Langlais F, Tomeno B, eds. Limb salvage: major reconstruction in oncologic and nontumoral conditions. Berlin, Springer Verlag p23-31

Kim S.E, Pozzi A., Kowaleski M.P., Lewis D.D., (2008) Tibial osteotomies for cranial cruciate ligament insufficiency in dogs. Veterinary Surgery 37, 111-23

Krotscheck U., Nelson S.A., Todhunter R.J. *et al*, (2016) Long term functional outcome of tibial tuberosity advancement vs. tibial plateau leveling osteotomy and extracapsular repair in a heterogeneous population of dogs. Veterinary Surgery 45, 261-268

Lampman T.J., Lund E.M., Lipowitz A.J. (2003) Cranial cruciate disease: current status of diagnosis, survery, and risk for disease. Veterinary and Comparative Orthopaedics and Traumatology 16, 122-126

Leibinger R. Tibial tuberosity advancement rapid. History of TTA – techniques by Rita Leibinger medical. Available from: http://leibinger-medical.com/en/products/veterinary/tta-rapid/tta-techniques-history/

Lorenz N.D., Pettitt R. (2014) Cranial tibial plating in the management of failed tibial tuberosity advancement in four large breed dogs. Veterinary and Comparative Orthopaedics and Traumatology 27, 236-242

Maquet P. (1976) Advancement of the tibial tuberosity. Clinical Orthopaedic and Related Research 115, 225-230

Mendes DG, Soundry M, Iusim M. Clinical assessment of Maquet tibial tuberosity advancement. Clinical Orthopaedic and Related Research 222, 228-238

Montavon P.M., Damur D.M., Tepic S. editors. (2002) Advancement of the tibial tuberosity for the treatment of cranial cruciate deficient canine stifle. Proceedings of the 1st World Orthopaedic Veterinary Congress, September 5-8, Munich, Germany.

Ness M.G. (2014) Orthofoam MMP Wedge. For Canine Cruciate Disease. User Guide (Version V1.2). Orthomed; vailable from: http://www.orthomed.co.uk/orthofoam-mmp-cruciate-repair-system/mmp-implants/othofoam-mmp-wedge.

Orthomed MMP Training Brochure downloaded from www.Orthomed.co.uk 17th June 2016.

Piermattei D.L., Flo G.L., DeCamp C.E. (2006) Fractures of the tibia and fibula. In Brinker, Piermattei and Flo's handbook of small animal orthopedics and fracture repair, ed 4, Philadelphia, Saunders, p 633.

Proot J.L., Corr S.A. (2013) Clinical audit for the tibial tuberosity advancement procedure: establishing the learning curve and monitoring ongoing performance for the tibial tuberosity advancement procedure using the cumulative summation technique. Veterinary and Comparative Orthopaedics and Traumatology 26, 280-284

Ramirez J., Barthelemy N., Noel S., *et al*. (2015) Complications and outcome of a new modified Maquet technique for treatment of cranial cruciate ligament rupture in 82 dogs. Veterinary and Comparative Orthopaedics and Traumatology 28, 339-346

Samoy Y., Verhoeven G., Bosmans T., *et al*. (2015) TTA Rapid: Description of the technique and short term clinical trial results of the first 50 cases. Veterinary Surgery 44, 474-484

Walton M.B., Cowderoy E., Lascelles D., *et al*: (2013) Evaluation of construct and criterion validity for the 'Liverpool Osteoarthritis in Dogs' (LOAD) clinical metrology instrument and comparison to two other instruments. PLoS One 8, e58125

Worff R.E., Scavelli T.D., Hoelzler M.G., et al. (2012) Surgical and postoperative complications associated with tibial tuberosity advancement for cranial cruciate ligament rupture in dogs: 458 cases (2007-2009). Journal of American Veterinary Medical Association 240, 1481-7

Yap FW, Calvo I, Smith KD *et al*. (2015) Perioperative risk factors for surgical site infection in tibial tuberosity advancement: 224 stifles. Veterinary and Comparative Orthopaedics and Traumatology 28, 199-206

Figure legends

Figure 1 and 2. Mediolateral (A) and craniocaudal (B) radiographs taken pre -, immediately post -, and at 6-8 weeks post-revision surgery in a sequential order. Note the 4 -fragment tibial fracture through the drill hole and fibula fracture. Figure 1, fracture repaired with a medial 3.5 LCP, a caudal 2.7 LCP and a k-wire/tension band wire while maintaining the tibial tuberosity advancement (case 17). Figure 2, fracture repaired with a medial 2.7 LCP and cranial 2.4 LCP with replacement of the TTA rapid cage with a standard TTA cage (Case 4). Post-operative radiographs taken at 6-8 weeks post-surgical repair show progression of bone union and implant positioning.

Figure 3. Mediolateral (A) and craniocaudal (B) radiographs taken at 6 weeks post-operative (Case 5). Note the breakage of the medial plate (arrow) which was an incidental findings and the position of the cranial plate extending proximally to the tibial crest.

Figure 4. Mediolateral (A) and craniocaudal (B) radiographs taken at -1, 0, 28 and 55 days post revision surgery (Case 3). Note the short work-length of the proximal aspect of the cranial plate positioned below the tibial tuberosity. An incidental proximal tibial tuberosity fracture was identified at 6 weeks post-surgical repair with minimal proximo-distal displacement. Subsequent radiographs showed progression of bone union and satisfactory implant positioning.

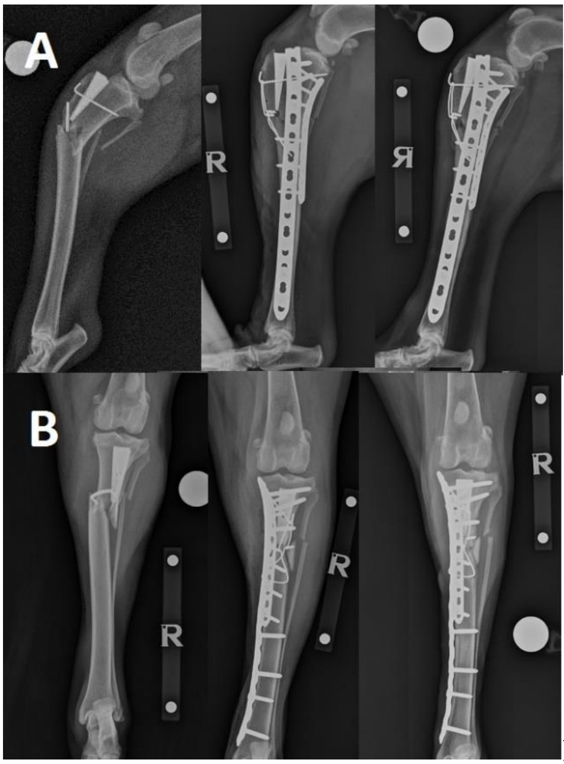

Figure 1

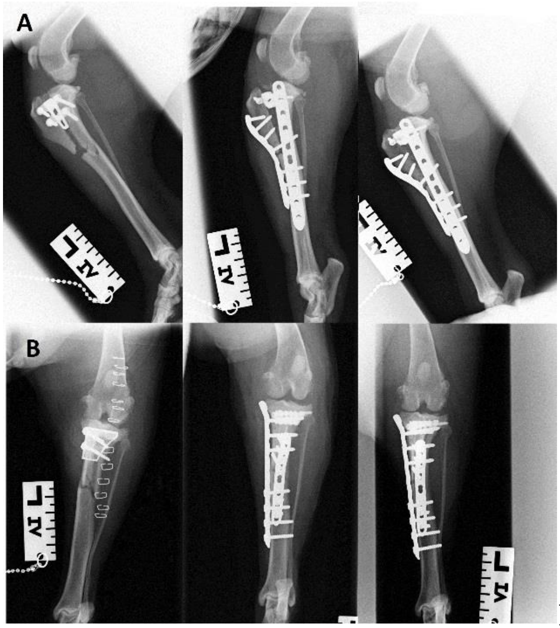

Figure 2

Figure 3

figure 4