Short and long-term outcome following surgical stabilisation of tarsocrural instability in dogs

L. Beever1; E. Kulendra1; R. L Meeson1.

Running head

L. Beever et al.: Outcome of tarsocrural instability in dogs

1Queen Mother Hospital for Animals, Department of Clinical Sciences and Services, Royal Veterinary College, Hawkshead Lane, North Mymms, Hertfordshire, UK

Keywords

Canine, tarsocrural, (tibiotarsal, talocrural), instability, luxation.

Conflict of interest

None declared.

Correspondence to:

Richard Meeson MA VetMB, MVetMed, DECVS, FHEA, MRCVS
Lecturer in Orthopaedic Surgery
The Royal Veterinary College
Queen Mother Hospital for Animals
Hawkshead Lane, North Mymms
Hatfield, Hertfordshire AL9 7TA
United Kingdom
Phone: +44 707 666 366
E-mail: rmeeson@rvc.ac.uk

Abbreviations

- **CBPI**- Canine Brief Pain Inventory

- **α**- IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp
- **β**- GraphPad Prism version 6.00 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com

Summary

Objectives: Evaluate outcome and complications following surgical stabilisation of canine tarsocrural luxations.

Methods: Medical records were reviewed. Surgical technique, complications and long-term outcome (questionnaire and Canine Brief Pain Inventory) were assessed.

Results: Twenty-four dogs (26 joints) were included. All injuries were traumatic. All joints had associated fractures; malleolar in 21/26 limbs (13/26 medial). Eight joints had internal fracture fixation and transarticular external skeletal fixator, six had fixator alone, four had prosthetic ligaments with fixator, and four had prosthetic ligaments with external coaptation. Two joints had pantarsal arthrodesis and two primary ligament repair. Complications occurred in 24/26 limbs giving 45 distinct complications; 16 were minor, 29 major, 31 complications were fixator-associated. Prosthetic ligaments were significantly associated with major complications (p-0.017); 5/8 required subsequent removal between 105-1006 days. Cost was significantly associated with major complications (p-0.017) and soft tissue wounds (p-0.03). Long-term lameness was seen in 9/14 dogs. There was no association between pain severity (p-0.3) and pain interference scores (p-0.198) when comparing stabilisation methods.

Clinical significance: Complications are common; however many are fixator related. Prosthetic ligaments are significantly associated with major complications. Regardless of technique, a degree of ongoing lameness is likely.

Introduction

The tarsocrural joint is formed by the tibia, fibula, talus and the calcaneus (1). Tarsocrural instability is an uncommon distal limb injury in dogs generally involving fractures of one or more of the bones contributing to the joint, varying degrees of ligament impairment, or a combination of both (1-5). The tarsocrural joint is particularly prone to fractures and shear injuries due to the paucity of soft tissue protection in this area (2, 6, 7). Injuries commonly occur following road traffic accidents, resulting in skin, muscle, ligament, and bone injury (1, 2, 7).

The anatomy of the tarsus is complex (1, 3, 8, 9), often making diagnosis and management challenging. Initial management of tarsocrural instability aims to limit further damage to the articular surface and supporting soft tissue structures, allowing restoration of anatomic joint alignment with stability to facilitate healing (3, 10, 11). Treatment modalities include combinations of primary ligamentous repair, prosthetic ligament reconstruction, external coaptation, transarticular external skeletal fixation, arthrodesis and amputation (1-5, 7, 10, 12-15). Management with external coaptation alone can be inconvenient, poorly tolerated and may result in coaptation driven soft tissue injuries (16). Some injuries of the tarsocrural joint are too extensive to be successfully reconstructed, leading to arthrodesis in order to maintain limb function (1, 2). Arthrodesis with a plate or external fixator may also be used as a salvage procedure if other methods of stabilisation have failed (1, 2, 7).

To date, no studies compare treatment outcomes following surgical stabilisation of tarsocrural joint instability in dogs. The purpose of this study was to retrospectively evaluate the outcome and complications following surgical stabilisation of canine tarsocrural luxation/subluxations. In addition, the study aimed to evaluate differences in functional outcome as assessed by owner questionnaire.

Material and methods

Medical records of dogs with tarsocrural joint instability treated surgically between February 2007 and June 2014 were reviewed. Tarsocrural instability was defined as palpable instability at that joint level, then confirmed as loss of articulation between the talus and the tibial cochlea on survey or stressed radiographs **(Figure 1).** The following information was gathered for each patient: signalment, injury, cause of injury, concurrent fractures, presence of soft tissue wounds, duration of hospitalisation, number of recheck visits, complications, cost of treatment and stabilisation method.

The luxations and fractures were stabilised with internal fixation when appropriate. Primary collateral ligament repair was attempted if possible when instability was attributable to ligament damage. Complications were categorized as minor or major. Minor were defined as those not requiring additional surgical treatment. Major were those requiring further surgical treatment. Soft tissue wounds were divided into minor or major. Minor included superficial abrasions and puncture wounds. Major included all wounds other than superficial abrasions and puncture wounds.

Final outcome of each dog was assessed by owner questionnaire consisting of two sections: section one assessed owner satisfaction, ongoing medication and long-term complications. In section two, owners assessed long-term function and pain using a validated client questionnaire; the Canine Brief Pain Inventory (CBPI) (17, 18). The CBPI assesses owner perception of pain severity and pain interference. The pain severity questions were scored on a scale of 0 (no pain) to 10 (extreme pain). The pain interference questions i.e. how much pain interfered with the dog's normal function, were scored on a scale of 0 (no interference) to 10 (completely interferes). The responses to these questions were averaged to generate the pain severity and pain interference scores (17, 18).

Commercially available statistical software programmes were used to perform all statistical analyses (α, β). Data were assessed for normality using the Shapiro-Wilk test. Associations between the presence of wounds, major complications, minor complications, fractures, non-tarsal injuries, soft tissue injuries, presence of an external skeletal fixator and the final cost of treatment were assessed using the Mann-Whitney U test. The same associations were assessed in relation to hospitalisation time. Fisher's exact test was used to determine associations between the stabilisation type and presence of complications. The Kruskal-Wallis test was used to compare pain severity and pain interference scores between treatment groups. Pain interference and severity score association with talar fractures and wounds was assessed with Mann-Whitney U test. Association of weight and complication development was assessed using t-test. A $p<0.05$ was considered significant.

Results

Twenty-four dogs with surgically managed tarsocrural joint instability met the inclusion criteria. Age on presentation ranged from 10 months to 10 years 10 months (median 4 years 11 months), weight from 10kg to 43kg (mean 27kg). Breed and sex distribution are outlined in **Appendix 1**. All recorded injuries were traumatic in origin; 13/24 dogs sustaining a road traffic accident, 4/24 developed an injury whilst running and 3/24 fell from a height. The remaining known causes included being trodden on and limb entrapment. Suspected trauma was reported in one dog and in another the cause of the injury was unknown. Concurrent non-tarsal injuries were present in 9/24 dogs, including superficial soft tissue wounds, tibial fracture, femoral fracture, metatarsal fractures, coxofemoral luxation, partial lung collapse, stifle laceration, pneumothorax and stifle shear injury.

Two dogs had bilateral instability following road traffic accident giving 26 joints stabilised (15/26 left, 11/26 right). Of the 26 tarsocrural joints, instability was medial in 15/26, lateral in 5/26 and bilateral in 6/26. All dogs had fractures associated with the tarsocrural joint, typically malleolar fractures in 21/26 limbs; 13 medial, 8 lateral malleolar fractures. The remaining five joints had talar fractures. Tarsal soft tissue wounds were present in 12/26 limbs of which 8/26 were shear injuries.

Eight joints had internal fracture fixation and transarticular external skeletal fixator, six had transarticular fixator alone, four had prosthetic ligaments with a transarticular fixator **(Figure 2)**, and four had prosthetic ligaments with external coaptation. Two tarsocrural joints were stabilised by plated pantarsal arthrodesis. Two had primary ligament sutured repair, one with a transarticular fixator, the other with malleolar k-wire and tension band repair followed by coaptation. Total hospitalisation ranged from 4-33 days (median 10 days). Fixators were applied in 19/26 limbs**,** placement duration ranged from 17-96 days (median 47 days).

Complications

Complications occurred in 24/26 joints, with some joints having multiple complications, giving a total of 45 distinct complications **(Appendix 1)**. Of these distinct complications 16 were minor and 29 major including pin breakage, implant failure, sequestrum formation, implant migration, implant infection and septic arthritis. All 19 joints with a fixator placed developed a complication directly attributable to the fixator, accounting for 31/45 complications (9/31 minor, 22/31 major). Fixator-associated complications included pin tract infection in 11/19 joints, pin failure/loosening in 14/19, and one dog formed a sequestrum at the tibial pin insertion leading to euthanasia. Non-fixator attributable complications occurred in 10/26 joints and half of these were minor complications related to casting/bandaging **(Appendix 1)**. Following exclusion of complications directly attributable to the fixator; there was no significant association between the use of plated pantarsal arthrodesis (p-0.63) or internal fracture fixation with development of (non-fixator-associated) complications (p-0.31). Placement of a transarticular fixator was not a significant risk factor for the development of complications (p-0.12) not related to the fixator itself. There was no significant association between shear injury and development of complications. Interestingly, the use of a transarticular fixator alone was protective against developing all other complications which were not fixator-associated (p-0.035).

Eight limbs were stabilised with prosthetic ligaments; six using multifilament fiberwire and two with monofilament nylon-leader-line. Both joints using nylon and 3/6 using fiberwire developed major long-term complications requiring implant removal from infection. Four of five infected prostheses also developed clinical joint instability which was absent prior to implant infection. Owners reported swelling or sinus tract formation from 105-1006 days postoperatively (median 156 days) **(Figure 3)**. Placement of prosthetic ligaments was significantly associated with postoperative complications (p-0.017) compared to limbs which had no prosthetic ligaments placed when fixator-associated complications were excluded. Two dogs, (1 and 19) required revision surgery following implant removal after prosthetic ligament infection. Both dogs had prosthetic ligament removal and subsequent stabilisation with a transarticular external skeletal fixator in dog 1 and plated pantarsal arthrodesis in dog 19 **(Figure 3)**. The two dogs (7 and 10) with no complications were stabilised by both fiberwire prosthetic ligaments combined with postoperative coaptation and plated pantarsal arthrodesis respectively. Total cost of referral treatment was significantly increased if major complications occurred (p-0.017), or tarsal soft tissue wounds were present (p-0.03). No significant association was seen between cost of treatment and development of minor complications, the presence of non-tarsal soft tissue injuries, fixator placement or the presence of non-tarsal fractures. Similarly the development of major or minor complications and soft tissue injuries had no significant association with hospitalisation time. Patient weight was not associated with development of minor (p-0.86), major (p-0.27) or non-fixator related complications (p-0.73).

Owner questionnaire

Fifteen of 24 owners provided questionnaire responses at a median postoperative time of 54 months (range 7-94 months) **(Appendix 2)**. Six dogs were lost to long-term follow up and four were deceased at the time of data collection. Of the deceased dogs one owner responded. Owners rated the success of surgery as excellent in 8/15 dogs, good in 3/15, satisfactory in 1/14 and poor in 3/14. Owner impression of their dogs overall quality of life and satisfaction with their dogs treatment is shown in **Appendix 2**. Ongoing lameness or stiffness was noted in 9/14 dogs with 7/14 being treated with long-term non-steroidal anti-inflammatory drugs. Activity levels following surgery were reported as very active in 3/15 dogs, active in 6/15, average in 4/15, inactive 2/15 **(Appendix 2)**.

CBPI

Mean post-operative pain severity scores and pain interference scores are shown for all patients with available CBPI in **Appendix 2.** No significant association between pain severity (p-0.3) or pain interference score (p-0.198) were identified when comparing surgical stabilisation techniques. No significant association between pain severity (p- 0.164) or pain interference (p-0.77) score was identified when comparing dogs with and without talar fractures. Similarly no association was seen when comparing dogs with and without major wounds, (p-0.494) and (p-0.29) respectively.

Discussion

Canine tarsocrural instability leads to severe loss of limb function. All our patients were managed surgically, whereas in humans the question of surgery vs conservative treatment for ankle fractures remains controversial and is influenced by the specific injury combination (19, 20). The difference in approach between human and veterinary patients may in part lie in the plantigrade nature of the human pes with its inherent mediolateral stability, whereas the canine digitigrade stance continually loads the tarsocrural support structures in the stance phase. Human patients are also more amenable to resting for extended periods. There are several surgical stabilisation techniques available, however assessment of long-term outcome and surgical complication rate was not previously available in dogs. Whether human or veterinary, treatment aims are to re-establish anatomic reduction of talus in the ankle mortise and maintain joint stability (19). Generally results following reduction of human ankle fractures appear to be good, although post-traumatic arthritis has been described in 10% of patients despite anatomic reduction (21). This study showed that there is generally a reasonable outcome following a variety of surgical techniques in canine patients; however a degree of permanent lameness is expected regardless of fixation type, and minor complications are very common.

In this study, several surgical methods of stabilisation were used; however all included tarsocrural joint reduction with immobilisation. Many had reduction and immobilisation alone using a transarticular external skeletal fixator. Fixator application alone is well documented in canine shear injuries, in one study 6/7 canine distal limb shear injuries were stabilised with a transarticular fixator (7). The aim of joint stabilisation is to provide sufficient support until the periarticular tissues including ligaments and joint capsule can heal and fibrose sufficiently to provide stability. We found that clinical results from transarticular fixator stabilisation alone were similar to ligament repair or prosthetic ligament placement in addition to temporary immobilisation. A small number went straight to salvage with pantarsal arthrodesis which has previously been advocated for salvage of severe tarsal injuries in both dogs and cats (5, 22). Interestingly, whatever method was chosen long-term outcome was similar, with a large portion of dogs suffering postoperative complications and long-term lameness.

Transarticular external skeletal fixators are a well-documented joint immobilisation technique (2, 7, 10, 11, 13, 23, 24). We found that fixators were used extensively in these injuries as either sole-fixation device or as adjunct immobilisation to protect a primary repair. Fixator complication rate was 19/19 in the present study with pin tract infection in 11/19 and implant failure in 14/19 limbs. Previous transarticular fixator studies reported variable rates of complications ranging from 14%(7) to 71%(10). The current study findings indicate a higher overall chance of complications; however this could relate to recording differences, or perhaps this location is particularly vulnerable due to the high loads placed upon a joint-spanning frame. The alternative method of immobilisation was coaptation which can save on intraoperative surgical time and hence cost (23), although continued dressing changes with coaptation should be considered. Following exclusion of fixator-associated complications when comparing fixation groups in the six dogs that had fixator placement as their only stabilisation, there was a significant reduction in non-fixator-associated complications. This likely reflects that 50% of non-fixator complications were coaptation related. Overall, the immobilisation method appears to affect the complications seen. We suggest that fixators may still be preferable as although the complication rate was high, they are generally manageable and self-limiting following frame removal, and although in our small coaptation group no major complications developed, (16)it has been previously documented that coaptation has a 63% risk of causing soft tissue injuries (16). The ultimate choice of immobilisation however should be based on clinical experience on an individual patient basis.

Some dogs had prosthetic ligament placement in addition to tarsocrural reduction and immobilisation. Prosthetic ligaments have been described for medial and lateral collateral ligament replacement in dogs and cats, they can be an effective way of maintaining range of motion while providing stabilisation (3, 12, 15, 25). Use of prosthetic ligaments however was significantly associated with severe long-term complications, occurring up to two and a half years following placement. Previous studies have shown the high potential for complications with up to 50% infection rate with braided material and their use has been advised with caution (2, 13). In the current study monofilament prostheses also required removal due to infection. Importantly, increasing antimicrobial resistance in small animals in conjunction with the increased cost of treatment associated with surgical site infections makes prosthetic ligament use questionable given the high rate of infection (26, 27) and comparable clinical outcome when they are not used. Therefore, given the increased risk of complications with prosthetic ligaments the authors would suggest using them with extreme caution, and warn owners of the potential for late complications developing. Four of five dogs that developed implant infection also developed clinical joint instability, which was not present prior to infection and may indicate that prosthesis use reduces long term periarticular fibrosis development, or infection development can subsequently reduce soft tissue stability. Overall, the emphasis should be on strict aseptic technique if prosthetic ligaments are used.

Primary repair of ruptured collateral ligaments is also possible and can result in excellent outcomes. There were no complications directly attributable to ligament repair, and again, the clinical outcome was not hindered by their usage. Therefore, if the injuries present allow, attempting direct ligament suture repair remains an option; although a monofilament absorbable suture is recommended. This repair would duly need to be protected by either a fixator or coaptation. Plated pantarsal arthrodesis was performed in two dogs as the primary treatment and in another following initial stabilisation failure. Previous papers documenting outcome following pantarsal arthrodesis in 40 dogs showed an overall complication rate of 75% with a major complication rate of 32.5%. A high proportion of these were soft tissue related, including catastrophic plantar necrosis associated with injury to the dorsal pedal or perforating metatarsal arteries. A minor complication rate of 42.5% was shown, frequently caused by prolonged external coaptation (4). In the current study owner questionnaire results are only available for two dogs following plate pantarsal arthrodesis and one dog following primary ligament repair making group size too small to infer substantial conclusions.

Long-term owner questionnaire results showed that 9/15 dogs were active to very active following surgery with 11/15 owners rating surgical success as good to excellent. Owner satisfaction with treatment was similarly high compared to those reported previously for both tarsocrural instability and shearing injuries (2, 7, 11, 28). Overall owner satisfaction with surgery was high regardless of surgical stabilisation type and in spite of the high complication rate. Nonetheless, 9/15 dogs were reported as having long-term lameness or stiffness by their owners with half receiving long-term non-steroidal anti-inflammatory drugs. This discrepancy could reflect owner counselling at the outset of treatment as to the severity of the injury sustained and the possibility of complications. The alternative to stabilisation in many of these cases would be arthrodesis or amputation, and whilst many dogs showed signs of ongoing lameness post stabilisation this may be felt to be a relatively good outcome compared with the alternatives. In other studies, degenerative joint disease was seen in 81% of canine joints evaluated following tarsal shear injury, with 23.5% of canine patients suffering long-term lameness (2). Additionally, periarticular fibrosis and post-traumatic osteoarthritis are likely to be a cause of ongoing lameness.

Five dogs with prosthetic ligaments required implant removal; however only two of these owners completed the questionnaire. Overall success of surgery was rated as excellent following revision surgery in one dog which had a subsequent pantarsal arthrodesis using a transarticular fixator. The other dog (19), had its prosthetic ligament removed and plated pantarsal arthrodesis performed, but further long-term implant associated infection was ongoing at the time of data collection **(Figure 2)** and surgical success was rated as poor. Overall, there is an indication that the long-term outcome following implant infection may be guarded and while dogs can recover the risk of ongoing infection should be considered prior to choosing any revision stabilisation method. Only dog 15 had a long-term pain and severity score of zero. This excellent outcome could be attributable to the nature of the injury sustained and does indicate that full return to function can be achieved.

Inherent limitations of this study include its retrospective nature, use of owner questionnaire and lack of objective gait analysis. Multiple surgeons contributed cases over the study period, which inevitably creates variation in case management and record-keeping. A variety of injury combinations were seen resulting in tarsocrural injury, however due to the small numbers, further stratification was not possible. Multivariate analyses were not performed due to the small number of dogs in the study and any benefit with regard to surgical technique requires further prospective studies including objective force plate analysis with increased case numbers. Owing to our small sample sizes our statistical analyses were inherently at risk of type two error.

On balance, tarsocrural fracture/luxations are complex injuries to manage. Temporary joint immobilisation is essential, and can be successfully used alone or in combination with direct ligament repair and/or internal fixation of fractures as appropriate. Transarticular external skeletal fixators remain the authors preferred method of immobilisation, however fixator complications are guaranteed. Placement of prosthetic ligaments is significantly associated with infection-related complications that typically require further surgery to extract the prosthesis, and these problems can occur over a protracted time frame. The authors therefore would counsel against using prosthetic ligaments as part of the surgical management. Whatever the method of fixation, owner satisfaction appears high, the clinical outcome is reasonable, but a degree of ongoing lameness appears likely. We suggest that owner education is paramount, as expectations for full return to normal function must be managed due to the low proportion of dogs returned to pre-injury status. Given the large case variability ultimate choice of stabilisation must be made on a patient by patient basis with consideration to our findings.

Legend

Tables

- **Table 1**- Median Canine Brief Pain Inventory results for comparison of surgical fixation methods.

Fixation group	Number of CBPI completed	Median pain severity score	Median pain interference score
Plate pantarsal arthrodesis	2	4.85	3.00
TESF alone	3	2.3	3.00
Prosthetic ligament placement	4	2.00	4.15
Internal fracture fixation with TESF	4	2.0	1.7
Primary ligament repair with TESF	0	X	X
Primary ligament repair with internal fracture fixation	1	0.00	0.00

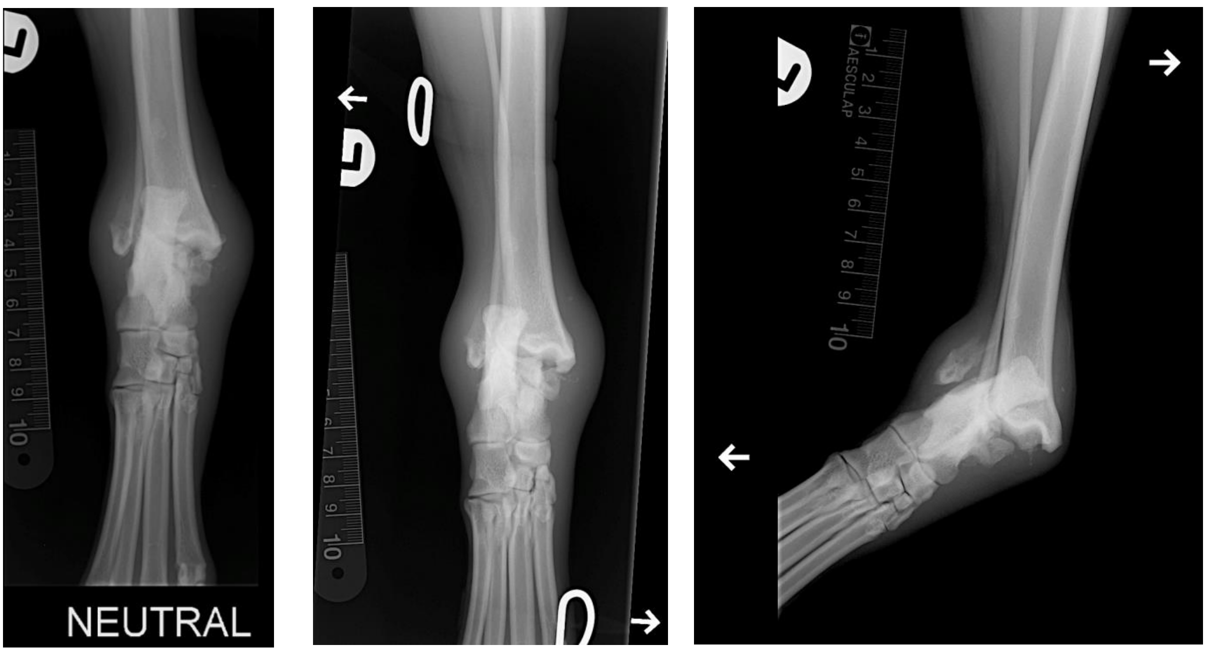
TESF=Transarticular external skeletal fixator

CBPI= Canine Brief Pain Inventory

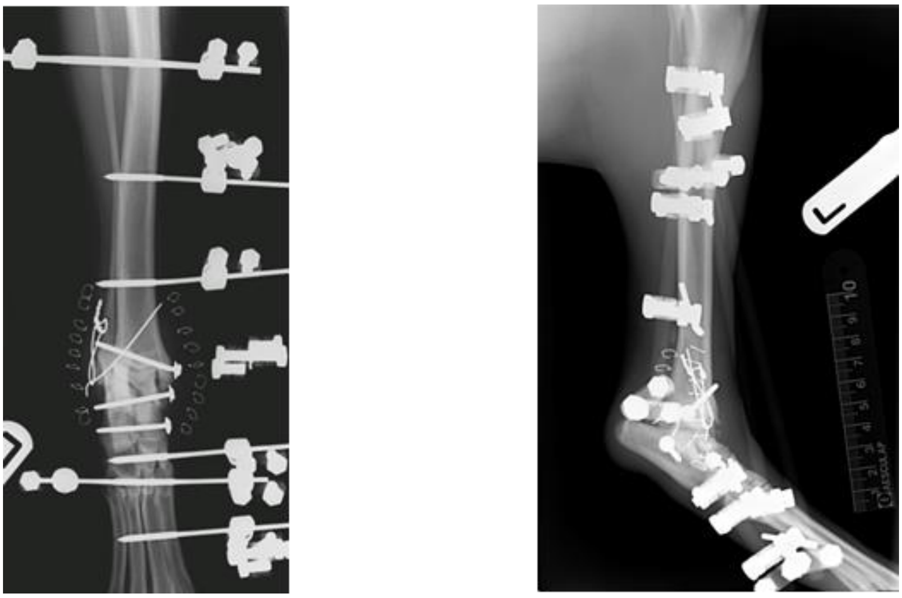
X=No CBPI questionnaires completed

Figures

- **Figure 1-** Preoperative dorsoplantar radiographs of the tarsocrural joint of dog 12 in (**A)** neutral, (**B**) varus and (**C)** valgus stress; showing marked angular displacement of the tarsocrural joint and lateral malleolus, indicating severe medial collateral ligament instability following application of valgus stress.



- **Figure 2**- Postoperative **(A)** dorsoplantar and **(B)** mediolateral radiographs of the tarsocrural joint of dog 18 showing placement of three 2.7mm screws with washers and fiberwire as prosthetic ligaments medially. A distal fibula fracture was stabilised with a 1.2mm K-wire and 1mm figure of eight tension band. A modified type II external skeletal fixator was placed to immobilise the joint.



- **Figure 3- (A)** Dorsoplantar and **(B)** mediolateral radiographs of the tarsocrural joint of dog 19 taken 156 day postoperatively showing extensive periosteal new bone formation on the lateral aspect of the lateral malleolus, dorsodistal tibia, calcaneus, 4th tarsal bone, distal intertarsal bone and tarsometatarsal joint. The central screw has backed out. Marked soft tissue swelling of the tarsus.

References

1. Piermattei DL, Flo GL, DeCamp CE. Brinker, Piermattei, and Flo's handbook of small animal orthopedics and fracture repair: Saunders/Elsevier; 2006.

2. Diamond DW, Besso J, Boudrieau RJ. Evaluation of joint stabilization for treatment of shearing injuries of the tarsus in 20 dogs. J Am Anim Hosp Assoc 1999; 35: 147–153.

3. Sjöström L, Håkanson N. Traumatic injuries associated with the short lateral collateral ligaments of the talocrural joint of the dog. J Small Anim Pract. 1994; 35: 163-8.

4. Roch SP, Clements DN, Mitchell RA, et al. Complications following tarsal arthrodesis using bone plate fixation in dogs. J Small Anim Pract 2008; 49: 117–126.

5. McKee WM, May C, Macias C, et al. Pantarsal arthrodesis with a customised medial or lateral bone plate in 13 dogs. Vet Rec 2004; 154: 165–170.

6. Earley TD, Dee JF. Trauma to the carpus, tarsus, and phalanges of dogs and cats. Vet Clin N Am Sm Anim Pract 1980; 10: 717–747.

7. Benson JA, Boudrieau RJ. Severe carpal and tarsal shearing injuries treated with an immediate arthrodesis in seven dogs. J Am Anim Hosp Assoc. 2002; 38: 370-380.

8. Deruddere KJ, Milne ME, Wilson KM, et al. Magnetic Resonance Imaging, Computed Tomography, and Gross Anatomy of the Canine Tarsus. Vet Surg. 2014; 43: 912-919.

9. Gielen IM, De Rycke LM, van Bree HJ, et al. Computed tomography of the tarsal joint in clinically normal dogs. Am J Vet Res 2001; 62: 1911–1915.

10. Jaeger GH, Wosar MA, Marcellin-Little DJ, et al. Use of hinged transarticular external fixation and adjunctive joint stabilization in dogs and cats: 14 cases (1999–2003). J Am Vet Med Assoc. 2005; 227: 586-591.

11. Kulendra E, Grierson J, Okushima S, Cariou M, et al. Evaluation of the transarticular external skeletal fixator for the treatment of tarsocrural instability in 32 cats. Vet Comp Orthop Traumatol. 2011; 24: 320-325.

12. Aron D, Purinton P. Replacement of the collateral ligaments of the canine tarsocrural joint: a proposed technique. Vet Surg. 1985; 14: 178-184.

13. Fox SM, Guerin SR, Burbidge HM, et al. Reconstruction of the medial collateral ligament for tarsocrural luxation in the dog: a preliminary study. J Am Anim Hosp Assoc. 1997; 33: 268-274.

14. Dyce J, Whitelock RG, Robinson KV et al. Arthrodesis of the tarsometatarsal joint using a laterally applied plate in 10 dogs. J Small Anim Pract 1998; 39: 19–22.

15. Jaeger G, Roe S. Isometry of potential suture attachment sites for the medial aspect of the tibiotarsal joint. Vet Comp Orthop Traumatol. 2005; 18: 73-76.

16. Meeson RL, Davidson C, Arthurs GI. Soft-tissue injuries associated with cast application for distal limb orthopaedic conditions. A retrospective study of sixty dogs and cats. Vet Comp Orthop Traumatol 2011; 24: 126-131.

17. Baltzer W, Cooley S, Warnock J, et al. Augmentation of diaphyseal fractures of the radius and ulna in toy breed dogs using a free autogenous omental graft and bone plating. Vet Comp Orthop Traumatol. 2015; 28: 131-139.

18. Brown DC, Boston RC, Coyne JC, et al. Development and psychometric testing of an instrument designed to measure chronic pain in dogs with osteoarthritis. Am J Vet Res 2007; 68: 631–637.

19. Brown DC, Boston RC, Coyne JC, et al. Ability of the canine brief pain inventory to detect response to treatment in dogs with osteoarthritis. J Am Vet Med Assoc. 2008; 233: 1278-1283.

20. Singh R, Kamal T, Roulohamin N, et al. Ankle Fractures: A Literature Review of Current Treatment Methods. Open Journal of Orthopedics. 2014; 4: 292.

21. Donken CC, Al-Khateeb H, Verhofstad MH, et al. Surgical versus conservative interventions for treating ankle fractures in adults. The Cochrane Library. 2012.

22. Herscovici D, Scaduto J, Infante A. Conservative treatment of isolated fractures of the medial malleolus. J Bone Joint Surg. 2007; 89: 89-93.

23. Fitzpatrick N, Sajik D, Farrell M. Feline pantarsal arthrodesis using pre-contoured dorsal plates applied according to the principles of percutaneous plate arthrodesis. Vet Comp Orthop Traumatol. 2013; 26: 399-407.

24. Nielsen C, Pluhar G. Outcome following surgical repair of achilles tendon rupture and comparison between postoperative tibiotarsal immobilization methods in dogs-28 cases (1997–2004). Vet Comp Orthop Traumatol. 2006; 19: 246-249.

25. Halling K, Lewis D, Jones R, et al. Use of circular external skeletal fixator constructs to stabilize tarsometatarsal arthrodeses in three dogs. Vet Comp Orthop Traumatol. 2004; 17: 204-209.

26. Nicholson I, Langley-Hobbs S, Sutcliffe M, et al. Feline talocrural luxation: A cadaveric study of repair using ligament prostheses. Vet Comp Orthop Traumatol. 2012; 25: 116-125.

27. Nicoll C, Singh A, Weese JS. Economic impact of tibial plateau leveling osteotomy surgical site infection in dogs. Vet Surg. 2014; 43: 899-902.

28. Beever L, Bond R, Graham PA, et al. Increasing antimicrobial resistance in clinical isolates of Staphylococcus intermedius group bacteria and emergence of MRSP in the UK. Vet Rec. 2015; 176: 172-172.

29. Beardsley S, Schrader S. Treatment of dogs with wounds of the limbs caused by shearing forces: 98 cases (1975-1993). J Am Vet Med Assoc. 1995; 207:1071-1075.