Abstract

Objective: To report the surgical technique, associated complications and clinical outcome of elbow arthrodesis using a medially positioned plate.

Study Design: Retrospective case series.

Results: 6 cases met the inclusion criteria. In all cases the elbow was approached medially without the requirement for ulna osteotomy. A non-locking 2.7/3.5mm pre-contoured elbow arthrodesis plate was applied in 5/6 cases and a 2.0mm SOP applied in one case. The mean angle of arthrodesis was 118 degrees (range 113-130 degrees). 1 major intraoperative complication occurred. 3 minor and 3 major post-operative complications occurred. Post-operative imaging was available for 5/6 cases. Complete arthrodesis was confirmed by either radiography or CT scan in 4/5 cases, partial progression of arthrodesis was documented in 1/5 cases and no further images were deemed necessary. Post-operative LOAD score was available for two cases with scores of 20/52 and 10/52. Subjective outcomes in the remaining three cases were rated as acceptable > 1year post-operatively.

Conclusion: Positioning the plate medially for elbow arthrodesis simplified the surgical approach, could be performed with a pre-contoured plate and allowed successful revision of an arthrodesis previously stabilised with a caudally positioned plate. The cases in this series had acceptable outcomes despite a high risk of complications.

Keywords: Elbow, arthrodesis, medial plate, angle of arthrodesis, outcome of elbow arthrodesis, dog

Introduction

Elbow arthrodesis can be used as a salvage procedure for intractable articular fractures, luxations or subluxations, and failed total elbow replacement (TER) (1, 2). Elbow arthrodesis is also an alternative to TER for dogs for the management of severe, end-stage osteoarthritis (1). The most commonly described technique for elbow arthrodesis is via application of a caudally positioned bone plate (2-6). The surgical procedure for application of a caudal bone plate is complex, time consuming and requires osteotomy of the olecranon for access to the joint surface (6, 7). Olecranon osteotomy has been previously reported to have a complication rate of 37% (8, 9). There are currently ten cases reported in the literature where elbow arthrodesis was achieved using a caudally positioned bone plate (3, 4). Three of these cases suffered a major complication, one of which was migration of the Kirschner wires used for the olecranon osteotomy requiring further surgery for removal (3, 4, 10). At follow up four cases used the limb consistently, five used the limb intermittently and one case never used the limb again. Lag screw fixation has been described in two dogs, with screw migration requiring removal occurring in one of these cases (3). Kirschner wires were used exclusively for elbow arthrodesis in a single case weighing 2kg but this technique is not recommended as the implants failed and amputation was subsequently performed (3). Theoretically a medial approach to the elbow would allow luxation of the joint and adequate exposure for removal of articular cartilage as part of elbow arthrodesis, negating the requirement for an olecranon osteotomy and preventing complications associated with this. The subsequent exposure of the medial elbow would allow application of a bone plate medially. Applying the plate medially is technically less challenging, requires less plate contouring, therefore minimising surgical time, and theoretically offers the biomechanical advantage of ‘edge loading’ the plate (11, 12).To the authors’ knowledge, there have been

no previous reports where elbow arthrodesis was achieved via application of a medially-positioned bone plate. The purpose of this case series is to report the surgical technique, associated complications and clinical outcomes.

Material and Methods

Ethical approval was provided by the Institute of Veterinary Science Ethics panel at the XXXX. The hospital records from the XXXX were searched for cases where elbow arthrodesis was performed between January 2009 and November 2017. Cases were included if elbow arthrodesis was performed with a medially-applied plate and if complete records were available including history, clinical examination and radiographs. Follow-up was achieved via telephone conversation with the primary care veterinarian in all cases and with the owner where possible. Six cases met the inclusion criteria.

On initial assessment, lameness was recorded under a numeric rating system using either a scale of 1-5 or 1-10 assigned by the clinician managing the case. A score of 1 = no lameness at walk or trot and then a gradually ascending scale used for worsening lameness up to 5 or 10 which equates to a severe lameness with intermittent or complete non-weight bearing. For ease of comparison in the article the scores given from 1-10 have been divided by two to give a score from 1-5.

Complications and outcome were defined based on previously reported criteria (see appendix) (10). Outcome was assessed either by subjective clinical assessment by the referring veterinarian, by subjective clinical assessment by the treating specialist or by acquisition of a Liverpool Osteoarthritis in Dogs (LOAD) questionnaire via telephone interview with the owner. Post-operative imaging was assessed subjectively by the authors (XX and XX) for progression and completeness of arthrodesis based on bridging new bone formation across the surgical site. The angle of arthrodesis was calculated by assessing the

immediate post-operative mediolateral radiograph and determining two separate points in the centre of the diaphysis of the humerus and connecting them with a line. Two points in the centre of the diaphysis of the radius were measured and connected by a line and the angle measured where the radial and humeral lines intersected.

Case histories

Three cases in this series (cases 1, 2 and 5) had an elbow arthrodesis following explantation of a total elbow replacement (TER). Of the remaining three cases the indication for elbow arthrodesis was severe osteoarthritis for case 3, a persistent septic arthropathy for case 4 and a fracture non-union in case 6.

Case 1 had an elbow arthrodesis following explantation of a chronically luxated Sirius (i) TER implant (Figure 1).

Four years post TER (Iowa State Elbow Replacement (ii)) case 2 was unable to fully weight bear through the operated limb with scuffing of the toes during the swing phase of the gait cycle. Radiographs (Figure 2) indicated that the polyethylene part of the radioulnar component of the prosthesis was severely worn. The TER was explanted and arthrodesis performed.

Case 3 had a left elbow arthrodesis to manage chronic pain and lameness secondary to osteoarthritis. The patient suffered from multiple joint disorders including right cranial cruciate ligament rupture, left medial patella luxation and bilateral carpal hyperextension injury.

Case 4 underwent elbow arthrodesis to manage severe osteoarthritis and a septic arthropathy which had failed to respond to medical management. At the time of surgery the patient was suffering from moderate contracture of the flexor tendons on the ipsilateral limb, attributed to chronic disuse.

Case 5 had a TER (Iowa State Elbow Replacement (ii)) to manage a malunion of a left lateral humeral condylar fracture. Intra-operative subluxation of the implants occurred and resolution was not possible, therefore explantation was performed with conversion to an elbow arthrodesis using a caudal plate. Three months postoperatively the elbow arthrodesis failed with breakage of the caudal plate. All implants were removed and fixation of the elbow for arthrodesis achieved with a medial plate.

Case 6 sustained a lateral humeral condylar fracture which failed to heal despite initial open reduction and fixation and two further revision surgeries. The previously placed implants were removed immediately prior to elbow arthrodesis with a medially-positioned plate. Further details on the case histories can be found in the Appendix.

Anaesthesia

Anaesthetic protocols and post-operative analgesia regimes were tailored to each individual case (see Appendix for further details).

Surgical Technique

All medial elbow arthrodesis surgeries were performed at the XXXX. In all cases the elbow joint was exposed via a medial approach (13). In case 2, an initial lateral approach was made for attempted revision of the TER prior to the medial approach for elbow arthrodesis. In case 5, the medial approach was extended caudally using blunt dissection to expose the caudal bone plate and allow removal.

Tenotomies of the origins of *pronator teres*, *flexor carpi radialis* and the digital flexor muscles were necessary to expose the medial aspect of the humeral condyle. The medial collateral ligament and joint capsule were incised to allow the elbow to be luxated. As much cartilage as was feasible was removed from the joint surface using either a surgical spinal burr or a Volkmann Bone Curette. The medial humeral epicondyle was removed using an

oscillating saw or rongeurs to a point which maximised bone-plate contact and reduced the degree of contouring required.

Cases 1, 2, 4, 5 and 6 had a custom made 2.7mm/3.5mm elbow arthrodesis plate, pre-contoured to 130°, (iii) applied (Figures 1 and 2). Case 3 had a 2.0mm SOP plate contoured to 120° (Orthomed; XX) (Figure 3); chosen due to the small size of the patient.

Prior to closure, the tenotomised pronator teres, flexor carpi radialis and digital flexor muscles were apposed to their origins on the medial humeral condyle using a locking loop suture or a three-loop pulley (2, 14).

Canine demineralised bone matrix (DBM, (Veterinary Tissue Bank Wrexham, UK)) was used in case 1, 2 (3cc), 3 (1cc), 4 (volume not recorded) and 6 (3cc). In case 1 the DBM was combined with an autogenous cancellous bone graft and in cases 2 and 6 it was combined with 5cc of cancellous bone chips (Veterinary Tissue Bank, Wrexham, UK). The use of a bone graft was not reported for case 5.

Antimicrobials

All cases received perioperative intravenous antibiotics and all, except case 3, received post-operative antimicrobials (see Appendix for details).

Post-operative management

Two cases (case 3 and 5) were discharged with a modified spica splint. Case 3 had the splint maintained for three weeks until a severe ulceration developed over the olecranon. For case 5 the spica splint was kept in place for 10 weeks.

Results

Patients

Six mature dogs were included: two Labrador retrievers (case 1 and case 2), one toy poodle (case 3), one Old English sheepdog (case 4), one Border collie (case 5) and one English

springer spaniel (case 6). The median age at the time of arthrodesis surgery was 5.1 years (range 0.75 to 10). Four dogs were female and two male. The median body weight was 21.3kg (range 2.2kg to 42.5kg).

Imaging

Post-operative imaging was available for 5/6 cases (case 3 was euthanised prior to post-operative imaging being performed). Arthrodesis was assessed as complete in 4/5 cases and in 1/5 satisfactory progression of arthrodesis was seen, such that further imaging was not deemed necessary. The median angle of arthrodesis was 115° and the mean 118° (range 113° -130°).

Complications

One major intraoperative complication occurred in case 4. A non-displaced radial spiral fracture developed which was stabilised with a cranially applied 2.7mm, 12 hole, dynamic compression plate that spanned the length of the diaphysis. Eight week post-operative radiographs showed evidence of progression of healing of the fracture with no evidence of implant loosening.

Postoperatively, three major complications (cases 3, 4 and 5) and three minor complications (cases 1, 2 and 5)
occurred (10). Case 4 also had a major intraoperative complication and case 5 had both a major and minor complication.

Two of the major complications which occurred (case 3 and 5) were wounds that developed over the olecranon due to irritation from the supportive dressings. In case 3 the patient presented to the referring veterinary surgeon three weeks post-operatively where removal of the dressing revealed ulceration over the olecranon with a small portion of the olecranon bone exposed. Referral for wound management was offered but the owners did not want to

continue treatment and the patient was euthanatized. In case 5, a circular area of ulceration approximately 1cm in diameter, developed over the olecranon seven weeks post-operatively. The patient was hospitalised for 6 days of open wound management and the ulceration healed completely. The third major complication (case 4) was a recurrent discharging sinus tract over the dorsal, proximal antebrachium. Initially only the dynamic compression plate on the radius was removed (placed due to an intra-operative radial spiral fracture), however the sinus recurred and the arthrodesis plate was subsequently explanted.

Minor complications which occurred were: incidentally identified breakage of a single screw in case 1, radial nerve neuropraxia in case 2, which resolved after 10 weeks of conservative management, and incidental loosening and migration of the most distal ulna screw in case 5.

Outcome

Follow-up via telephone conversation or repeat examination was available for all cases (see table 1), except case 3 which was euthanatized three weeks post-operatively.

In addition to the LOAD score (20/52) at 8 months post-operatively, case 1 was examined by the referring veterinarian 18 months post-operatively, who found no discomfort on palpation of the arthrodesed elbow nor during ipsilateral shoulder manipulation. The patient was receiving analgesia due to orthopaedic disease in multiple limbs.

Case 2 was reassessed seven months post elbow arthrodesis due to a continued intermittent non-weight bearing lameness with scuffing of the foot when weight bearing was attempted. Scuffing of the toes had been present prior to performing the arthrodesis and the exact cause of the lameness was unknown but was suspected to be related to a failure to adapt to restricted elbow flexion. Physiotherapy was advised but no further follow

up was available because 13 months postoperatively the patient was euthanised due to an illness unrelated to orthopaedic disease.

At the eight week postoperative examination case 4 was intermittently weight bearing on the operated limb, able to tolerate off lead exercise and was not receiving any analgesia. Orthopaedic examination revealed an ongoing inability to extend the carpus to a normal weight-bearing position, similar to assessment prior to elbow arthrodesis. This was presumed to be secondary to contraction of the flexor carpi ulnaris and ulnaris lateralis muscles. Both were tenotomised distally which led to an increase in the range of movement of the carpal joint allowing normal extension. 11 months post elbow arthrodesis the radial plate was removed due to the presence of a discharging sinus. 13 months post elbow arthrodesis the medial arthrodesis plate was removed due to recurrence of the discharging sinus. The carpus was still abnormally flexed during walking and pancarpal arthrodesis was considered but the owners opted for non-surgical management. At 29 months post elbow arthrodesis case 4 was able to bear weight on the operated limb intermittently but was euthanatised for reasons unrelated to orthopaedic disease.

Case 5 returned for assessment three months post elbow arthrodesis at which time the patient was weight bearing on the operated limb at a walk and slow trot and did not require any analgesia. Six months after elbow arthrodesis case 5 had a marked functional lameness; able to place the foot normally but with incomplete weight-bearing. Examination revealed marked disuse muscle atrophy of the arthrodesed limb and a reduction to approximately 20% of the normal range of movement in the shoulder and 50% in the carpus. Physiotherapy was recommended and although physiotherapy reports are lacking, when case 5 last presented to the referring veterinarian, 2 years post-arthrodesis, no lameness issues were noted.

The owners of case 6 completed a LOAD questionnaire two years postoperatively which gave a score of 10/52.

Discussion

This is the first report on the use of a medially positioned plate for elbow arthrodesis in dogs. Elbow arthrodesis is a limb salvage option and four of the six cases in this report had undergone prior surgery. Before arthrodesis all of the dogs were significantly disabled by the affected elbow, three were 5/5 lame, one 4/5, one 3/5 and one unable to fully weight bear through the limb with scuffing of the toes when ambulating. Following elbow arthrodesis, an owner questionnaire validated for use in the assessment of canine osteoarthritis, was available for two cases (case 1 and 6) with scores correlating to borderline moderate/severe and mild orthopaedic disease respectively (15). Using the previously described criteria for subjective clinical outcomes to assess cases 2,4 and 5, they all achieved acceptable function of the limb (10). All five cases were able to ambulate but often with a lameness which required activity to be limited in duration and/or require analgesia to achieve (10).

Applying the plate on the medial aspect of the elbow simplified the approach by avoiding an ulna osteotomy, whilst still allowing adequate exposure of the joint. Where required, removal of all articular cartilage could be performed, evidenced by successful arthrodesis documented in all cases for which imaging was available (5/6). Previous reports on elbow arthrodesis document complete arthrodesis radiographically in a single case at 10 weeks post-operatively (4). In a case series of 12 dogs, the progression of radiographic elbow arthrodesis was not reported (3). It is therefore difficult to draw accurate comparisons between the two techniques and the relative likelihood of progression to arthrodesis. An advantage of applying the plate on the medial aspect of the elbow is the ability to use a pre-

contoured plate (iii) rather than relying on intra-operative goniometry to determine the angle of contour (3, 4). The pre-contoured plate resulted in a narrower range in angle of arthrodesis (113° to 130°) compared to the previous report using either a caudally applied bone plate, lag screws or kirschner wires (85° and 145°) (3). However the accuracy of measurement of angulation in this study was limited by imperfect radiographic positioning and by over collimation preventing assessment of the entire humerus and radius. Without the entirety of the humerus and radius/ulna present on every radiograph we were unable to define the level of specific repeatable points at which to perform the measurements for the centre of the diaphysis. This has likely led to be some variability in the measure of the angulation between subjects in this study. This limitation was also highlighted in a previous report where post-operative angles were assessed using only the distal diaphysis of the humerus and proximal diaphysis of the radius (3). Measurement of the centre of the diaphysis of the bones was also made challenging in some patients by superimposition of the implants over the cortices. Previous studies have investigated the standing elbow joint angles of dogs, with a reported range between 120° and 159° (3, 16, 17). The clinical effect of the final angle of arthrodesis is unknown and further studies into a reliable, repeatable method of measuring the post-operative joint angle would need to be performed prior to assessment of this.

Case 5 in this series demonstrated that medial application of the plate can also be used for elbow arthrodesis revision if there is failure of a caudal plate. A caudally positioned plate is loaded via bending along its width in a cranial to caudal direction (11). Applying the plate medially has a mechanical advantage over the same size plate placed caudally since the main force is craniocaudal bending. Applying the plate medially means the plate is ‘edge loaded’, increasing the area moment of inertia and therefore its relative bending stiffness

(11, 12). In addition, the plate used in 5/6 cases in this study (iii) has been designed so that its width is increased in the mid-section in the region of greatest bending force.

One intra-operative complication occurred (case 4) as the elbow was luxated. Elbow luxation requires considerable force and we suspect the soft bone of this juvenile patient predisposed the radius to iatrogenic fracture. The fracture was identified on post-operative radiographs and stabilised the following day. No intra-operative complications have previously been reported during elbow arthrodesis (3, 4). A caudal approach with ostecotmy of the ulna may reduce the risk of intra-operative iatrogenic radial fracture however the ostectomised ulna requires rigid internal stabilisation and may itself be liable to complications (8, 9, 18, 19).

There were 3/6 minor and 3/6 major post-operative complications in this case series. This is considerably higher than the previously reported 2/12 minor and 2/12 major post-operative complications (3). The two minor complications in the previous study were related to implant migration and similarly two cases in this study suffered from minor implant related issues. The third minor complication of radial nerve neuropraxia was likely related to the lateral approach used for TER explantation but has been included as arthrodesis was performed under the same anaesthesia and cannot be excluded as a contributing factor.

Two of the major complications related to the supportive dressings placed postoperatively. Soft tissue damage is the most frequently reported complication of external coaptation and the immobilised point of the olecranon was susceptible to ulceration in the cases in this report (20-22). A spica splint was placed in case 3 due to concerns that the 2.0mm SOP plate would not provide enough stability alone. In case 5 the splint was placed to provide additional support because a large bony deficit was present secondary to the TER.

Theoretically rigid internal fixation with the bone plates used in this report should not have

287 required additional support through external coaptation and it is unlikely that the modified
288 spica splints provided significant additional stability to the arthrodesis. Due to the small case
289 numbers and the high complication rate, we are unable to evaluate risk factors for
290 developing dressing-related complications. Based on our experience in these cases and on
291 the reported complication rates associated with external coaptation, we would caution
292 against the use of post-operative supportive dressings following elbow arthrodesis (20-22).
293 The third major complication was recurrence of sinus drainage tracts, a complication also
294 seen in a single case in the previous report of elbow arthrodesis (3). Case 4 was identified
295 pre-operatively as at a higher risk of post-operative infection due to the previous history of
296 septic arthritis in the operated elbow joint and this led to the decision to perform an
297 arthrodesis rather than total joint replacement. This case also had revision surgery for
298 stabilisation of an iatrogenic radial fracture which may have further increased the risk of
299 post-operative surgical site infection (23). Although post-operative infection occurred, we
300 were able to remove the implants and still preserve the limb.
301 The high rate of complications in this case series compared to the previous report is likely
302 due to a combination of low case numbers in both reports, variable follow-up because of
303 the retrospective nature of both reports, and a difference in classification of major and
304 minor complications.
305 The goal of elbow arthrodesis in these cases was to salvage a severely disabled limb and this
306 was achieved in 5/6 of the cases. Follow-up in the previous report found 7/9 dogs had
307 improved limb use following elbow arthrodesis compared to pre-operatively (3). Most of the
308 patients in the previous two reports did not use the limb all of the time, especially when
309 running, similar to our findings of intermittent weight bearing (3, 4). Future studies into
310 elbow arthrodesis should use objective lameness assessment combined with the use of

validated questionnaires for both pre- and post- operative assessments to allow further assessment of outcome.

Positioning the plate medially for elbow arthrodesis was advantageous due to the simplified surgical approach, the ability to use a pre-contoured plate and allowed successful revision of an arthrodesis previously stabilised with a caudally positioned plate. The cases in this series had acceptable outcomes despite a high risk of complications and we would caution against the use of post-operative external coaptation.

Footnotes

i) Sirius Canine Elbow, model 2, Osteogen Ltd, Bristol, UK

ii) Iowa State Total Elbow Replacement, Biomedtrix, Whippany, New Jersey, USA

iii) A version of the custom made plate used in these cases is now commercially available at Veterinary Instrumentation: Elbow arthrodesis plate product code:152951 (left) 152950 (right), Veterinary Instrumentation, Sheffield, UK

References

1. Johnston S. A TKM. Veterinary Surgery Small Animal. 2nd Edition ed. Canada: Elsevier; 2018.
2. Brinker WO, Piermattei DL, Flo GL. Handbook of small animal orthopedics and fracture treatment. Fifth Edition ed: WB Saunders Co.; 2016.
3. De Haan J, Roe S, Lewis D, Renberg W, Kerwin S, Bebchuk T. Elbow arthrodesis in twelve dogs. VCOT Archive. 1996;9(3):25-8.
4. Choate C, Arnold G. Elbow arthrodesis following a pathological fracture in a dog with bilateral humeral bone cysts. Veterinary and Comparative Orthopaedics and Traumatology. 2011;24(05):398-401.
5. McLaughlin R. Arthrodesis. Manual of Internal Fixation in Small Animals: Springer; 1998. p. 247-54.
6. Penwick RC. Arthrodesis. Veterinary Clinics of North America: Small Animal Practice. 1987;17(4):821-40.
7. Cook JL, Payne JT. Surgical Treatment of Osteoarthritis. Veterinary Clinics of North America: Small Animal Practice. 1997;27(4):931-44.
8. Hume MC, Wiss DA. Olecranon fractures. A clinical and radiographic comparison of tension band wiring and plate fixation. Clinical orthopaedics and related research. 1992(285):229-35.
9. Macko D, Szabo RM. Complications of tension-band wiring of olecranon fractures. The Journal of bone and joint surgery American volume. 1985;67(9):1396-401.
10. Cook JL, Evans R, Conzemius MG, Lascelles BDX, McIlwraith CW, Pozzi A, et al. Proposed Definitions and Criteria for Reporting Time Frame, Outcome, and Complications For Clinical Orthopedic Studies in Veterinary Medicine. Veterinary Surgery. 2010;39(8):905-8.
11. Benamou J, Demianiuk RM, Rutherford S, Beckett C, Ness MG, Haut RC, et al. Effect of bending direction on the mechanical behaviour of 3.5 mm String-of-Pearls and Limited Contact Dynamic Compression Plate constructs. Veterinary and comparative orthopaedics and traumatology : VCOT. 2015;28(6):433-40.
12. P. Muir KAJ, M. D. Markel. Area Moment of Inertia for Comparison of Implant Cross-Sectional Geometry and Bending Stiffness. Veterinary and Comparative Orthopaedics and Traumatology. 1995;8(3):24-30.
13. Johnson KA. Piermattei's Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat: Elsevier Health Sciences; 2013.
14. Berg R, EGGER EL. In vitro comparison of the three loop pulley and locking loop suture patterns for repair of canine weightbearing tendons and collateral ligaments. Veterinary Surgery. 1986;15(1):107-10.
15. Walton B, Cox T, Innes J. 'How do I know my animal got better?' – measuring outcomes in small animal orthopaedics. In Practice. 2018;40(2):42-50.
16. Milgram J, Slonim E, Kass PH, Shahar R. A radiographic study of joint angles in standing dogs. Veterinary and comparative orthopaedics and traumatology : VCOT. 2004;17(02):82-90.
17. Watson C, Rochat M, Payton M. Effect of weight bearing on the joint angles of the fore- and hind limb of the dog. Veterinary and comparative orthopaedics and traumatology : VCOT. 2003;16(04):250-4.
18. Halling KB, Lewis DD, Cross AR, Kerwin SC, Smith BA, Kubilis PS. Complication rate and factors affecting outcome of olecranon osteotomies repaired with pin and tension-band fixation in dogs. The Canadian veterinary journal = La revue veterinaire canadienne. 2002;43(7):528-34.
19. Palmer RH, Aron DN, Chambers JN. A combined tension band and lag screw technique for fixation of olecranon osteotomies. Veterinary surgery : VS. 1988;17(6):328-32.
20. Meeson RL, Davidson C, Arthurs GI. Soft-tissue injuries associated with cast application for distal limb orthopaedic conditions. Veterinary and comparative orthopaedics and traumatology : VCOT. 2011;24(02):126-31.

21. Bristow PC, Meeson RL, Thorne RM, Butterworth SJ, Rutherford S, Renwick AIC, et al. Clinical Comparison of the Hybrid Dynamic Compression Plate and the Castless Plate for Pancarpal Arthrodesis in 219 Dogs. Veterinary Surgery. 2015;44(1):70-7.
22. Nielsen C, Pluhar GE. Outcome following surgical repair of achilles tendon rupture and comparison between postoperative tibiotarsal immobilization methods in dogs. Veterinary and comparative orthopaedics and traumatology : VCOT. 2006;19(04):246-9.
23. Griffon D, Hamaide A. Complications in small animal surgery: John Wiley & Sons; 2016.

Figure 1.A Mediolateral radiograph of case 1 demonstrating severe elbow osteoarthritis prior to TER.

Figure 1.B Craniocaudal radiograph of case 1 demonstrating severe elbow osteoarthritis prior to TER.

Figure 1. C Mediolateral radiograph of case 1 immediately post Sirius TER.

Figure 1. D Craniocaudal radiograph of case 1 immediately post Sirius TER.

Figure 1. E Mediolateral radiograph of case 1 at seven months post TER showing luxation of the implant.

Figure 1. F Craniocaudal radiograph of case 1 at seven months post TER showing implant failure and luxation.

Figure 1. G: Mediolateral radiograph of case 1 immediately post elbow arthrodesis with the Veterinary Instrumentation non-locking 2.7mm/3.5mm elbow arthrodesis plate. A 3.5mm humeral-ulna screw and 2.7mm radio-ulna screw have been placed to provide additional stability.

Figure 1.H Craniocaudal radiograph of case 1 immediate post elbow arthrodesis with the Veterinary Instrumentation non-locking 2.7mm/3.5mm elbow arthrodesis plate. A 3.5mm humeral-ulna screw and 2.7mm radio-ulna screw have been placed to provide additional stability.

Figure 2. A Mediolateral radiograph of case 2 immediately post Iowa State TER.

Figure 2.B Craniocaudal radiograph of case 2 immediately post Iowa State TER.

Figure 2. C Mediolateral radiograph of case 2 four years post TER showing collapse of the elbow compartment due to severe wearing of the radioulna component.

Figure 2.D Craniocaudal radiograph of case 2 four years post TER showing collapse of the elbow compartment due to severe wearing of the radioulna component.

Figure 2.E Mediolateral radiograph of case 2 immediately post elbow arthrodesis with the Veterinary Instrumentation non-locking 2.7mm/3.5mm elbow arthrodesis plate.

Figure 2.F Craniocaudal radiograph of case 2 immediately post elbow arthrodesis with the Veterinary Instrumentation non-locking 2.7mm/3.5mm elbow arthrodesis plate.

Figure 2.G Mediolateral radiograph of case 2 at 28 weeks post elbow arthrodesis demonstrating bridging new bone and the completion of elbow arthrodesis.

Figure 2.H Craniocaudal radiograph of case 2 at 28 weeks post elbow arthrodesis demonstrating bridging new bone and the completion of elbow arthrodesis.

Figure 3.A Mediolateral radiograph of case 3 immediately post elbow arthrodesis with a 2.0mm SOP plate. Additional radioulna screws were placed to add stability.

Figure 3.B Craniocaudal radiograph of case 3 immediately post elbow arthrodesis with a 2.0mm SOP plate. Additional radioulna screws were placed to add stability.

420 Table 1 Indication for arthrodesis, pre-operative lameness, timing, method and result of follow-up

421 for all cases.

Case Number	**Indication for arthrodesis**	**Lameness score prior to elbow arthrodesis**	**Time of follow-up (months post arthrodesis surgery)**	**Method of follow-up**	**Outcome based on LOAD or Cook definition[1]**	**Receiving analgesia at follow-up (Yes/No)**	**Additional comments by owner or examining veterinarian**
1	Explanted TER	4/5	8	Phone conversation with owner	LOAD score = 20/52	Yes	Owner satisfied and patient pain free and able to ambulate
2	Explanted TER	4/5	7	Examination at XXX[2]	Acceptable function	No	Intermittent non-weight bearing lameness
3	Osteoarthritis	3/5	Euthanised 3 weeks post-operatively	n/a	n/a	n/a	n/a
4	Septic arthritis	5/5	29	Referring veterinarian	Acceptable function	No	Intermittent weight bearing
5	Explanted TER	5/5	24	Referring veterinarian	Acceptable function	No	No lameness issues noted
6	Fracture non-union	5/5	24	Phone conversation with owner	LOAD score = 10/52	No	No comments

[1] Cook et al 2010: “Acceptable function: restoration to, or maintenance of, intended activities and performance from preinjury or predisease status that is limited in level or duration and/or requires medication to achieve.”

[2] XXX = XXXXXX XXXXXX XXXXXXX XXXXXXX XX XXXXXX

Appendix

Definition of complications used in this report as defined by J.L Cook et al 2010

"Catastrophic complication: complication or associated morbidity that causes permanent unacceptable function, is directly related to death, or is cause for euthanasia.

Major complication: complication or associated morbidity that requires further treatment based on current standards of care:

1. Requires surgical treatment to resolve based on current standards of care
2. Requires medical treatment to resolve based on current standards of care

Minor complication: not requiring additional surgical or medical treatment to resolve (eg. Bruising, seroma, minor incision problems, etc.).

Definition of outcomes used in this report as defined by J.L Cook et al 2010

Full function: restoration to, or maintenance of, full intended level and duration of activities and performance from preinjury or predisease status (without medication).

Acceptable function: restoration to, or maintenance of, intended activities and performance from preinjury or predisease status that is limited in level or duration and/or requires medication to achieve.

Unacceptable function: all other outcomes."

Case Histories, further details:

Three cases in this series (cases 1, 2 and 5) had an elbow arthrodesis following explantation of a total elbow replacement (TER). Of the remaining three cases the indication for elbow arthrodesis was severe osteoarthritis for case 3, a persistent septic arthropathy for case 4 and a fracture non-union in case 6.

Case 1 had chronic luxation of the Sirius (i) TER implant (Figure 1) which was associated with a 4/5 lameness, a reduced range of motion and pain. The TER was explanted seven months after implantation and arthrodesis of the left elbow joint using a medial plate was performed.

Four years post TER (Iowa State Elbow Replacement (ii)) case 2 was unable to fully weight bear through the operated limb with scuffing of the toes during the swing phase of the gait cycle. Radiographs (Figure 2) indicated that the polyethylene part of the radioulnar component of the prosthesis was severely worn. The TER was explanted and arthrodesis of the elbow joint was performed using a medially-positioned bone plate.

Case 3 had a left elbow arthrodesis with a medial plate to manage chronic pain and a 3/5 left thoracic limb lameness secondary to osteoarthritis. The patient suffered from multiple joint disorders including right cranial cruciate ligament rupture, left medial patella luxation and bilateral carpal hyperextension injury.

Case 4 underwent elbow arthrodesis, with a medially positioned plate, to manage a 5/5 right thoracic limb lameness caused by severe osteoarthritis and a septic arthropathy which had failed to respond to medical management. At the time of surgery the patient was suffering from moderate contracture of the flexor tendons on the ipsilateral limb, attributed to chronic disuse.

Case 5 had a TER (Iowa State Elbow Replacement (ii)) to manage a malunion of a left lateral humeral condylar fracture associated with a 5/5 lameness. Intra-operative subluxation of the implants occurred and resolution was not possible, therefore explantation was performed with conversion to an elbow arthrodesis using a caudal plate. Three months postoperatively the elbow arthrodesis failed with breakage of the caudal plate. All implants were removed and fixation of the elbow for arthrodesis achieved with a medial plate.

Case 6 sustained a lateral humeral condylar fracture secondary to a humeral intracondylar fissure. Open reduction and fixation was performed and two further revision surgeries but the fracture failed to heal. A non-union of the supracondylar fracture, with loosening of the transcondylar screw and persistence of an intracondylar fissure was documented by computed tomography seven months after the initial fracture was sustained. Clinically, the patient had a 5/5 lameness of the right thoracic limb, moderate muscle atrophy of the affected thoracic limb and a contralateral humeral intracondylar fissure. The previously placed implants were removed immediately prior to an elbow arthrodesis with a medially-positioned plate.

Anaesthetic protocols

Anaesthetic protocols varied between cases. Most commonly an opioid combined with an alpha -2 adrenergic agonist were used for pre-medication, propofol (Propoflo Plus; Zoetis; Surrey United Kingdom) for induction and either isoflurane or sevoflurane for maintenance of anaesthesia. A brachial plexus block using bupivacaine at 1mg/kg (Marcain; AstraZeneca; Cambridge, United Kingdom) was used in all cases where electronic records were available (case 1, 3 and 4). Intra-operative breakthrough pain was variably managed with either an opioid or N-methyl-D-aspartate (NMDA) receptor antagonist or a combination of both. Post-operative analgesia regimes were tailored to each individual case. Opioid analgesia combined with a non-steroidal anti-inflammatory drug (NSAID) and/or paracetamol was continued for a minimum of 24 hours post-operatively in all cases.

Case 1, 3, 4 and 6 were discharged with a NSAID and paracetamol/codeine (Pardale-V; Dechra Limited; Northwich, UK), case 2 was discharged with paracetamol/codeine and tramadol and case 5 was discharged with a NSAID only.

Informed consent for the off-license use of tramadol and paracetamol/codeine was obtained. Although paracetamol/codeine is a licensed product, the dose used, length of administration and concurrent use with non-steroidal anti-inflammatory drugs were all off-license.

All cases received perioperative intravenous antibiotics in the form of either cefuroxime (15mg/kg every 90 minutes) or amoxicillin/clavulanic acid (20mg/kg combined, every 90 minutes). Cases 1, 2 and 5 received a post-operative course of oral amoxicillin/clavulanate (12.5-16mg/kg twice daily for five to seven days). Cases 4 and 6 continued a course of cephalexin (20mg/kg twice daily PO) for five and seven days respectively, and case 3 did not receive any postoperative antimicrobials.