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| **TITLE OF CASE**  |
| Use of bone anchors for the treatment of partial and complete traumatic elbow luxations: a retrospective case series of three dogs |
| **SUMMARY**  |
| Three dogs presented with traumatic lateral elbow luxation following road traffic accidents. Concurrent injuries included skin abrasions and coxofemoral luxation. All luxations were reduced and stabilised with bone anchors through a lateral approach to the elbow joint and had an augmented or prosthetic lateral collateral ligament placed. One elbow joint was stabilised with FASTak® anchor (Arthrex, Karsfeld, Germany) and two with suture anchors by Veterinary Inc., Longview, TX. Reluxation occurred in one case 24 hours after discharge requiring revision surgery. Median follow-up time for the three cases was 180 days (range, 49-2920) and the functional outcome was considered excellent in all cases as determined by veterinary assessment, clinical record reviews, owner communication and Liverpool Osteoarthritis in Dogs (LOAD) questionnaire. In conclusion, placement of bone anchors with augmentation of the lateral collateral ligament for management of traumatic elbow luxation in dogs is a good alternative to previously reported surgical techniques.  |
| **BACKGROUND**  |
| Traumatic elbow luxation is the second most common joint luxation in the dog, after luxation of the coxofemoral joint, although its occurrence is uncommon. (1, 2) We report a technique for stabilisation of elbow luxations which has not been previously reported. Most traumatic elbow luxations are a result of road traffic accidents. (3, 4) In a canine cadaveric study, elbow luxation after application of indirect rotational forces was not possible, unless at least the lateral collateral ligament was transected. (5) The collateral ligaments in the canine elbow joint can be torn along their length, be avulsed or stretched. (6, 7)Closed reduction is the first approach to management of the luxated elbow joint. (1, 4, 6, 8) Instability of the elbow joint and integrity of the collateral ligaments can be assessed after reduction with the ‘Campbell’s test’. (1) To perform the test, the elbow and carpal joints are flexed and maintained at 90o, while the manus is abducted and adducted. (1) If the ligaments are intact, lateral rotation of the manus (pronation) is permitted up to 40-50o and medially (supination) 60-70o, or according to a more recent study, 27.3±8o in pronation and 45.5±10.8o in supination. (1, 5) If the lateral collateral ligament is severed or avulsed medial foot rotation increases up to 140o, while with medial ligament involvement lateral movement of the foot can be produced up to 100o. (1) Instability following closed reduction, reluxation or inability to reduce the elbow would indicate surgical intervention (6, 9) Options for surgical stabilisation for the luxated elbow joint include direct collateral ligament repair, reattachment of ligament avulsions and collateral ligament replacement with synthetic suture or orthopaedic wire. (1, 2, 4, 6, 10-13) Elastic transarticular external skeletal fixators, transcondylar bone tunnels with circumferential suture repair, or combination of all above surgical methods have also been reported. (2, 5, 14) Use of conventional screws as anchors for ligament replacement has been previously reported, with or without washers. (2, 9, 10) To the best of the authors’ knowledge only prong-type tissue anchors have been reported in veterinary orthopaedics for the reduction of traumatic elbow luxations in one dog. (15) We could not identify any studies reporting the use and outcome of screw-in bone anchors as a treatment option for cases of traumatic elbow luxation. The objective of this report was to describe the use and outcome of using specific bone anchors for managing traumatic lateral elbow luxations. |
| **CASE PRESENTATION**  |
| Medical records from August 2005 to May 2019 were reviewed. Inclusion criteria were complete records of dogs that had a traumatic elbow luxation which had been managed surgically by stabilisation with bone anchors. Information obtained from the medical records included dog signalment, bodyweight, physical and orthopaedic examination findings, radiographic investigations, surgical treatment and outcome. Four cases were identified during review of the hospital’s medical records; however, one was excluded due to incomplete records.Case 1 was a two-year nine-month-old female neutered cross-bred dog. History and clinical examination findings can be found in Table 1. Orthopaedic examination revealed non-weight bearing lameness on the right thoracic and left pelvic limb. Case 2 was a six-year-old male English springer spaniel. Orthopaedic examination revealed non-weight bearing lameness on the right thoracic limb (Table 1). Full conscious orthopaedic assessment was not possible due to pain. Orthopaedic assessment under sedation on the day of presentation, found a right lateral elbow luxation. The luxation was managed by closed reduction but reluxated spontaneously after reduction whilst the patient was sedated.Case 3 was a three-year eight-month old male neutered cross-bred dog. Orthopaedic examination revealed a mild-to-moderate fully weight-bearing left thoracic limb lameness (2/5) (Table 1). Examination of the left elbow joint under sedation, revealed pain on extension and flexion of the left elbow. A Campbell’s test was suggestive of a left lateral elbow luxation with >70o supination.  |
| **INVESTIGATIONS**  |
| On Case 1, an abdominal ultrasonographic examination was unremarkable. Orthogonal radiographic views of the right elbow joint and pelvis confirmed a right lateral elbow luxation (Figure 1) and left craniodorsal coxofemoral luxation, respectively.On Case 2, radiographs of the confirmed right elbow confirmed the right lateral elbow luxation.On Case 3, preoperative orthogonal left elbow radiographic views revealed radial head subluxation and humeroulnar subluxation (Figure 2). |
| **DIFFERENTIAL DIAGNOSIS**  |
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| **TREATMENT**  |
| All surgical procedures were performed by a Royal College of Veterinary Surgeons (RCVS) or European College of Veterinary Surgeons (ECVS) board-certified surgeon or a surgical resident under their direct supervision. Closed reduction of the luxated elbow joint was performed in all cases under general anaesthesia, as described by Campbell. (1) A lateral surgical approach to the elbow joint was performed. (16) The antebrachial fascia was incised, followed by elevation of the anconeus muscle and transection of the tendon of the ulnaris lateralis muscle. The lateral collateral ligament was identified by cranial retraction of the common and lateral digital extensor muscles and transection of the tendon of origin of the ulnaris lateralis muscle. The lateral collateral ligament was examined and type of tear and location recorded. Predrilling was performed when an IMEX™ bone anchor (Veterinary Inc., Longview, TX) was used (Figure 3A). An anchor bone hole was pre-drilled using a 2.7mm drill bit at the insertion of the lateral collateral ligament on the lateral epicondyle. The bone anchor was then inserted at the predrilled hole. A locking loop suture pattern was used to suture the distal part of the lateral collateral ligament to the anchor, through its eyelet with 3 metric polydioxanone (PDS II, Ethicon, Cincinnati, Ohio). Case 1 and 2 were stabilised with the IMEX™ bone anchors (Veterinary Inc., Longview, TX) as above (Figure 4, A-D). Both lateral collateral ligaments in these cases were fully ruptured at their midportion. The left coxofemoral luxation in Case 1 was treated by transarticular pinning with a 2.0mm A-wire, during the same procedure.No predrilling was performed when a FASTak® Anchor (Arthrex, Karsfeld, Germany) was used (Figure 3B). This anchor was used in Case 3, in which case, the lateral collateral ligament was seen intact but non-functional as it appeared lax/stretched and frayed. A 2.4mm FASTak® Anchor (Arthrex, Karsfeld, Germany) was inserted in the lateral humeral epicondyle and the preloaded 3 metric FiberWire® (Arthrex, Karsfeld, Germany) was sutured to the lateral collateral ligament in a locking loop pattern to imbricate the frayed ligament (Figure 4, E-F).In all cases, the tenotomy of the ulnaris lateralis muscle was sutured with a three loop pulley suture (polydioxanone 3 metric, PDS II, Ethicon, Cincinnati, Ohio), followed by routine closure of the brachial/antebrachial fascia, subcutaneous tissue and skin. Postoperative opioids included methadone 0.2mg/kg IV Q4h (Comfortan®, Dechra, UK) which was replaced by buprenorphine 0.02mg/kg IV (Buprecare®, AnimalCare, UK) 24-48 hours after surgery. A modified spica splint bandage was placed immediately postoperatively in Case 3 and was removed three days later. Case 1 was hospitalised for five days, Case 2 for three day and Case 3 for four days.All cases were discharged with meloxicam 0.1mg/kg PO SID (Metacam® 1.5mg/ml, Boehringer Ingelheim, UK), or carprofen 2mg/kg PO BID (Rimadyl®, Zoetis, UK) for 2 weeks. Paracetamol 10mg/kg PO TID (Pardale-V® 400mg/9mg, Dechra, UK) was also prescribed for 2-3 weeks. One week of antimicrobial therapy with potentiated amoxicillin 20mg/kg PO BID (Synulox®, Zoetis, UK) was administered for Case 1 and 2 and cephalexin 20mg/kg PO BID (Rilexine®, Virbac, UK) in Case 3. Exercise restriction was advised in all cases with short lead-walks for toileting purposes for eight weeks. According to the available records, the authors did not discuss physiotherapy with the clients.A major complication occurred in one case according to the classification by Cook et al. (17) Case 1 returned to the referral hospital 24 hours following discharge with non-weight bearing right thoracic limb lameness. Reluxation of the right elbow was diagnosed on radiographic examination, with a stable anchor implant. The surgery was revised by the surgeon that performed the initial surgery (EC) by replacing the polydioxanone suture with 4 metric polypropylene (Prolene, Ethicon, Cincinnati, Ohio) in a modified Bunnell-Mayer suture pattern. A spica splint bandage was placed at the end of the procedure using cast material. Orthogonal radiographs of the right elbow joint two weeks later, confirmed stable implant positioning and no further reluxation. The patient returned to the referring veterinary practice for bandage removal one week later. The elbow joint was stable at that time. |
| **OUTCOME AND FOLLOW-UP**  |
| The referring veterinary surgeon of Case 1 was contacted via telephone eight years postoperatively. No further complications had occurred, and the patient was not currently receiving analgesia but had occasional episodes of right thoracic limb lameness which had been managed with intermittently administered analgesics. This intermittent lameness was not further investigated by the primary veterinarian of this Case.Case 2 was reassessed seven weeks postoperatively at the referral hospital. There was no evidence of a right thoracic limb lameness and the range of movement of the right elbow joint was within normal limits and pain free. Radiographs revealed stable implant positioning and a congruent elbow joint (Figure 5). This case was lost to further follow up.Postoperative clinical and radiographic assessment was declined by the owner of Case 3. There was no evidence of a left thoracic limb lameness on video footage provided by the owner with the dog walking and trotting on lead-walks outdoors. The owner completed the LOAD questionnaire at 24 weeks postoperatively; the score was 0/52 indicative of normal mobility. (18) At 28 weeks postoperatively, the owner was contacted again via telephone; no concerns were reported and was very pleased with the outcome.  |
| **DISCUSSION**  |
| The authors describe the novel use of bone anchors and prosthetic ligaments for treatment of traumatic elbow luxation. Reluxation occurred in one case which was managed by revision surgery using the same bone anchor. All three dogs returned to normal function. One case was reported to have recurrent episodes of lameness on the affected limb following surgery. The authors believe that persistent lameness could be explained by elbow osteoarthritis secondary to elbow luxation, without being necessarily related to the surgical method used to treat the elbow luxation. (2, 11)All cases initially presented after a traumatic incident such as road traffic accident, which has been reported as the most common cause of traumatic elbow luxation, in up to 100% of cases. (2, 3, 19) All elbow luxations in this study were lateral which has been most commonly reported. (1) Two cases had a complete rupture of the lateral collateral ligament (complete luxations) and one had a frayed, non-functional lateral collateral ligament (partial luxation). A bandage was placed in two of the three cases of this report. Case 1 had a bandage placed for three weeks following revision surgery and Case 3 had a bandage placed for three days. Both Cases were supervised by one author (EC). It is unclear whether the use of a bandage can offer additional postoperative stabilisation in cases of elbow luxation. (2) The efficacy of the sole use of external coaptation after closed reduction of elbow luxations has been questioned in a recent study where five out of six cases reluxated, (2) and considerations must be given to the complications and the effect of a bandage on limb function. (20, 21)Closed reduction of traumatic elbow luxation should be initially attempted and then Campbell’s test be performed to check for elbow stability. (6) If Campbell’s test suggests elbow instability (up to 140o in supination, up to 100o in pronation), surgical stabilisation should follow. (6) In Case 3, Campbell’s test was performed and showed partial instability (>70o) of the elbow, and as a result a surgical approach was chosen. Partial traumatic elbow luxation has been reported twicein dogs, but both had medial luxation of the anconeal process and medial humeroulnar subluxation. (22, 23) Case 3 is the first lateral subluxation of the radial head reported in veterinary literature.Instability following closed reduction, reluxation or inability to reduce the elbow are indications for surgical intervention (6, 9) Cases 2 and 3 had clear indication for surgical intervention with spontaneous reluxation following reduction and residual instability following closed reduction, respectively. Exact reasoning for surgical stabilisation in Case 1 was not recorded in the clinical records but may have been associated with surgeon preference. External coaptation with a spica splint for at least 2-3 weeks along with strict rest for 4-6 weeks is recommended for conservative management of acute elbow luxations, which are stable after reduction and stabilising the elbow joint in extension provides inherent stability to the elbow joint. (1, 3, 6, 10) With the elbow in extension, the anconeal process sits in the olecranon fossa and prevents medial and lateral luxation. (6) Efficacy of external coaptation is based on providing time for healing and fibrosis to occur on the periarticular tissues which will prevent reluxation following removal of the bandage. (10) Excellent or good outcomes were reported in 88.6% of dogs (30/35) with elbow luxations treated with closed reduction and external coaptation, in contrast to 55.6% dogs (5/9) treated with open reduction. (3) External coaptation alone can have good clinical results, however, the risks of reluxation, bandage complications and decreased range of motion of the joint should be kept in mind. (10, 20, 21)The authors did not discuss physiotherapy with the owners, according to the available records. Physiotherapy assists healing and preservation of function in tendinous injuries. (24, 25) *Takai et al.* showed that early passive range of motion accelerated tendon healing and improvedtendon strength compared to controls. (26) Rehabilitation is usually recommended straight after surgery in increasing intensitiy depending on the condition treated. (27) Potentially rehabilitation was orally discussed with the owners, however, some surgeons do not advise physiotherapy until the final radiographic check of the patient.Bone anchors have been used *in vivo* and *ex vivo* in the shoulder, stifle, coxofemoral and tarsal joint for treatment of joint luxations or ligament/tendon avulsions and ruptures but not reported in the elbow. (15, 28-31) Clinical application of bone anchors (IMEX Vet, Arthrex) was straight forward and uncomplicated in the three cases described here. The Arthrex bone anchor was placed without predrilling minimising the necessary additional equipment. A unilateral approach and implants being preloaded with suture material decreased the surgical time. (32) Bone anchors also offer a robust attachment for augmentation of the damaged or ruptured ligament. (33) Due to the above, the authors feel this technique was more straight forward and less time consuming then previously reported techniques to stabilise traumatic elbow luxations.Within 24 hours after discharge (6 days postoperatively), Case 1 presented to the referral hospital and a reluxation of the right elbow was diagnosed. Elbow reluxation is common, having occurred in 6/37 dogs (16%) in a recent multicentre study on traumatic elbow luxation. (2) Four out of the six cases with elbow reluxation on the same study, occurred in dogs with other concurrent orthopaedic injuries. (2) Similarly, Case 1 had a left traumatic coxofemoral joint luxation. Concurrent orthopaedic injuries are speculated to increase weight-bearing on the operated limb, and potentially increase stress on the implants and cause failure. (2) Cases with concurrent orthopaedic injuries are also proposed to have a worse outcome, albeit the longterm outcome on Case 1 was acceptable with only occasional episodes of right thoracic limb lameness which are managed medically. (4) The method of failure of the initial stabilisation in Case 1 was not recorded during the second surgery. The bone anchor had not been displaced on radiographic examination of the right elbow. As a result, one could speculate the reluxation could be related to suture failure via breakage or tearing through the distal ruptured ligament, or suboptimal surgical reconstruction. It is possible the remnant of the distal ruptured ligament was of poor quality due to the initial trauma. Taking into consideration the successful outcome of the revision surgery, the integrity of the ruptured distal ligament was most likely satisfactory. During the revision surgery, the 3 metric polydioxanone (PDS II, Ethicon, Cincinnati, Ohio) was replaced with a 4 metric polypropylene (Prolene, Ethicon, Cincinnati, Ohio). Potentially the increase of the suture size alone may have been enough to stabilise the elbow joint. The suture material was changed from an absorbable to a nonabsorbable material. However, degradation of the absorbable material is unlikely to have caused the failure as it failed only 6 days after implantation and polydioxanone’s tensile strength reduces by 20% in 2 weeks.(34)Although the revision surgery with replacement of the suture anchor was successful in Case 1 following elbow reluxation, different techniques could have also been employed to reinforce the anchor fixation. These would include a distal screw anchors or bone anchor on the distal insertion of the collateral ligament and replacement of the suture by orthopaedic wire. (11) This technique would provide a stronger construct with bone-to-bone anchorage and a wire instead of suture, however, soft tissue irritation from the screw with swelling, seroma, discharge and local pain have been seen in 50% of cases with screw and wire fixation. (11) An elastic transarticular external fixators could have also been used along with the replacement of the failed suture. (14) This technique provides joint stability to allow fibrosis and healing, while allowing joint mobility and avoiding complications through joint immobilisation. (14) Possible complications with this fixation are drainage and infection from the pin tracts, irritation from the blood tube stoppers, fracture of the olecranon, premature pin loosening, pin breakage and deterioration of the bands. (10, 14) External coaptation with a spica splint was chosen in this case as additional stabilisation for 3 weeks following revision surgery. This provided enough immobilisation for healing to occur, without having the complications of joint immobilisation like reduced synovial fluid production, cartilage stiffness and thickness and range of motion which occur if stabilisation lasted for longer than 3 weeks. (10, 14)In Case 3 where a follow-up was not possible, a LOAD questionnaire was used a validated tool to evaluate canine activity. (18) This questionnaire consists of questions from an initial appointment and follow-up, which are concerning the dog’s background, lifestyle and mobiltity. This questionnaire has been previously validated after being compared to other validated metronomy instrucments. (18) Other metronomic instruments for the measurement of osteoarthritis are the Canine Brief Pain Inventory (CBPI) and the Helsinki chronic pain index. (35, 36) The LOAD questionnaire was chosen in this case as a matter of preference and availability to the authors. A similar questionnaire has been validated in felines for the assessment of osteoarthritis; the Feline musculoskeletal pain index (FMPI). (37)This study has several limitations, concerning its retrospective nature, limited number of cases and follow up information. As a retrospective study the clinical information rely on the completeness of the clinical records. Diagnostic, medical and surgical management varied between clinicians and was not standardised between all cases. We are not sure if physiotherapy was advised to the owners as this was not mentioned on the clinical records. All cases were advised to come for postoperative assessment in 10 days to 6 weeks following the operation. However, the owners did not comply with all these recommendations. Follow up varied between cases; only two cases received follow up radiographs to reassess elbow reduction and implant positioning. The cases that could be re-examined only had subjective gait evaluation, which is not an objective outcome measure like force plate analysis. Long-term follow up in Case 1 was obtained by contacting the referring veterinarian and assessing the case’s medical records. We are uncertain if occasional analgesic usage in Case 1 could be related with the coxofemoral or elbow joint pain. The owner of Case 3 refused reassessment at the referral hospital and outcome was only assessed with a pre-recorded video examination and with the LOAD questionnaire which is a validated tool for assessment of locomotion. (18)To the best of our knowledge this is the first case series reporting the use of screw-in bone anchors in augmenting collateral ligament injuries following traumatic elbow luxation. We describe an uncomplicated approach and technique with good short- and long-term outcomes as well as high owner satisfaction. Further studies including larger number of cases are warranted to evaluate this technique and compare the outcome with other previously reported surgical methods of elbow stabilisation. |
| **LEARNING POINTS/TAKE HOME MESSAGES**  |
| 1. Treatment of traumatic elbow luxation can be challenging and the different treatment options have to be carefully considered , before deciding on a treatment plan.
2. Bone anchors provide another surgical treatment option for management of traumatic elbow, although further studies are needed to support their use.
3. According to the authors experience bone anchors provided a simple approach and technique with good short- and long-term outcomes as well as having a high owner satisfaction for stabilisation of traumatic elbow luxation in the reported three cases.
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| **FIGURE/VIDEO CAPTIONS**  |
| Figure 1: Craniocaudal (A) and mediolateral (B) radiographs of the right elbow joint in Case 1. Lateral elbow luxation is evident and mineralised fragments are visible in both views which are suspected small avulsion fractures (white arrows).Figure 2: Craniocaudal (A) and mediolateral (B) radiographs of the left elbow joint in Case 3. Radial head and humeroulnar subluxation are present (white arrows).Figure 3: IMEX suture anchor (A) (provided courtesy of IMEX Veterinary.Inc), and FASTak suture anchor (B) (provided courtesy of Arthrex.Inc)Figure 4: Craniocaudal and mediolateral postoperative elbow radiographs in Case 1 (A, B), 2 (C, D) and 3 (E, F). All elbows were reduced and stabilised with sutures around the bone anchor implanted on the lateral epicondyle.Figure 5: Craniocaudal (A) and mediolateral (B) radiographs of the right elbow in Case 2, seven weeks postoperatively. The elbow remains reduced with no implant complications.  |
| **TABLES CAPTION** |
| Table 1: Signalment, history, presenting complaint and clinical signs of the cases presented with elbow luxation. |
| **TABLE** |
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| **Case**  | **Breed** | **Age** | **Gender** | **Bodyweight** | **Recent history** | **Presenting complaint** | **Clinical findings** |
| **Case 1**  | Medium cross-breed | 2y 9m | Female neutered | 10.8kg | Road traffic accident 5 days prior to referral, pneumothorax treated by primary veterinarian by needle drainage | Right traumatic elbow luxation, left traumatic coxofemoral joint luxation | Normal clinical examination, normal neurologic examination, 5/5 lame right thoracic and left hind limb, abrasions of skin above the left eye, on medial right elbow and rostral upper lip |
| **Case 2** | English springer spaniel | 6y | Male entire | 19.2kg | Road traffic accident<24h prior toreferral | Right traumatic elbow luxation | Normal clinical examination, normal neurologic examination,5/5 lame on right thoracic limb, right elbow luxation easily reduced and reluxating, missing nail and abrasion on digit IV of the affected limb |
| **Case 3** | Medium cross-breed | 3y 8m | Male neutered | 13kg | Road traffic accident 4 days prior to referral | Left thoracic lameness, suspected radial head fracture | Normal clinical examination, normal neurologic examination, mild-to-moderate fully-weight-bearing left thoracic limb lameness (2/5), pain on left elbow joint, Campbell test suggestive of lateral elbow luxation: >70o pronation, small abrasions on skin on left thoracic limb |

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| **OWNER’S PERSPECTIVE**  |
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| **ACKNOWLEDGEMENTS** |
| We would like to acknowledge all the veterinary surgeons and nurses and allied professional that helped with the care of these cases. The authors are grateful for permission to use the Liverpool Osteoarthritis in Dogs (LOAD) questionnaire, a clinical metrology instrument developed by the University of Liverpool and exclusively distributed by Elanco Animal Health for the evaluation of osteoarthritis and outcome in this study. |
| **CONFLICT OF INTEREST STATEMENT** |
| None to be declared. |
| **ETHICS STATEMENT** |
| Ethical approval was provided by the local Institutional ethical review panel (VREC974). |
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