Title: Ulnar Osteotomy Decreases The Stability Of Canine Cadaver Carpi As Assessed With Stress Radiography.

Authors: Aisha N. Young, Pierre Amsellem, Tammy L. Muirhead, LeeAnn Pack, Andrea R. Matthews

Key words: Distal ulna, limb-sparing, hyperextension, varus, valgus

Running head: Stress radiography to assess ulnar osteotomy

Funding sources: Companion Animal Trust Fund, Graduate Studies and Research Committee, Atlantic Veterinary College, University of Prince Edward Island

Previous presentations or abstracts: Portions of this study were published in an abstract and presented at 2015 American College of Veterinary Radiology Annual Scientific Conference

Abstract:

Distal ulnar osteotomy may be performed palliatively in patients with distal ulnar osteosarcoma. Concurrent arthrodesis of the carpus has been proposed to counteract joint instability following transection of carpal ligaments associated with removal of the distal ulna. The objective of this prospective one group pre-test, post-test study was to assess stability of the carpus following distal ulnar osteotomy using pre- and postoperative stress radiographic views in a group of canine cadaver limbs. Seven thoracic limbs from six canine cadavers weighing more than 20 kg were obtained. Lateral and dorsopalmar, extended lateral, medial stress, and lateral stress radiographs were made before and after distal ulnar osteotomy. Pre-surgical canine cadaver carpal angle measurements were as follows (mean $\pm$ SD): extension

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1111/vru.12684](https://doi.org/10.1111/vru.12684).

This article is protected by copyright. All rights reserved.

205.9° ± 5.4; medial stress 25.1° ± 5.7; and lateral stress 13.3° ± 5.2°. Cadaver limb joint angles exceeded those previously reported in live dogs. A significant increase in carpal angle was noted following ulnar ostectomy. The mean increases in carpal angle were as follows: (mean ± SD (95% CI)): extension 6.2° ± 4.9 (2.6-9.8) (P = 0.007); medial stress 3.2° ± 3.0 (1.0-5.5) (P = 0.015); lateral stress 6.2° ± 5.2 (2.4-10.1) (P = 0.010). Findings from this cadaver study support the use of supplementary stabilization for clinical patients undergoing distal ulnar ostectomy. Future studies are needed in clinical patients to evaluate changes in limb positioning and gait associated with distal ulnar ostectomy.

Introduction:

Surgical excision of the styloid process of the ulna may be implemented in palliative treatment of distal ulnar osteosarcoma.¹ Improved understanding of the effects of distal ulnar ostectomy on carpal joint stability is important for assessing postoperative and follow-up radiographs of the surgical site as well as for differentiating between causes of lameness or joint laxity should they occur following treatment. Additionally, for clinicians making recommendations regarding treatments for distal ulnar osteosarcoma, knowledge of expected outcomes and possible side effects is necessary.

The canine carpus is a complex weight-bearing *ginglymus* (hinge) joint comprised of three joints; antebrachiocondylar, middle carpal and carpometacarpal. These joints primarily allow for flexion and extension with some lateral movement.² The antebrachiocondylar and middle carpal joints provide the most movement in the carpus.² The antebrachiocondylar joint is reinforced by extra- and intraarticular ligaments, the palmar carpal fibrocartilage (a part of the carpal joint

capsule), the flexor retinaculum, and the flexor and extensor tendons.³ The ligaments stabilizing the antebrachiocarpal joint include the short medial and lateral collateral, radioulnar, dorsal radiocarpal, palmar radiocarpal, palmar ulnocarpal (with a connection to the accessory carpal bone), and accessorio-carpoulnar.⁴ Transection of the palmar carpal ligaments (palmar radiocarpal, palmar ulnocarpal, and short collateral) individually result in hyperextension of the carpus.⁵ However, tendons crossing the palmar aspect of the carpus as well as the palmar joint capsule contribute minimally in limiting hyperextension.⁵ Additionally, in a racing Greyhound, it was reported that tears in the short lateral collateral ligament, the dorsal radiocarpal ligament and the dorsolateral portion of the joint capsule lead to lateral carpal instability and varus during weight-bearing.⁶ Normal canine carpal range of motion has been reported in non-weight bearing and weight-bearing dogs using goniometry,⁷⁻⁹ stress radiography,⁷ radiography in standing dogs,¹⁰ and in kinematic studies.^{10, 12} In stress radiography, a controlled force is applied to a joint to demonstrate any abnormal spatial relationships between its components.¹³ In addition to its use in evaluating normal range of motion, stress radiography has also been used previously to aid the diagnosis of medial or lateral carpal instability⁹ and ligamentous tears and sprains.^{6, 14} Currently, there is a lack of standardization for making stress radiographs of the canine carpus and the radiographic anatomic landmarks to be used in assessing laxity that correlate with findings from goniometric and kinematic studies. Information regarding complications associated with limb-sparing surgery of the antebrachium is prevalent but commonly refers to the distal radius and grafting procedures.¹⁵⁻¹⁸ Little literature exists addressing carpal stability following distal ulnar ostectomy. Of five dogs in an abstract evaluating peri- and postoperative complications of partial ulnectomy and pancarpal arthrodesis, all five dogs were found to use the affected limb the day after surgery; and the arthrodesis "was satisfactory in the menagement [sic] of the radiocarpal instability resulting from the removal of the ulnar styloid."¹⁹ The amount of instability in patients undergoing partial ulnar ostectomy without concurrent stabilization is not addressed in this abstract. In a study of 30 dogs with primary ulnar osteosarcoma, three were treated with partial ulnar ostectomy

including removal of the styloid process with no concurrent carpal stabilization.¹ Of these, no lameness was observed two to three months following surgery in two of the dogs, and follow-up information was not available for the third dog.¹

At the time of this study, no systematic reports on the effect of removal of the styloid process with transection of supporting ligaments on the stability of the canine carpus were found. The hypothesis for the current study was that transection of the palmar ulnocarpal ligament and short lateral collateral ligament that typically occurs during distal ulnar ostectomy will cause postoperative hyperextension and lateral instability of the carpus in a group of canine cadavers.

Materials and Methods:

Study Design and Power Analysis:

The study was a prospective, one group, pre-test, post-test design. All procedures were approved by the University of Prince Edward Island Animal Care Committee. Sample size was estimated prior to the onset of the study by conducting a power calculation from preliminary data using a power of 0.8 and sigma level of 0.05. In the pilot study, six canine cadaver limbs were used, with four being bilateral limbs from two cadavers. Mean body weight, accounting for limbs from the same cadavers, was 22.2 kg (range 19.5-27.0). All limbs without evidence of pathologic or morphologic abnormalities on palpation or radiographs were included. The differences in carpal angulation before and following distal ulnar ostectomy were as follows (mean $\pm$ SD): $3.9^\circ \pm 4.8$ in extension, $8.2^\circ \pm 4.1$ during medial stress, and $10.6^\circ \pm 7.0$ during lateral stress. Using the standard deviation from these data, it was determined that to detect a difference of 5° , eleven limbs would be required, to detect a difference of 7° , seven limbs would be required, and to detect a difference of 10° , five limbs would be required. Because of the lack

of published references and uncertainty of the clinical implications of our findings, we aimed to feasibly detect a small (5°) change in carpal angle.

Subject selection:

For the current study, cadavers of dogs weighing more than 20 kg were acquired from the Prince Edward Island Humane Society or the Atlantic Veterinary College Veterinary Teaching Hospital. These dogs had been euthanized for reasons unrelated to lameness. Clinical history was often incomplete in dogs surrendered at the humane society. Because some of the cadavers were to be used for teaching purposes, not all limbs were harvested from each dog. Dogs were excluded if they were chondrodystrophic, immature or had conformational abnormalities. All decisions to exclude cadavers based on gross and conformational findings were made by a board-certified surgeon (PA). Thoracic limbs were removed in their entirety from the thorax by transecting the extrathoracic muscles, and frozen at -21°C. Prior to ulnar ostectomy, limbs were thawed in a water bath for approximately eight hours. Limbs were examined by a board-certified surgeon (PA) for evidence of pathology and to evaluate range of motion at the elbow and carpus. Limbs were excluded from the study if pathologic or morphologic abnormalities were noted. The proximal brachium to the level of the distal humeral metaphysis was removed to facilitate data collection for a separate study.²⁰

Radiographic protocol:

Radiographs were acquired by a veterinary radiology resident (AY) with the assistance of a board-certified veterinary surgeon (PA) for stress radiographs. The humerus was stabilized with sandbags and dressing tape while radiographs were acquired. Digital radiographs were obtained (RapidStart™ Clinical Radiography System, Sound-Eklin, Carlsbad, CA and Canon

Imaging System Sensor Panel, Canon USA, Lake Success, NY) using 250 mA, 10 ms, and a kVp between 70-78, based on a radiographic technique chart and the thickness of the limb. Neutral dorsopalmar and mediolateral radiographs were made using established radiographic techniques.²¹

A metallic Kirschner wire was placed through the distal humeral metaphysis and held in place by one of the authors for stress radiographs. For stress radiographs, the radial and ulnar styloid processes were palpated and used as anatomic landmarks. For the mediolateral radiographs of the carpus in extension, the carpus was stabilized by a wooden spatula placed at the radiocarpal joint immediately distal to the styloid processes. The digits were secured with a nylon lead and the manus was manually distracted dorsally until maximum angulation was achieved (Fig. 1). Maximum angulation was defined as a point at which additional force yielded no palpable or grossly observable difference in angulation of the carpus. For the lateral and medial stress views, a wooden spatula was placed distal to the radial styloid process and ulnar styloid processes, respectively (Figs. 2 and 3A). The digits were secured with a nylon lead and manually distracted alternately medially and laterally while the carpus was stabilized with the wooden spatula. The manus was distracted until maximum angulation was achieved. Limb-positioning and application of stress on the limbs was performed by one author (AY) for consistency in technique.

Surgical protocol:

Partial ulnar ostectomies were performed by one veterinary surgeon (PA) using a previously described approach to the styloid process of the ulna.²² The osteotomy was performed immediately distal to the interosseous ligament, at 50% of the length of the ulna. The styloid process was then disarticulated and freed from its attachments. The ulnaris lateralis tendon and

flexor retinaculum were preserved. The short lateral collateral, palmar ulnocarpal, and radioulnar ligament were transected. The distal radioulnar synovial joint and the lateral aspect of the carpal joint capsule were cut during this procedure. As part of a separate study,²⁰ screws were placed at the caudal proximal aspect of the ulna, an external fixator was placed with pins placed mediolaterally through the distal humeral and distal radial metaphyses, and thin pins were placed as markers into the cranial distal radial metaphysis and the dorsal fourth metacarpal diaphysis. All but one of the surgical implants were removed prior to imaging. A pin was left in the distal humerus to aid in positioning during radiography. Following partial ulnectomy, all radiographic projections were repeated through coordination of both the radiology resident (AY) and the surgeon (PA) in the positions described for preoperative radiographs.

Data recording:

Radiographs were evaluated by a veterinary radiology resident (AY) under the supervision of one of two board-certified veterinary radiologists (AM and LP) using commercially available software (eFilm Workstation, Merge Healthcare, Mississauga, Ontario) on a designated viewing station (AlphaView liquid crystal display (LCD) MM20, Quest International, Inc., Irvine, CA, USA; Dell XPS, Dell XPS Desktop Computer, Dell Canada, North York, ON, Canada). Results were recorded in a prefabricated datasheet (Excel 2010, Microsoft, Redmond, WA, USA).

Preoperative radiographs were evaluated for signs of pathology. Limbs were excluded from the study if any radiographic orthopedic abnormalities or open physes were detected by the radiology resident (AY) or one of the board-certified veterinary radiologists (AM or LP). Images were also evaluated for proper positioning and similarity between pre- and postoperative

images. If mild obliquity was persistent on radiographs, repeat images were made to obtain a straight view of the carpus, sacrificing mild obliquity of the elbow.

Angle measurements were made by a radiology resident (ANY) in duplicate for all radiographic views. A mean of the two measurements was calculated. The methods of carpal angle measurement were slightly modified from previously published methods.⁷ On the mediolateral view, a line representing the axis of the antebrachium was drawn from the center of the humeral condyle through the middle of the distal surface of the intermedioradial carpal bone. A line representing the axis of the metacarpus was drawn parallel to the dorsal aspect of metacarpal bone III or IV; the more dorsal of the two was used to draw this line. Carpal angle was measured between the antebrachial and metacarpal axes along the palmar aspect of the limb, with a perfectly straight carpus measuring 180° (Fig. 1). On the dorsopalmar view, a line representing the axis of the antebrachium was drawn from the tip of the medial coronoid process through the tip of the radial styloid process. A line representing the axis of the metacarpus was drawn between the long axes of metacarpal bones III and IV. Carpal angle was measured between the antebrachial and metacarpal axes, with a perfectly straight carpus measuring 0° . (Fig. 2) The carpal angle was recorded as an absolute value.

Statistical analyses:

The radiology resident analysed data using statistical software (MiniTab 16, Minitab, State College, PA, USA) under the recommendation and supervision of a professor in biostatistics (HS). Data were tested for normal distribution using the Shapiro-Wilk test and a paired Student's t-test was used to compare mean pre- and postoperative carpal angles. A P-value less than 0.05 was considered significant.

Results:

Eleven canine cadavers were initially selected. Because some of the limbs were to be used for teaching purposes, not all limbs were harvested from the cadavers for the current study. In total, thirteen thoracic limbs were collected, six of which were excluded. Four limbs (two from the same dog) were excluded due to a preoperative valgus conformation, one limb was excluded for skeletal immaturity based on radiographic assessment, and one limb was excluded due to radiographic evidence of flexor enthesopathy. A total of seven limbs from six canine cadavers were used for subsequent analyses. Five cadavers were male and one was female; reproductive status was not available in all dogs. Mean body weight was 31.6 kg (range 27.0-41.0). Both thoracic limbs from one male dog and one thoracic limb from each of the remaining dogs (three right thoracic limbs and four left thoracic limbs) were sampled.

On preoperative radiographs, the carpal angle measured as follows (mean $\pm$ SD): $205.9^\circ \pm 5.4$ in extension, $25.1^\circ \pm 5.7$ during medial stress, and $13.3^\circ \pm 5.2$ during lateral stress. A significant difference was present between post- and preoperative carpal angle measurements in all three positions evaluated (Figs. 3A and 3B). The differences were as follows (mean $\pm$ SD (95% CI)): $6.2^\circ \pm 4.9$ (2.6-9.8) ($P = 0.007$) in extension, $3.2^\circ \pm 3.0$ (1.0-5.5) ($P = 0.015$) during medial stress, and $6.2^\circ \pm 5.2$ (2.4-10.1) ($P = 0.010$) during lateral stress. Radiographically measured carpal angle measurements are summarized in Table 1. A comparison between preoperative carpal angles from the current study and previously reported carpal angles from normal limbs is

provided in Table 2. A tendency was noted for supination of the carpus during medial and lateral stress radiographs, which lead to multiple repeat radiographs in some limbs.

Discussion:

Statistically significant increases in carpal angle were found in the cadaver carpi post-distal ulnar ostectomy in extended lateral, medial stress and lateral stress radiographic positions compared to preoperative angles. In our study, preoperative canine carpal angle measurements approximate previously published data; however, our carpal angles acquired from cadaver limbs are larger than those that have been found in live dogs (Table 2). Although the cause of discrepancy between current and previously published carpal angles is uncertain, we suspect that the method of carpal angle measurement and the use of cadaver limbs are likely sources of this difference.

The method of carpal angle measurement was altered slightly from previously reported methods. On the dorsopalmar radiographs, the long axis of the antebrachium has been defined as a line at the medial cortex of the radius.^{7,8} A separate report defines the axis of the antebrachium as a line bisecting the radius drawn through two points at two and six centimeters proximal to the distal radius.¹⁴ The authors felt that the mild curvature of the radial cortex would cause inconsistency in defining the antebrachial line when using the medial radial cortex as a landmark. The latter method was also not used in the current study, as it required multiple measurements that could add to variability in the data. A line drawn from the medial coronoid process of the ulna to the radial styloid process produced a similar line to those reported, and was reproducible throughout this study. In the current study, the axis of the

manus on the dorsopalmar view was drawn bisecting the space between metacarpal bones III and IV, as was reported previously.⁷ This is in comparison to using the lateral cortex of metacarpal III as a landmark as reported in another study.¹⁴ On the mediolateral view, the axis of the metacarpus has been previously defined as a line along the long axis of metacarpal bones III and IV.⁷ The authors of the current study found that the multiple overlapping cortices of the metacarpal bones obscured the long axis of the individual metacarpal bones. Moreover, the dorsal aspects of metacarpal bones III and IV were the best-defined portions of the bone, which is why they were selected to determine the axis of the antebrachium. The metacarpal bone (III or IV) that was more dorsally positioned was used as the anatomic landmark. These differences between measurement methods likely account for mild differences between previously reported and current carpal angle measurements.

Prior to performing this study, the effects of utilizing cadaver limbs compared to live patients were considered. The authors speculated there would be muscle laxity and associated tendon laxity that could lead to some carpal instability. However, the contribution of the flexor tendons and the joint capsule to joint stability has previously reported to be minimal.⁵ Consequently, such a large difference between previously reported and current preoperative range of motion was not expected. To limit post-mortem changes, cadavers were frozen immediately after euthanasia. Even so, freezing and thawing may have contributed to degradation of the soft tissues stabilizing the carpus.

Two thoracic limbs were collected from the same cadaver in one case. Because each postoperative angle was compared against the preoperative angle from the same limb there should have been no difference between values obtained from limbs from the same dog compared to values obtained from limbs of different dogs. However, there may be subtle

individual differences in the way limbs respond to surgery that were not accounted for during this study.

Lateral carpal instability might be expected in carpi following distal ulnar ostectomy because of the transection of the lateral supporting structures of the radiocarpal joint. As was reported in a racing Greyhound, tears in the short lateral collateral ligament, the dorsal radiocarpal ligament and the dorsolateral portion of the joint capsule lead to lateral carpal instability and varus during weight-bearing.⁶ In the current study, a mild but significant medial carpal instability was found in addition to the lateral carpal instability. The authors speculate that this may be due to absence of the styloid process to act as a buttress at the lateral aspect of the radiocarpal joint.

The appearance of carpal instability can change with positioning of the joint.⁶ In the case report of the racing Greyhound, lateral carpal instability was not detected using stress radiography while the carpus was extended. When the carpus was flexed 90° and the same stress was applied, marked widening of the radiocarpal joint and carpal subluxation was found.⁶ In the current study, dorsopalmar stress radiographs were made with the joint positioned at 180° (neither flexed nor extended) as has been described.²¹ Flexion of the joint may lead to radiographic distortion and miscalculation of the carpal joint angles.²³ Further investigation may be warranted to evaluate the effects of joint flexion on the amount of carpal instability detected radiographically, and the accuracy of such radiographic measurements.

In the current study, carpal stability during physiologic weight-bearing was not assessed; this data was collected as part of a separate study.²⁰ Horizontal-beam radiography is not routinely used in assessing weight-bearing joints in small animal patients. The methods used in the

present study more closely reflect radiographic techniques used for patients presented following distal ulnar ostectomy or suspected carpal laxity.

Our study has several limitations. The small sample size precluded statistical analysis of possible effects of outside factors such as sex. The number of limbs originally included in the study exceeded the amount determined by the power calculation from our pilot study; however, because of poor anatomic conformation, skeletal immaturity, and pathology, several limbs were necessarily excluded. Another limitation was the lack of a complete orthopedic history in the canine cadavers acquired for the study. Previous soft tissue injury to the carpus could have possibly caused increased joint laxity or restricted range of motion. An incomplete history was unavoidable in canine cadavers that were acquired from the local humane society. Examination of the limbs by a surgeon and radiographic examination should have minimized inclusion of cadavers with unreported orthopedic disease. The unequal distribution of male and female canine cadavers in our study as well as incomplete information regarding reproductive status in the cadavers is also a limitation. Canine cadavers that met inclusion criteria were collected chronologically as they became available. Reproductive status was unavailable in some cadavers as complete necropsies were not performed, and the bodies of the cadavers were collected for other educational purposes. Possible effects of sex and reproductive status on carpal measurements therefore remain unknown. Another limitation in our study was the mild variation in carpal positioning on radiographs. Mild obliquity of radiographs could lead to inaccuracy in joint angle measurements. Pre-determined radiographic anatomic landmarks were used in an attempt to minimize variation in positioning. These landmarks included the degree of superimposition of the radius and ulna, superimposition of the humeral epicondyles on mediolateral views, foreshortening of the accessory carpal bone on dorsopalmar views and its elongation on mediolateral views, and symmetrical spacing of metacarpal bones II through IV on dorsopalmar views as well as their superimposition on mediolateral views. When obliquity

was present, repeat images were made to obtain a straight view of the carpus, sacrificing mild obliquity of the elbow, because the carpus was our primary area of interest. Pre- and postoperative radiographs were selected for straightness as well as similarity in positioning for consistency. The mild obliquity in radiographic positioning in this study should reflect the mild variation that would likely be encountered clinically.

In conclusion, findings from the current study supported the hypothesis that distal ulnar ostectomy performed in canine cadaver limbs causes a significant decrease in carpal stability as assessed with stress radiography. These results should be considered when distal ulnar ostectomy as a limb-sparing procedure for osteosarcoma is performed in live canine patients. However, further studies of radiographically measured joint angles are warranted in live patients, as differences were found between previous established values in live patients and the cadaver limbs in the current study. The degree of radiographic laxity should also be correlated with the patient's clinical signs to determine the clinical relevance of radiographic findings. Studies using a larger number of patients may help to detect differences in the effect of this surgical procedure in sub-populations undergoing ulnar ostectomy.

Acknowledgements:

The authors would like to thank Dr. Henrik Stryhn for assistance with statistical analysis. Funding for this project was provided by the Companion Animal Trust Fund of the Graduate Studies and Research Committee at the University of Prince Edward Island.

List of author contributions:

This article is protected by copyright. All rights reserved.

Category 1

- (a) Conception and design: Young AN, Amsellem P, Muirhead TL, Matthews AR
- (b) Acquisition of data: Young AN, Amsellem P
- (c) Analysis and interpretation of data: Young AN, Amsellem P, Pack L

Category 2

- (a) Drafting the article: Young AN, Amsellem P
- (b) Revising article for intellectual content: Young AN, Amsellem P, Muirhead TL, Matthews AR, Pack L

Category 3

- (a) Final approval of the completed article: Young AN, Amsellem P, Muirhead TL, Matthews AR, Pack L

References:

1. Sivacolundhu RK, Runge JJ, Donovan TA, et al. Ulnar osteosarcoma in dogs: 30 cases (1992-2008). *J Am Vet Med Assoc*. 2013; 243:96-101.
2. Evans HE, de Lahunta A. Arthrology. *Miller's Anatomy of the Dog*. 4th ed. Ed. HE Evans, A de Lahunta. St. Louis: Elsevier. 2013. 225-298.

3. Mikic ZD, Ercegan G, Somer T. Detailed anatomy of the antebrachiocarpal joint in dogs. *Anat Rec*. 1992; 233:329-334.
4. Guilliard MJ. The nature, incidence and response to treatment of injuries to the distal limbs in the racing greyhound (Fellowship thesis for Royal College of Veterinary Surgeons). Retrieved from RCVS Knowledge. (T/736). 2012.
5. Milgram J, Milshtein T, Meiner Y. The role of the antebrachiocarpal ligaments in the prevention of hyperextension of the antebrachiocarpal joint. *Vet Surg*. 2012; 41:191-199.
6. Roe SC, Dee JF. Lateral ligamentous injury to the carpus of a racing greyhound. *J Am Vet Med Assoc*. 1986; 189:453-454.
7. Jaegger G, Marcellin-Little DJ, Levine D. Reliability of goniometry in Labrador retrievers. *Am J Vet Res*. 2002; 63:979-986.
8. Thomas TM, Marcellin-Little DJ, Roe SC, et al. Comparison of measurements obtained by use of an electrogoniometer and a universal plastic goniometer for the assessment of joint motion in dogs. *Am J Vet Res*. 2006; 67:1974-1979.

9. Tomlinson JE, Manfredi JM. Evaluation of application of a carpal brace as a treatment for carpal ligament instability in dogs: 14 cases (2008-2011). *J Am Vet Med Assoc*. 2014; 244:438-443.
10. Milgram J, Slonim E, Kass PH, et al. A radiographic study of joint angles in standing dogs. *Vet Comp Orthop Traumatol*. 2004; 17:82-90.
11. Holler PJ, Brazda V, Dal-Bianco B, et al. Kinematic motion analysis of the joints of the forelimbs and hind limbs of dogs during walking exercise regimens. *Am J Vet Res*. 2010; 71:734-740.
12. Nielsen C, Stover SM, Schulz KS, et al. Two-dimensional link-segment model of the forelimb of dogs at a walk. *Am J Vet Res*. 2003; 64:609-617.
13. Farrow CS. Stress radiography: applications in small animal practice. *J Am Vet Med Assoc*. 1982; 181:777-784.
14. Langley-Hobbs SJ, Hamilton MH, Pratt JNJ. Radiographic and clinical features of carpal varus associated with chronic sprain of the lateral collateral ligament complex in 10 dogs. *Vet Comp Orthop Traumatol*. 2007; 20:324-330.

15. Hodge SC, Degner D, Walshaw R, et al. Vascularized ulnar bone grafts for limb-sparing surgery for the treatment of distal radial osteosarcoma. *J Am Anim Hosp Assoc.* 2011; 47;98-111.
16. Liptak JM, Dernell WS, Straw RC, et al. Intercalary bone grafts for joint and limb preservation in 17 dogs with high-grade malignant tumors of the diaphysis. *Vet Surg.* 2004; 33:457-467.
17. Séguin B, O'Donnell MD, Walsh PJ, et al. Long-term outcome of dogs treated with ulnar rollover transposition for limb-sparing of distal radial osteosarcoma: 27 limbs in 26 dogs. *Vet Surg.* 2017; 46:1017-1024.
18. Straw RC, Withrow SJ. Limb-sparing surgery versus amputation for dogs with bone tumors. *Vet Clin North Am Small Anim Pract.* 1996; 26:135-143.
19. Massari F, Romanelli G. Limb sparing for distal ulnar osteosarcoma with ulnectomy and pancarpal arthrodesis: 5 cases. In: Proceedings from the 18th Annual Scientific Meeting for the European College of Veterinary Surgeons; July 2-4, 2009; Nantes, France.
20. Amsellem PM, Young AN, Muirhead TL, et al. Effect of distal ulnar ostectomy on carpal joint stability during weight bearing in the dog. *Vet Surg.* 2017; 46:1154-1160.

21. Brown M, Brown LC. Small animal forelimb. *Lavin's Radiography for Veterinary Technicians*, 5th ed. St. Louis: Elsevier. 2014. 223-248.
22. Piermattei DL, Johnson KA. The forelimb. *An Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat*. 4th ed. Ed. DL Piermattei, KA Johnson. Philadelphia: Elsevier. 2004. 149-276.
23. Piras LA, Peirone B, Fox D. Effects of antebrachial torsion on the measurement of angulation in the frontal plane: a cadaveric radiographic analysis. *Vet Comp Orthop Traumatol*. 2012; 25:89-94.

Table 1. Carpal Angle Measurements of Seven Canine Cadaver Limbs During Stress Radiographs.

	Preoperative	Postoperative	Difference[^]	P-value	CI
	mean° (SD)	mean° (SD)	mean° (SD)		
Extension	205.9 (5.4)	212.1 (4.9)	6.2 (4.9)*	0.007	2.6-9.8
Medial stress	25.1 (5.7)	28.3 (4.0)	3.2 (3.0)*	0.015	1.0-5.5
Lateral stress	13.3 (5.2)	19.5 (3.1)	6.2 (5.2)*	0.010	2.4-10.1

Notes. [^]difference between pre- and post-ulnar ostectomy carpal angles; *significant difference; CI, 95% confidence interval; SD, standard deviation

Table 2. Comparison of Current and Previously Reported Carpal Angle Measurement in Normal Limbs of Dogs Assessed Using Stress Radiography and Goniometry.

Conscious State	Demographic Information	n	Method of Measurement	Measured Parameter	Flexion (°)	Extension (°)	Medial Stress (°)	Lateral Stress (°)	Reference
Post-mortem	Surrendered, adult, mixed-breed	7	radiography	mean (SD)	____ —	205.9 (5.4)	25.1 (5.7)	13.3 (5.2)	Current study
General anesthesia	Healthy, adult, German shepherd	1 2	radiography	mean (SD)	____ —	195 (5)	____ —	____ —	⁸
Sedated	Healthy, adult, Labrador retriever	1 6	goniometry ^a	mean (SD)	32 (2)	196 (2)	12 (2)	7 (1)	⁷
Not reported	Healthy limbs*, adult, breed not specified	1 4	goniometry	median (range)	30 (30-45)	195 (190-200)	15 (15-25)	15 (15-25)	⁹

Non-sedated	Healthy, age not specified, mixed-breed	1	standing	mean	_____	193.66	9.57	_____	10
		7	radiograph	(SD)	—	(5.70)	(3.76)	—	
			y~						

Notes. ^no significant difference was found between goniometric and radiographic measurements; however radiographic measurements were not

reported; *contralateral limbs of adult dogs with medial or lateral unilateral carpal instability and no other evidence of orthopedic disease;

~measurements were extrapolated based on the different angles measured in this study compared to the current study; -----information not available

Figure 1. Mediolateral radiograph of a canine cadaver carpus in a hyperextended position. A line was drawn from the center of the humeral condyle through the middle of the dorsopalmar length of the distal aspect of the intermedioradial carpal bone to represent the axis of the antebrachium. A second line was drawn parallel to the dorsal aspect of either metacarpal bone III or IV; whichever was more dorsally positioned. This second line represents the axis of the

metacarpus. Carpal angle was measured between the antebrachial and metacarpal axes along the palmar aspect of the carpus along the curved line.

Figure 2. Dorsopalmar lateral stress radiograph of a canine cadaver carpus. A line was drawn from the tip of the medial coronoid process through the tip of the radial styloid process,

representing the axis of the antebrachium. The dotted line is parallel to the axis of the antebrachium, and is included in this image to demonstrate the carpal angle (but was not drawn for the purposes of this study). A second line was drawn between the long axes of metacarpal bones III and IV, representing the axis of the metacarpus. Carpal angle was measured between the antebrachial and metacarpal axes along the curved line.

Figure 3. Comparison between dorsopalmar radiographs of a canine cadaver carpus pre-ulnar ostectomy (A) and post-ulnar ostectomy (B) showing a difference in the angle of the carpus during medial stress. In this limb, an angle difference of 3.5° was found.

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Young, AN;Amsellem, P;Muirhead, TL;Pack, L;Matthews, AR

Title:

Ulnar ostectomy decreases the stability of canine cadaver carpi as assessed with stress radiography

Date:

2019-01-01

Citation:

Young, A. N., Amsellem, P., Muirhead, T. L., Pack, L. & Matthews, A. R. (2019). Ulnar ostectomy decreases the stability of canine cadaver carpi as assessed with stress radiography. VETERINARY RADIOLOGY & ULTRASOUND, 60 (1), pp.19-27. <https://doi.org/10.1111/vru.12684>.

Persistent Link:

<http://hdl.handle.net/11343/284480>