Considerations on the Pathophysiology of Canine Condylar Fractures by Finite Element Analysis

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Introduction: Condylar humeral fractures are classified as medial, lateral or bicondylar (Y-T) fractures and are believed to be associated with minor, indirect trauma, predominantly in immature dogs. It is believed that these fractures occur in extension of the elbow by proximal translation of the radius[1].

Objective of the study: The objective of this three-dimensional finite element analysis was to confirm the pathogenesis of condylar fractures, to determine the influence of bone positioning on fracture type and to evaluate the intraosseus stress distribution before fracturing.

Materials and Methods: Based on computer tomographic scans (n=6; two right forelimbs, Beagle, 4 months of age, male, 7-7,5 kg, scans in -10°,0° and +10° of endo-/exorotation; 1mm sections) finite element analysis was performed[2,3] (n=3) to create a three-dimensional model of the canine elbow, simplified by considering the unit of radius and ulna as a rigid body. Trabecular (Young's Modulus E= 775 MPa, Poisson's Ratio V= 0,3) and cortical (E= 3 GPa; V= 0,3) humeral bone[4] were both considered isotropic and homogenous. In this study, cartilage was not considered. Bone contact, stress-strain distribution within the distal humerus before fracture and failure mode as highest intraosseus stress distribution were reported in 60°, 130° and 150° of flexion- extension angle (FEA), abduction- adduction angle (AbAdA) of -20°, 0° and +20° and in -10°, 0° and +10° of radioulnar endo-/exorotation angle (RA) (see Fig.1).

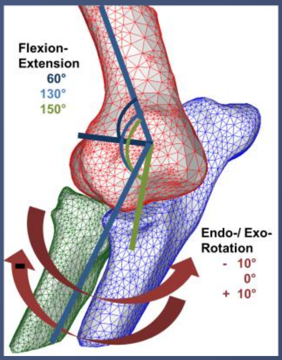

Fig.1. Illusttration of the FEA and RA used.

FEA	AbAdA	RA	Bone contact to	Fracture Type
60	0	0	Ulna	Lateral
60	-20	0	Ulna	Lateral
60	20	0	Ulna	Medial
130	0	0	Ulna	Medial
130	-20	0	Radius+Ulna	Lateral
130	20	0	Ulna	Medial or Y
150	0	0	Radius+Ulna	Medial
150	-20	0	Ulna	Lateral
150	20	0	Ulna	Medial
60	0	10 endo	Ulna	Y
60	-20	10 endo	Ulna	Y or Lateral
60	20	10 endo	Ulna	Medial
130	0	10 endo	Radius	Lateral
130	-20	10 endo	Radius	Lateral
130	20	10 endo	Radius+ Ulna	Y ou Medial
150	0	10 endo	Ulna	Lateral
150	-20	10 endo	Ulna	Lateral
150	20	10 endo	Ulna	Y
60	0	10 exo	Ulna	Lateral
60	-20	10 exo	Ulna	Lateral
60	20	10 exo	Ulna	Lateral
130	0	10 exo	Radius	Lateral
130	-20	10 exo	Radius	Lateral
130	20	10 exo	Radius	Lateral
150	0	10 exo	Radius	Lateral
150	-20	10 exo	Radius	Lateral
150	20	10 exo	Radius	Lateral

Tab.1. Tested conditions in different FEA, AbAdA and RA.: stress-strain dependent expected fracture type of the humerus and the contributing bones.

Results:

In contrast to the hypothesis that the radial bone would be the interacting structure, the humeroulnar interaction is clearly dominant, less often radius and ulna are both interacting. In 60°FEA, the interacting bone is always the ulna, independent of AbAdA and RA.

Abduction/ Adduction of the elbow at the time of trauma seems to be an important influence on fracture type. At an AbAdA of –20°, the fracture type suspected is always a lateral condylar fracture, independent of FEA and RA. With exclusion of exorotation studies, at an AbAdA of 20° mostly medial or complex fractures, equally distributed, are expected. Endo- and exorotation of the radioulnar bones additionally influences the stress-strain distribution within the distal humerus. In exorotation all humeral fractures are expected to be lateral condylar fractures, independend of FEA and AbAdA. In endorotation humeral fractures are expected to be lateral condylar fractures when +20° of AbAdA are excluded. See tab.1 and examples given in Fig. 2.

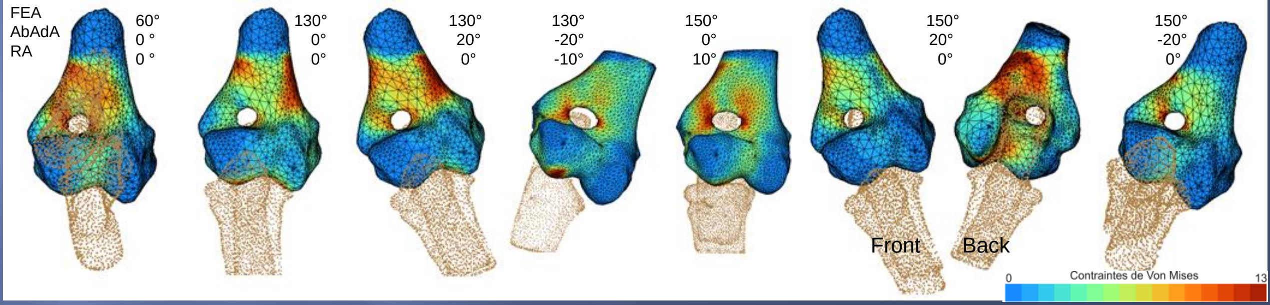

Fig.2. Examples for stress-strain distribution within the distal humerus at various FEA, AbAdA and RA.

Conclusion:

Condylar fracture pathogenesis is more complex than described in the literature. They may not only occur in elbow extension as previously reported. The ulna may even play a more important role in condylar fracture pathogenesis then the radius. Additionally fracture type may be sensitive to bone positioning during trauma. The suspected fracture type is sensitive to abduction-adduction as well as radioulnar endo-/exorotation.

References: [1] Knight,G. Internal fixation of the fractured lateral humeral condyle. Veterinary Record 71, 667-668. 1959. [2] d'Otreppe Vinciane, Boman Romain and Jean-Philippe Ponthot. Smooth multiple-region mesh generation for biomedical applications. *ECCM 2010, 4th European Conference on Computational Mechanics. Paris,* 16-21 May 2010. [3] METAFOR, finite element software . *http://metafor. ltas. ulg. ac. be*. [4] Polikeit,A., Ferguson,S.J. & Schawalder,P. 2007. [4]Ellbogendysplasie beim Hund: Finite-Elemente-Analyse / Elbow dysplasia in the dog: finite element analysis. *Biomedizinische Technik/ Biomedical Engineering* **52,** 308-314.