

# PROCEEDINGS

## 31<sup>th</sup> annual meeting of the INTERNATIONAL ELBOW WORKING GROUP



August 30<sup>th</sup> 2017  
EVDI congress, VeronaFiera  
Verona, Italy.

## Welcome to the 31<sup>st</sup> meeting of the I.E.W.G.!

It is a great honour for the board of the International Elbow Working Group (IEWG), that the congress committee of the European Veterinary Diagnostic Imaging (EVDI) invited the International Elbow Working Group to organize its annual meeting in conjunction with that of the EVDI in Verona, Italy.

The IEWG has been founded in 1989 by a group of veterinarians and dog breeders with a concern about ED. The purpose of the IEWG is to gather and exchange knowledge and experiences about hereditary elbow diseases in dogs regarding hereditary aspects, aetiology, diagnosis, and prevention as well as screening of elbows of dogs. All these aspects of concern of the IEWG are directed to diminish the incidence of the developmental disturbances of the elbow joint in growing dogs in an increasing amount of dog breeds, with a great impact on the quality of life for both the patient and its owner. Therefore the World Small Animal Veterinary Association (WSAVA) recognized the IEWG as an affiliated group of the WSAVA since 2001.

The role of radiology and veterinary radiologists in the founding of the IEWG is nicely demonstrated on the iconic picture (visible on the web page of IEWG: <http://www.vet-iewg.org/about/>) with famous, international radiologists as Prof. Marc Flückiger (Switzerland), Prof. Lida Wind (USA), Dr. Lars Audell (Sweden) together with others who founded the IEWG. Prof. Paul W. Poulos, radiologist and bone pathologist who worked in Sweden, The Netherlands and California, and who has been the president of IEWG in the late 90's of last century, and Dr. Bernd Tellhelm radiologist at Giessen University (Germany) and treasurer of the IEWG for 16 years demonstrate the close connection between IEWG and specialized radiologists.

It is with gratefulness that the IEWG put together a program especially dedicated to update radiologists with a variety of aspects of direct importance to their speciality and daily work, regarding elbow dysplasia. We are lucky to be able to present a program with the help of an international group of experts in their field who all responded enthusiastic to inform the audience of radiologists about their specific experiences.

The first speaker will be Dr Ingrid Gielen (Belgium), staff radiologist of Ghent University who will present a integrated overview of all relevant imaging techniques for elbow joint abnormalities she published about in the past 15 years in international journals. The next speakers will present imaging results on the fragmented coronoid process development in a group of Labrador puppies during their first 6 months of life, investigated by radiology, macro and micro CT-scanning, and eventually histology. These results are recently published in the thesis of Seng Fong Lau, a radiologist from Malaysia University who dedicated 4 years at the Radiology Department of Utrecht University to study the etiological aspects of FCP and the value of radiology and CT investigation in immature dogs. These findings are of increasing relevance for radiologists in response to breeders and organisations who want to have an early selection of their dogs.

After the break Dr Aldo Vezzoni, a well appreciated small animal surgeon from Cremona (Italy) who is not only a well-respected and honoured surgeon in the veterinary world, but also active in screening of hereditary skeletal diseases in his country. Dr Vezzoni will not tell the radiologists how to perform specialized elbow surgery, but he will highlight which specific aspects are pre- and postsurgical of importance to visualize and to recognise, and to report to the surgeon and the dog owner. Next speaker is Dr. Reunanen, from the Department of Veterinary Clinical Diagnostics of the Faculty of Veterinary Medicine, from Helsinki who is an expert in population genetics and will inform the radiologists the purpose of screening and the goals which have been reached so far to improve the dog population. Dr Tellhelm and Dr Ondreka, both Diplomates the ECVDI, and both from Giessen (Germany) and both well respected active members of the IEWG, will give a dual presentation on the use of the grading scheme as introduced by IEWG and amended over the years several times after input of IEWG participants. Standard cases and not so standard cases will be discussed with the participants of the meeting, to come to a final IEWG scoring as is now widely in use in by screening authorities of the FCI, Kennel Club, and AKC. Finally Dr Von Pückler, will present a proposal of the IEWG to screen CT-scans in those cases where CT scanning is offered by breeders and professional breeding organizations like Schools for the Blind, but also required when owners are in appeal for results of routine screening. Dr Von Pückler is staff radiologist at Giessen University and a well-known and highly appreciated speaker at IEWG-meetings. A practical approach with standardized form will be presented to inform the international radiologists community.

Also on behalf of the other board members of the International Elbow Working Group, Dr. K.L. How secretary and Dr. B. Tellhelm treasurer, I like to thank the IEWG-speakers who were so kind to spend their precious time in preparing the lecture and the proceedings text, and to travel to the beautiful city of Verona. We wish all participants a fruitful IEWG meeting and EVDI congress.

Prof. dr. H.A.W. Hazewinkel, DECVS, DECVCN  
President I.E.W.G.

Also on behalf of the other board members of the IEWG, Dr. B. Tellhelm and Dr. K.L. How, I thank the speakers who were so kind spending their precious time to prepare and present a lecture



# International Elbow Working Group Annual Meeting

**ECDI annual meeting,  
August 30<sup>th</sup> 2017,  
Verona, Italy.**

Chairperson: Prof. Dr. H.A.W. Hazewinkel

09.00 – 09.15	Welcome H.A.W. Hazewinkel, president IEWG
09.15 – 10.00	Different imaging modalities in ED; what is their specific added value? <u>I. Gielen</u> , A. Villamonte-Chevalier, B.J.G. Broeckx, H. Van Bree
10.00 – 10.20	Early development of FCP and the value of radiology and CT to detect FCP. <u>H.A.W. Hazewinkel</u> , S.F. Lau.
10.20 – 10.45	Radiographic and CT assessment of postnatal development of antebrachia and elbow joints in Labrador Retrievers. <u>S.F. Lau</u> , H.A.W. Hazewinkel, G. Voorhout.
10.45 – 11.00	Break
11.00 – 11.45	Radiographic evaluation before and after elbow surgery. A. Vezzoni.
11.45 – 12.15	Breeding against elbow dysplasia-BLUP indexes. V. Reunanen.
12.15 – 12.35	Explanation of grading according to IEWG and discussion of cases. <u>N. Ondreka</u> , B. Tellhelm.
12.35 – 13.00	Proposal IEWG CT-protocol. K.H. von Pückler.
13.00	Closure of the IEWG session.

# List of speakers

**Dr. I. Gielen**, DVM, PhD, MSc,  
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# Different imaging modalities in ED; what is their specific added value?

**I. Gielen**<sup>1</sup>, A. Villamonte-Chevalier<sup>1</sup>, B.J.G. Broeckx<sup>2</sup>, H. van Bree<sup>1</sup>

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The diagnosis of elbow dysplasia (ED) in lame dogs is made from a combination of clinical signs, palpation of the joints, and medical imaging. A wide range of imaging options are now available but the “perfect” imaging protocol does not exist because each modality has his strengths and limitations.

Although radiography is still the standard technique for diagnosing elbow disorders in the dog, other imaging techniques like scintigraphy, ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) can be useful.

In diagnosing ED there are two different issues: there is the need for selecting ED free breeding stock and there is the diagnosis of the condition in the individual patient presented for forelimb lameness. For selection purposes, most of the time the secondary degenerative joint (DJD) changes are scrutinised by means of radiographs and mostly the individuals are not suffering lameness. For the individual patient the early diagnosis of the primary lesion is very important because an early treatment guarantees a better prognosis. Although the most important cause of elbow lameness in dogs is medial coronoid disease (MCD), recently flexor enthesopathy (FE) has been recognized as an elbow disorder in medium and large breed dogs and is characterized by lesions of the medial epicondyle and the attaching flexor muscles. The differential diagnosis between both elbow disorders is not obvious and a combination of these two elbow diseases is possible. The challenge in these cases is to define the cause of the elbow pain in order to make the correct treatment decision. In both, MCD and FE, the radiographic features may be minimal and indistinct. A recent study, compared radiographic, CT and arthroscopic findings in a population of 90 dogs that presented with elbow lameness. Three standard radiographic views (lateral extension, lateral flexion and a 15° oblique cranio-medial caudo-lateral) when compared with CT presented a sensitivity of 97% and a specificity of 64%. In another recent study in 424 elbows screened for ED, the sensitivity and specificity were 65% and 93% respectively. Based on these results radiography remains a good imaging tool for screening purposes, however in cases where radiographic signs of MCD are not clear; CT remains as the imaging technique of choice.

In cases where the clinical examination is not providing a clear localisation or in case of uncertain radiographic findings, scintigraphy is a useful technique to localise the cause of lameness. Although it is very sensitive, it is not very specific and the spatial resolution offered, is not well enough to specify anatomic structures. A micro-single photon emission tomography ( $\mu$ -SPECT) technique has been described. HiSPECT has a much higher resolution and allows better differentiation of the anatomical areas in the elbow joint. A major drawback to joint imaging by scintigraphy is the normal uptake at the end of long bones, especially in immature animals. In some instances it is difficult to determine whether a difference in counts between two joints represents a meaningful finding. Comparison of bilateral images, acquired over the same time, and quantitative analysis of joint images by computer can provide diagnostic guidelines. In cases of flexor enthesopathy (FE), HiSPECT, reveals focal increased bone tracer uptake in the region of the medial humeral epicondyle.

Ultrasound (US) is a potential valuable imaging technique of the musculoskeletal system in small animals. High frequency linear transducers are used because of their flat application

surface and high resolution power. Accurate examination of joints requires substantial ultrasonographic experience and a standardised examination procedure. In most of the joints even small amounts of fluid accumulation (hypo- to anechoic) can be easily demonstrated in the area of the joint pouches. Although a thorough US study of the normal elbow joint has been conducted, US is only of limited use in the diagnosis of a fragmented coronoid process. Only large displaced fragments can be diagnosed with certainty. Also US is helpful in diagnosing flexor tendon pathology. The main ultrasonographic findings of flexor enthesopathy are pre-insertional hypoechoic swelling, outward bowing and thickening of the common tendon of the flexor muscles. The tendon appears to be heterogeneous with decreased echogenicity and focal or diffuse areas of irregular fibrillary appearance and ill-defined margins with partial or complete tears. Additionally cortical irregularities at the medial epicondyle (spur formation) and intratendinous calcifications can be detected.

Computed Tomography (CT) can help significantly in establishing a definite diagnosis. The positioning of the patient is very important and CT of both elbow joints extended with the head pulled back outside the gantry results in better quality images and less artefacts. A recent study was performed, where lateral positioning (with both thoracic limbs extended symmetrically cranially and the head pulled back out of the gantry) was compared with sternal positioning. Results demonstrated that on lateral recumbency less artefacts appear on the images, on the other hand images from sternal recumbency presented in most cases streak artefacts. Moreover, the quality of images (differentiation between cortical and subchondral bone, bone structures contours) was superior on images obtained on lateral recumbency. Lateral positioning is in general more reliable when it comes to image quality and absence of artefacts which is highly significant in the accurate detection of discrete lesions. The scan parameters kV and mA should be high and thin slices with an overlap are preferred. Images should be obtained in bone algorithm and proper windowing during the evaluation of a study is a necessity. The modality of multiplanar reconstructions in different planes is useful in order to evaluate the complete joint surface. Abnormalities in the area of the medial coronoid process include: fragmentation (displaced or nondisplaced), fissure, abnormal shape, sclerosis, osteophytes, and lucencies.

A recent study attempts to make objective the measurement of sclerosis. By means of CT, and specific regions of interest measurements, sclerosis can be evaluated in a reproducible way. The findings of this study suggest that an increase or a decrease of values of HU and bone density (BD) can be associated with the presence of elbow pathology. In particular that an increase in HU and BD values in regions such as the MCP base and MCP apex would be related to MCD. In the area of the medial humeral condyle sclerosis, lucency, and/or flattening can be evaluated and a differential diagnosis between kissing lesions and real OCD lesions can be made. All these abnormalities can be diagnosed on the transverse and reconstructed images. In several cases CT findings, like fissures at medial coronoid process and subchondral lucencies at medial humeral condyle, were useful for decision making in the arthroscopic treatment of these lesions.

A recent study shows that CT is a very reliable technique to evaluate fragmented coronoid process with a sensitivity and specificity of over 90% when compared to arthroscopy; whereas, the methods showed an almost perfect agreement ( $\kappa = 0.959$ ) between CT and arthroscopy which is still considered to be the "gold standard". Ununited anconeal process with or without humeroulnar incongruity can be appreciated and the incidence of incongruities of the humeroradial, humeroulnar, and/or radioulnar joints can be accurately appreciated. On transverse CT slices, at the level of the trochlear notch of the ulna and the humerus, the fitting of the joint space can be noticed. On the reconstructions in the sagittal and dorsal plane, at the level of the trochlea humeri and the lateral compartment the incidence of a step between the ulna and radial head, the shape of the trochlear notch and the fitting of the humeral condyle in the trochlear notch can be evaluated. In cases of FE, the medial epicondyle appears sclerotic and shows a clear periosteal reaction in all cases. Mineralized opacities can be present within the flexor tendons. CT also shows concomitant lesions like coronoid disease

whenever present. The soft tissue studies presents a thickening of the involved tendons and IV administration of contrast shows enhancement in the affected tendons and fluid pockets can easily be visualised. Arthro-CT can be used to evaluate loss of cartilage in cases of medial compartment syndrome.

Magnetic Resonance Imaging (MRI) has limitations for imaging the canine elbow based on the relatively small size of the joint and complex articulations in conjunction with the thin articular cartilage surfaces of the humerus, radius, and ulna. These limitations depend also of the field strength of the MR device. All MRI planes, dorsal, sagittal, and axial/transverse, are potentially useful for diagnosis of elbow disorders. The incidence of subchondral bone pathology and oedema can be diagnosed. This technique offers a great visualisation of the soft tissues around the elbow joint and in cases of pathology within the flexor tendons its application can be very useful. On Magnetic Resonance Imaging (MRI), the sagittal T2-weighted sequence reveals a hyperintense signal around the proximal aspect of the flexor muscles extending in the muscle bellies. This signal can be confirmed as being a fluid signal on the fat suppressed STIR sequence. The T1 and T2 studies showed a thickening and irregular delineation of the involved tendons. There is obvious enhancement on T1 contrast studies.

As well as providing valuable diagnostic information about the elbow, arthroscopy also allows minimally-invasive treatment of coronoid disease. It allows us to obtain a magnified panoramic view of the inside of a joint. The drawback of arthroscopy is that it only allows the inspection of the articular surface. The combination of CT and arthroscopy allows a more complete diagnosis of ED. In cases of FE, arthroscopy shows the presence of loose fibres, degenerated tendinous tissue, cartilage loss and/or local synovitis at the attachment of the flexor muscles to the medial humeral epicondyle.

### **Suggested reading:**

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The early development of medial coronoid disease in growing Labrador retrievers: Radiographic, computed tomographic, necropsy and micro-computed tomographic findings.  
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A. Villamonte-Chevalier, W. Dingemanse, A. Van Caelenberg, B. Broeckx, H. van Bree, I. Gielen. 2016. Bone density of elbow joints in Labrador retrievers and Golden retrievers: Comparison of healthy joints and joints with medial coronoid disease. *Veterinary Journal*, 2016, 216, 1-7.

A. Villamonte Chevalier , H. van Bree , B.J.G. Broeckx , W. Dingemanse, I. Gielen. 2016. Agreement between radiography and computed tomography for medial coronoid disease in the screening of 424 canine elbow joints. 6th CT-User Meeting, 2nd International Veterinary CT-User Meeting, Ghent University-DVG, 9-10 December 2016, Ghent, Belgium. p 155. Manuscript submitted for publication.

# Early development of FCP and the value of radiology and CT to detect FCP

**H.A.W. Hazewinkel<sup>1</sup> and S.F. Lau<sup>2</sup>.**

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## **Post-natal development of the medial coronoid process**

In the juvenile skeleton secondary ossification centers can be recognized in the distal humerus and proximal radius and ulna, including the lateral and medial part of the humeral condyle which fuse with each other at the age of 16 weeks, and the anconeal process which fuses with the olecranon before the age of 5 months (Voorhout and Hazewinkel, 1987). The anconeal process develops by apposition, by a separate ossification center, or by a combination of both (Breit et al., 2004). It has been reported by Fox et al (1983), Guthrie et al (1992), Wolschrijn et al (2004, 2008) Breit et al (2004, 2005) that the medial coronoid process develops exclusively by appositional ossification. Fusion of the medial coronoid process is completed when the process of endochondral ossification of the cartilaginous anlage is completed. The age of fusion of the secondary ossification centers varies in dogs of different breeds: the ossification of the coronoid process is completed at 16 weeks in small breed dogs and at 20 weeks (in large breed dogs) (Breit et al., 2004), since growth regulators differ between breeds and thereby influence growth rate (Tryfonidou et al, 2010). Research results revealed that complete ossification of secondary ossification centers differs within litters, but not by gender (Hare, 1961).

The medial plus lateral coronoid process bear 20-25% of the weight executed by the humerus on the elbow joint (Berzon & Quick, 1980, Sjöström 1998). Wolschrijn & Wijs (2004) demonstrated with micro-CT that bone density in the medial coronoid process increased from 8 weeks onward, with orientation of the trabeculae both toward the humero-ulnar joint surface and to the attachment of the annular ligament; this indicates functional adaptation of the medial coronoid process to weight bearing and ligamentous tensile forces starting at this young age.

## **Pathogenesis of fragmented coronoid process**

For the possible etiology for FCP the following factors can be considered: (1) disturbance of endochondral ossification of the cartilaginous template of the coronoid process and/or its subchondral bone, and/or (2) excessive mechanical loading on the developing medial coronoid process.

Endochondral ossification includes the process of chondrocyte proliferation, differentiation, maturation and eventually apoptosis together blood vessel ingrowth, and with matrix mineralization and replacement by bone. In the first publications reporting about the fragmented coronoid process (FCP) in dogs by Targari (1974) and Olsson (1981) the relationship between FCP and osteochondrosis (i.e., disturbance of the process of endochondral ossification) has been suggested. The process of endochondral ossification can be disturbed by failure of blood supply (Ytrehus et al, 2004), by nutritional and hormonal delay of chondrocyte differentiation in case of overfeeding (Hedhammar et al, 1974), calcium excess (Hazewinkel 2010), or vitamin D excess (Tryfonidou et al, 2003). Chondromalacia as described in cases of medial coronoid disease, and revealing softening on probing of the joint cartilage is due to chondronecrosis of the subchondral bone due to failure of blood supply (Wolschrijn et al, 2005; Mairee et al, 2014). In most advanced cases of osteochondritis dissecans, i.e. osteochondrosis of joint cartilage, a focal area of bone necrosis is bordering the thickened or detached cartilage, thus indicating that necrosis is secondary.

(2) Microcracks in the subchondral bone at the fragmentation site filled with fibrous tissue, indicating a fibrous non-union between the FCP and the remaining coronoid process (Danielson et al, 2006). The mean bone mineral density revealed 50% lower at the axial border of the medial coronoid than at the abaxial border, predisposing the microcracks at the axial side (Burton et al, 2010). Disparity in the length of radius and ulna, as known entity in Bernese Mountain dogs (Lavrijsen et al, 2012), causes impairment of mechanical loading of radius and ulna with overloading of the ulna (Samoy et al, 2006). Underdevelopment of the trochlear notch, as known entity in German Shepherd dogs (Wind, 1986), can cause pressure on both the coronoid process and the anconeal process, explaining the occurrence of UAP and FCP in the same dog (Meyer-Lindenberg et al, 2003). In addition the following aspects can play a role in overloading the affected area: physiological incongruity (House et al, 2009) during weight bearing, increased tensile forces during pronation (Wolschijn et al, 2004), repeated shear stress between the contact area of the proximal radial head and the axial border of the medial coronoid process during pronation and supination (Hulse, 2010), the latter possibly increased at the ulnar radial incisure by the biceps brachii/brachialis muscle complex during supination (Fitzpatrick and Yeadon, 2009). This incisure is often irregular on CT pictures of the radioulnar joint in case of a proven fragmented coronoid process, although it should be realized that only the subchondral bone contour can be made visible on CT-scanning of the elbow joint.

A difference in the rate of the process of endochondral ossification, (either as breed characteristic or as part of a pathological process due to non-genetic factors as nutrition), in combination with relative over-loading due to hyperactivity, radio-ulnar incongruity of increased tensile forces can be the combined etiological background of the fragmented coronoid process.

Additional reading:

The interested reader is referred to the article "Delayed endochondral ossification in early medial coronoid disease: a morphological and immune-histochemical evaluation in growing Labrador retrievers by S.F. Lau, H.A.W. Hazewinkel, G.C.M. Grinwis, C.F. Wolschrijn, M. Siebelt, J.C.M. Vernooij, G. Voorhout, M.A. Tryfonidou in *Vet J* 2013 Sep;197(3):731-738

A short summary will follow:

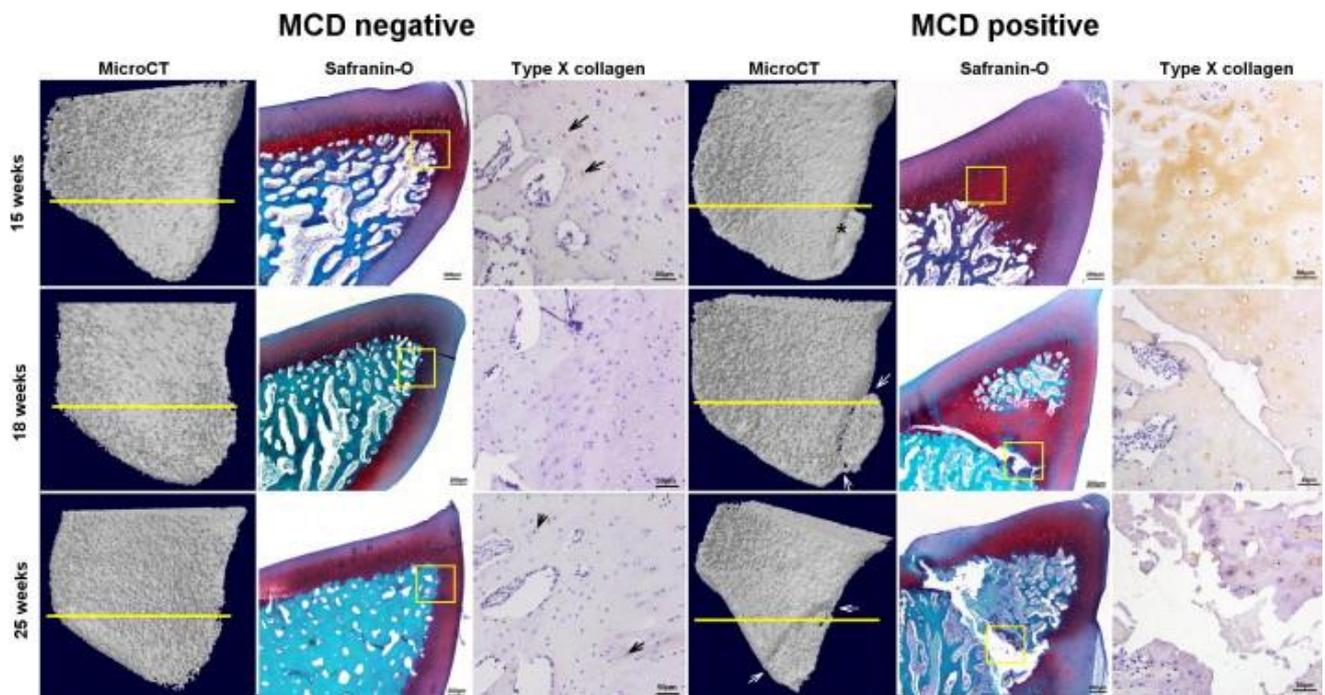
Three litters of MCD-prone young Labrador retrievers were purpose-bred from a dam and two sires with MCD. Comparisons of the micro-morphological appearance of the medial coronoid process (MCP) in MCD-negative and MCD-positive joints demonstrated that medial coronoid disease (MCD) was initially associated with a disturbance of endochondral ossification, namely a delay in the calcification of the calcifying zone, without concurrent abnormalities in the superficial layers of the joint cartilage. Cartilage canals containing patent blood vessels were only detected in MCD positive and MCD-negative dogs younger than 12 weeks old. Retained hyaline cartilage might ossify as the disease progresses, but weak areas can develop into cracks between the retained cartilage and the subchondral bone, leading to cleft formation and fragmentation of the MCP (see MCD positive dogs at 18 and 25 weeks).

Legend to figure 1:

Comparison of the proximal view of 3-D reconstructed micro-computed tomography (microCT) images of the medial coronoid process (MCP) with corresponding (cut at yellow line) safranin-O and type X collagen staining in medial coronoid disease (MCD)-negative and -positive joints obtained from dogs aged 15, 18 and 25 weeks. In the MCD-negative group, histologically, the lateral aspect of the medial coronoid process (latMCP) of dogs at 15, 18 and 25 weeks of age had a normal appearance, with articular cartilage covering the subchondral bone layer. In the MCD positive group, an MCP from a 15-week-old dog shows a 'fissure' (\*). MCPs from 18- and 25-week old dogs show 'fragmentation' (white arrows). Histologically, the latMCP of a 15-week-old dog showing evidence of retained

hyaline cartilage and of an 18-week-old dog showing an island of trabecular bone within the area of retained hyaline cartilage and a cleft separating the retained hyaline cartilage from the underlying bone. The latMCP of a 25-week-old dog showing a cleft separating the trabeculae from the rest of the bone. In the MCD-negative group, type X collagen staining from the area in the yellow box was found at the calcifying zone and stained in a pericellular pattern (arrows) in 15- and 25-week-old dogs. Type X collagen was not detected in the 18-week-old dog. In the MCD-positive group, type X collagen showed a pericellular and intercellular staining pattern; the retained hyaline cartilage and cartilage along the cleft also stained positive for type X collagen.

Illustration from thesis "Development of medial coronoid disease in Labrador retrievers, diagnostic and pathogenic studies" by Seng Fong Lau, 2013, Utrecht University.



CT findings were confirmed by the microCT studies, indicating that signs of MCD developed as early as 14 weeks in the Labrador retrievers studied. The combination of necropsy and microCT findings indicated that MCD only involved subchondral bone and did not affect joint cartilage in dogs younger than 18 weeks of age. Histological studies demonstrated that MCD was initiated in the deeper layer of the articular cartilage, i.e. in the calcifying zone. Clustered hypertrophic cartilage cells, which have been reported to be present in Golden retrievers at the age of 13 weeks ([Wolschrijn et al., 2008](#)), could no longer be detected in the section from the youngest dog (15 weeks of age).

These histological findings suggest that MCP modelling, especially of the latMCP, might underpin the development of MCD in the Labrador. The relative surface area of the calcifying cartilage zone was approximately twice as large in MCD-positive joints as in MCD-negative joints ( $P < 0.001$ ). Type X collagen used as a specific marker of the matrix produced by hypertrophic chondrocytes ([Von der Mark et al., 1992](#); [Shen, 2005](#)) revealed extensive type X collagen staining in MCD-positive joints ( $3.7 \pm 4.6\%$ ) compared to MCD-negative joints ( $0.3 \pm 0.7\%$ ; [Figure](#)). The retained hyaline cartilage stained positive for type X collagen in the MCD-positive joints, which suggests a localized delay in endochondral

ossification, mainly in the calcifying zone, as the three most superficial cartilage layers were not affected. The persistence of cartilage could give rise to cleft formation as a result of physiological or abnormal biomechanical forces, followed by secondary changes in articular cartilage.

The study design enabled to document the development of MCD in dogs of 15–27 weeks of age, and the findings led to the conclusion that there was modelling of the diseased MCP in growing Labrador retrievers. MicroCT and histological findings suggested that the retained hyaline cartilage within the MCD lesion ultimately ossified, giving rise to the typical histological appearance of MCD specimens obtained from dogs with advanced cases of MCD, possibly with clinical disease (Crouch et al., 2000; Danielson et al., 2006; Goldhammer et al., 2009, Mairee et al, 2014).

### **The value of radiology and CT to detect MCD at premature age**

In order to investigate the diagnostic value of radiography and computed tomography in Labradors at risk for MCD, a group of Labradors was investigated from 6 weeks till 6 months of age. Fourteen Labrador retriever pups, born out a bitch and one of two dams all with radiological proven MCD, were followed radiologically and with CT scanning of both elbow joints, every other week starting at 6 or 7 weeks of age, until lesions indicative for MCD were detected at which stage the dog, (plus an age- and weight-matched control, i.e., negative for MCD), were euthanized followed by micro-CT and histological examination of the elbow joints. Between 6-11 weeks, ML and CrCd views were taken; starting at 12 weeks additionally CrL-CdMO and extended supinated ML views (Voorhout et al, 1987) were taken. CT was performed with the dog in dorsal recumbancy, elbows 135° extended, with 1-mm (6-12 weeks) or 2-mm (>12 weeks) thick slices with a single-slice hemical Philips Secura CT scanner. The prevalence of MCD was 50% as revealed from in-vitro micro-CT scanning (with a Skyscan 1067 system)(Fig. 2) and from histology (see section above). Result analysis showed that at this young age, microCT and necropsy revealed 7 of the 14 dogs positive for MCD, with 6 dogs (5 ♂ and 1 ♀) bilateral affected and one (1 ♀) unilateral affected. Radiology had a 0% sensitivity for blunting of the cranial edge of the MCP, or subtrochlear sclerosis, or any other sign of primary or secondary lesions indicative for MCD in these Labradors of 6 weeks till 6 months of age.

On CT no abnormalities were found in 17 of the 28 elbow joints, 7 were suspected for MCD and in 4 elbows a FCP was found. In case of MCD, first a mineralized fragment at the base of the apex but not extending to the apex was noticed, some noticed in retrospect with the knowledge of the necropsy. All MCPs, excepted in dog #8, could be detected with CT by careful reading.

Results as presented in: “The early development of medial coronoid disease in growing Labrador retrievers: radiographic, computed tomographic, necropsy and micro-computed tomographic findings by S.F. Lau, C.F. Wolschrijn, H.A.W. Hazewinkel, M. Siebelt, G. Voorhout in *Veterinary Journal* 2013, 197, 724-730”.

Table 1. Details of dogs from the first and second litters (Lau et al, Vet J 2013)

Dog	Age (weeks)	Sex	Weight (kg)	Limb	CT	Necropsy (cartilage)	MicroCT ( <u>subchondral bone</u> )
1	15	F	14.8	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
2	15	F	16.2	L	Suspect	No fissure	Fissure
				R	Negative	No fissure (RUI)	Normal
3	16	M	16.6	L	Suspect	No fissure	Fissure
				R	Suspect	No fissure	Fragment
4	17	F	20.5	L	Suspect	No fissure	Fissure
				R	Suspect	No fissure	Fissure
5	18	M	19.2	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
6	18	M	19.1	L	Positive	Fissure	Fragment
				R	Positive	Incomplete fissure	Fragment
7	19	M	21.5	L	Positive	No fissure	Fissure
				R	Positive	Incomplete fissure	Fragment
8	19	M	22.8	L	Negative	Fissure	Fragment
				R	Negative	Incomplete fissure	Fragment
9	25	M	28.6	L	Suspect	Fissure	Fragment
				R	Suspect	Fissure	Fragment
10	25	M	28.4	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
11	26	M	28.4	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
12	26	F	29.4	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
13	27	F	24.4	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal
14	27	M	33.6	L	Negative	No fissure	Normal
				R	Negative	No fissure	Normal

\*Dogs 1-6 were from the second litter; dogs 7-14 were from the first litter.

\*CT, computed tomography; MicroCT, micro-computed tomography; F, female; M, male; L, left; R, right.

No sclerosis was detected in the MCD-positive cases, neither on radiographs nor at CT, leading to the conclusion that sclerosis is a secondary finding in case of MCD. MCD could be detected on CT as early as 15 weeks of age, starting as a subchondral lesion at the base of the MCP, as confirmed on pathological investigation (this study, and Danielson et al, 2006) and microCT investigation of others (Fitzpatrick et al, 2011). Fissures in the articular cartilage, as visible during arthroscopy, was only seen in these dogs, when > 18 weeks during necropsy. From clinical cases it is known that articular cartilage fissuring can occur at a much later age. Weakening of the subchondral bone, as might be palpable on probing the covering articular cartilage, was first present at 15 weeks in these Labradors, even without abnormalities of the articular cartilage itself: therefore an adaptation of the Modified Outerbridge Scoring System (Schulz, 2003) should be considered, since the softening

originates more from the delayed mineralization and necrosis of the subchondral bone than from the cartilage swelling.

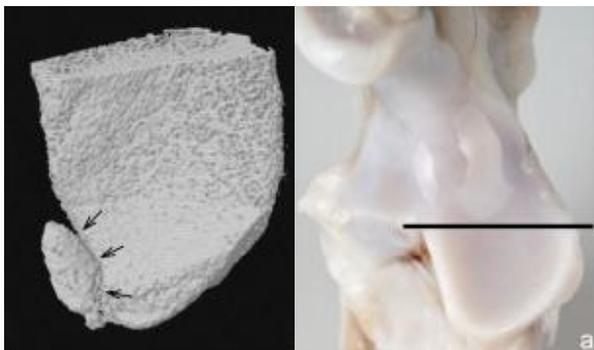


Figure 2. A 3-dimensional reconstruction of microCT of the MCP of a Labrador, female 17 weeks, showing a fissure line in the subchondral bone extending from the base to the apex of the MCP as demonstrated on the right figure, and covered by intact joint cartilage.

**In conclusion:** It was demonstrated in a prospective, controlled study that MCD development is due to disturbed endochondral ossification of the subchondral area, especially delayed calcification in the calcifying zone. The retained hyaline cartilage could ultimately ossify during the progression of MCD, but concomitantly weaker points might develop into cracks between the retained hyaline cartilage and the surrounding subchondral bone. Additionally, increased pressure, tensile or shearing forces during joint movement can lead to detachment of the medial coronoid process, with eventually partial or total fissuring of the overlaying joint cartilage. The fragment can, due to repetitive movements be detached from blood vessels and thus develop into necrotic subchondral bone surrounded by reactive bone sclerosis. Both delayed ossification and bone necrosis can explain the loss of contrast of the apex of the medial coronoid process, as visible on mediolateral radiological views (“c” on IEWG registration). However, since the first half year of the life of the dog with MCD there are still no secondary signs of sclerosis and osteoarthritis, radiology is not as sensitive as CT to detect delay in subchondral endochondral mineralization. Although there might be non-genetic factors (including nutrition, and activity), who may play a role in the development of dogs at risk for MCD, the chromosomal cause of this disturbance of endochondral ossification has still to be elucidated. Genetic research of MCD is hampered by the selection of MCD-free dogs, due to limitations in radiological technique or interpretation.

References are available on request.

# Radiographic and computed tomographic assessment of the postnatal development of the antebrachia and elbow joints in Labrador Retrievers

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Medial coronoid disease (MCD) includes pathological lesions of both cartilage and subchondral bone of the medial coronoid process (MCP). Current postulated etiopathogeneses contributing to MCD include osteochondrosis, fatigue-induced microdamage of subchondral bone, different distribution of loading or forces within the joint, shear stress between the contact area of the proximal radial head and axial border of the MCP during pronation and supination and mechanical overloading of the ulnar surface due to joint incongruity. The aim of the study was to compare the development, monitored by radiography and computed tomography (CT), of the antebrachium and elbow joint in MCD-negative and MCD-positive dogs, in order to evaluate whether disturbances in the development of the antebrachium and elbow joint between the age 6 and 17 weeks may contribute to the occurrence of MCD. Fourteen purpose-bred Labrador retriever puppies were monitored at two weeks intervals by radiography and CT of the antebrachia and elbow joints, from 6 (n=7) or 7 (n=7) weeks of age until euthanasia at the age of 15 weeks (2 dogs) or 17 weeks (12 dogs). The development of the antebrachia and elbow joints was assessed on the basis of the development of secondary ossification centers, the growth in length of the radius and ulna, radial angulation, and the inter-relationship between the humerus, ulna and radius. Of the 14 dogs, seven (four males, three females) were MCD-negative and six (five males, one female) were bilaterally MCD-positive. One female dog was MCD-positive unilaterally. The appearance of ossification of secondary ossification centers, medial proximal radial angle, lateral distal radial angle, proximal cranial radial angle, distal caudal radial angle, and radial procurvatum angle measured based on the *Center of Rotation of Angulation Methodology* did not differ significantly between MCD positive and MCD negative status. The radioulnar length ratio did not differ with MCP status. On CT images, radioulnar and humeroulnar incongruency was not detected. Despite no statistical differences could be demonstrated in between all measurements (appearance of ossification of secondary ossification centers, medial proximal radial angle, lateral distal radial angle, proximal cranial radial angle, distal caudal radial angle, and radial procurvatum angle measured based on the *Center of Rotation of Angulation Methodology*, radioulnar length ratio) obtained from MCD-positive and MCD-negative dogs, we have provided a breed specific joint reference angles from images of growing Labrador retrievers. Joint incongruity is unlikely playing a role in the development of MCD in Labrador retrievers based on the sagittal and dorsal plane reconstructions. All measurements should be interpreted with caution because the cartilage layers are not visualized on radiographs and CT images. Mild radioulnar incongruency may be missed on CT and dynamic radioulnar longitudinal incongruency also cannot be ruled out by using radiography. The MCP status was not influenced by a difference in radioulnar length ratio in this study. Despite all the measurements, no statistical differences in MCD-positive and -negative dogs could be demonstrated.

# RADIOLOGICAL EVALUATION BEFORE AND AFTER ELBOW SURGERY

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## Early treatment of developing elbow dysplasia MCPD with DDUO at 4 to 5 months of age

In 4 to 5 month-old puppies initial medial coronoid process disease (MCPD) is suspected when subchondral bone sclerosis of the subtrochlear notch is observed, with or without lameness.



Radiographic subchondral bone sclerosis is evaluated both subjectively and with objective measurement with digital assessment of bone mineral density using computer public domain application ImageJ (National Institute of Health, USA), which has been validated against DXA in human studies (SR Small 2013). With this method bone density of three standard regions, the air, a metal bullet and the subtrochlear region of the medial coronoid as the region of interest were compared. In our experience, even if not supported by scientific demonstration, subtrochlear bone sclerosis is quite a consistent and direct sign of overloading of

the corresponding joint surface, due to some form of joint incongruity or joint malformation; in the elbow joint it usually represents a very early and distinct sign of developing elbow dysplasia, whatever is the congruity or incongruity detected radiographically. In my opinion, subchondral bone sclerosis is a more reliable radiographic sign of joint incongruity than radiographic assessment of elbow joint congruity itself because the latter can be altered by radiographic positioning due to physiological joint laxity in growing dogs. In puppies with questionable sclerosis, repetition of the radiographs after 2-3 weeks is usually diagnostic in dysplastic elbows due to the progression of the disease. Subjective visual evaluation requires experience and training to be reliable, but in a study in progress the interobserver agreement looks very high after a short training. Objective digital measurement, while promising, is not yet validated for early screening of elbow dysplasia in puppies owing to the morphological differences in various breeds, requiring calibrations for each breed.

In affected puppies, treatment in our hospital consists of distal dynamic ulnar ostectomy (DDUO) only at the early age of 4 to 5 months. We believe that this minimally invasive surgical procedure releases the pressure on the medial and lateral coronoid processes though definitive peer-reviewed data to support this observation is lacking at this time. The DDUO procedure is performed subperiosteally by removing 4 to 5 millimetres of ulna with a rongeur, bite by bite, approximately 2 to 3 centimetres proximal to the distal ulnar physis. The operated puppies are re-checked clinically and radiographically 3 to 4 weeks later. In cases with persistent clinical signs and worsening radiographic lesions with osteophyte formation, indicative of progression of the elbow dysplasia, conventional joint inspection and MCPD treatment are carried out with arthroscopy. In 4 to 5 month-old puppies with more severe clinical and radiographic signs suggesting advanced MCPD, we perform joint inspection and treatment with arthroscopy in conjunction with proximal dynamic ulnar osteotomy (which we feel is more effective than DDUO to improve joint congruity).

In my unpublished data of 136 elbows with subtrochlear sclerosis at 4 to 5 months of age, follow-up evaluation revealed that in most cases OA continued to progress to a varying degree according to IEWG classification (41% grade 3, 33% grade 2, 24% grade 1 and 2% grade 0) following conservative management alone.

In contrast, in 141 elbows with the same early radiographic signs and treated very early with DDUO, there was no or less severe progression of OA in most cases (4% grade 3 and 4% grade 2 requiring further surgical treatment, 80% grade 1 and 12% grade 0). Apart from the 8% of dogs resulting in grade 2 and 3, the remaining dogs were without lameness showing no signs of OA or only mild osteophyte formation, indicating that the disease was any way present, but halted by the early DUO. Healing of the osteotomy resulted in a full remodelling of the ulna without affecting the residual growing of the distal physis and without formation of synostosis. Distal ulnar osteotomy is very well tolerated by patients and has no side effects when performed properly. This procedure entails a minimally invasive subperiosteal approach and the avoidance of injury to the radial periosteum and the interosseous vessels; contrarily, damage may result in synostosis between the radius and ulna during the healing process. For this reason no attempt is made to free the interosseous ligament.

### **Treatment of elbow dysplasia (MCPD and MCD) with BODPUO at 5 to 12 months of age**

In puppies 4-5 months of age with more severe ED and in older puppies up to skeletal maturity, without medial compartment disease (MCD) assessed at the arthroscopic inspection, FCP removal or regional debridement only is performed. In the more frequent condition where MCPD is associated to MCD, in dogs from 4-5 months up to 12-13 months of age, bi-oblique, dynamic proximal ulnar osteotomy (BODPUO) can still improve joint congruity; in order to reduce the morbidity and prolonged healing time associated with transverse proximal ulnar osteotomy, a maximal obliquity of the osteotomy was executed in the proximal mid-shaft of the bone, as described by Fitzpatrick (2013), with a bi-oblique direction (caudo-proximal to cranio-distal and proximo-lateral to disto-medial) to limit caudal and varus tilting of the proximal ulna under the triceps pull. With this BODPUO performed at this range of age, we observed a quick healing of the osteotomy 1 to 2 months after surgery, with complete remodelling at 4 to 8 months. Bone healing of the osteotomy was quicker in more immature dogs, and slower in dogs close to one year of age. After 12 months healing of the osteotomy was very slow and for this reason we selected to perform PAUL procedure in dogs over 12 months of age. While joint degenerative signs persisted at the follow-ups, significant decrease of subtrochlear bone sclerosis and improved function were constantly observed. The varus deformity of the proximal ulna decreases the load on the ulnar joint surface. In more severe cases progression of OA was observed in relation to the severity of the pre-operative conditions, mainly when MCPD was associated with OCD, to the increase in body condition score and to the level of physical activity.

We performed arthroscopic MCP debridement + BODPUO on 325 elbows in 293 dogs. In



a personal study done in 2015 on 117 dogs with MCPD + MCD between July 2012 and June 2015, eighty-three were re-evaluated with a minimum 6 months clinical and radiographic follow-up. 34 cases (41%) improved from grade 2 to grade 0 lameness, 27 cases (33%) improved from grade 1 to grade 0 lameness, 18 cases (22%) improved from grade 2 to grade 1 lameness, 4 cases (5%) with grade 1 (2 dogs) and grade 2 (2 dogs) lameness did not improve. Thereafter, good outcome (no lameness) was obtained in 73% of the cases, improvement in 22% and poor outcome in 5% of the cases. The

poor outcome was seen in dogs with combined FCP and OCD.

### **Early treatment of un-united anconeal process (UAP)**

UAP has different stages and clinical entities that can be differentiated by radiography and joint inspection (arthroscopy or mini-arthrotomy) as suggested by Bardet in 1998.

In growing dogs, the disease can be differentiated into four entities:

1. The process is not fused but is still firmly attached; the joint can be congruent or incongruent with a longer than normal radius.
2. The process is not fused and moves slightly. It is hinged at its caudal part, creating a small cranial gap; the joint is usually incongruent with a shorter than normal ulna.
3. The process is not fused and is completely loose; the joint is usually incongruent with a shorter than normal ulna.
4. The process is not fused, the coronoid process is fragmented and there is reversed joint incongruity (a longer than normal radius becomes a shorter than normal radius).

In adult dogs, the four most common entities are:

1. UAP without persistent joint incongruity; the anconeal process is not fused but is firmly attached and there is no or only slight osteoarthritis; this condition does not cause clinical problems and is incidentally diagnosed on routine radiographic examination. Usually, surgical treatment is not required.
2. Sudden detachment of the anconeal process due to forced hyperextension in dogs with the condition described in 1, causing acute lameness. Removal of the anconeal process is required.
3. UAP with persistent joint incongruity with a shorter than normal ulna and severe osteoarthritis. Conservative management.
4. UAP and severe degenerative joint disease with complete joint alteration such that joint incongruity can no longer be distinguished. Conservative management with poor prognosis.

Early diagnosis of UAP is based on radiographic evidence of non-fusion of the anconeal process in the mediolateral-flexed view. This can be determined by comparing radiographs of the diseased and opposite elbows or, in cases with bilateral disease, comparing the radiographs with those of healthy puppies of the same age and breed. Incongruity caused by a shorter than normal ulna can be better assessed in the extended (neutral) mediolateral view. It is also possible to evaluate the mobility of the anconeal process, the degree of incongruity and to stage the disease by comparing the extended and the flexed mediolateral views. In the extended position, if the anconeal process is mobile, the humeral condyle pushes the process caudally and the gap widens, whereas in the flexed position, the pressure against the process is released, allowing it to return closer to the ulna. According to our personal experience, and in contrast to previous reports (Hare 1961, Van Sickle 1966a,b), in most breeds, including German Shepherd Dogs, the anconeal process should be fused at 4 months of age, while in giant breeds, including Great Danes and Saint Bernards, union occurs between 4 and 6 months of age (Vezzoni et al, 1998).

Our early treatment of UAP consisted of proximal dynamic ulnar osteotomy (PDUO), which has a lengthening effect to release the pressure on the anconeal process. It is carried out proximally in patients with more advanced incongruity and centrally or distally in less severe cases. Screw fixation of the anconeal process in lag fashion is performed both when the process is mobile and when it is still firmly attached to enhance the probability of its bony fusion. Dynamic ulnar osteotomy is performed first to release the pressure on the process and then screw fixation is carried out. Internal fixation of the anconeal process is achieved via a caudolateral approach, using an aiming device to drill the screw hole from the caudal ulnar cortex to the tip of the process. One or two cortical 2.7-mm or 3.5-mm screws in lag fashion are inserted. When these procedures are done in 4- to 6-month-old puppies, restoration of joint congruity and fusion of

the anconeal process are very likely. However, in older puppies, joint degeneration that may already be present, together with increased mobility of the anconeal process, may prevent complete healing. In these dogs, the process is removed and joint incongruity is corrected with PDUO.

Oblique osteotomy, in a proximal to distal direction, is the most indicated osteotomy and it must be performed with an oscillating saw with a narrow long saw blade. Because of the larger osteotomy surface, the instability of an oblique osteotomy is reduced, resulting in less morbidity for the patient. Bone union is faster and excessive inclination of the proximal ulnar segment is inhibited by bone contact of the cut surfaces. A light padded bandage to protect soft tissues is applied for five days to make the patient comfortable.

When the treatment is successful, radiographic evidence of union of the anconeal process and ulna is seen in 5 to 8 weeks. Several months are required for complete healing of the osteotomy and remodelling of the spontaneous hypertrophic callus. Dynamic ulnar osteotomy results in much better function because of the resulting improvement in joint congruity, even when anconeal bony union is not achieved. Fixation of a completely loose process is unlikely to be successful, and failure of implants can be anticipated because of bone resorption of the process and remodelling of the troclear notch, which causes an abnormal cycling load on the process by the humeral condyle. In these cases, the loose anconeal process is removed together with the broken or loose implants. When FCP is also present, the coronoid fragments are removed, the anconeal process is fixed and PDUO is performed to improve joint congruity.

Outcome after UAP surgical treatment: personal experience confirms that, compared with traditional treatment of UAP by removal of the process, better functional results are obtained with proximal ulnar osteotomy and screw fixation of the anconeal process to promote healing.

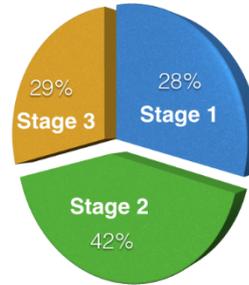


The stability of the elbow joint is ensured by fusion of the anconeal process, which allows normal joint function and halts osteoarthritis progression. In contrast, in dogs that had undergone removal of the anconeal process only, osteoarthritis progressed, the range of motion was decreased and function was impaired. Removal of the anconeal process when too loose, but in combination with PDUO in dogs up to 12 months of age provided a satisfactory outcome, better than removing the process only. The prognosis of UAP treatment is influenced by the age of the dog at the time of surgery and by the condition of the anconeal process. The younger the dog, the higher the likelihood that the UAP will heal, which emphasizes the importance of early diagnosis and treatment.

We found, as a general rule, that the prognosis in large breeds, such as German shepherd dogs and Rottweiler, was better when the surgery was done at 4 to 5 months of age. After 6 months of age, the prognosis deteriorates; in our own cases, we had few successful outcomes in dogs in this age group. Interestingly, in giant breeds, we found that an UAP can heal provided that surgery is carried out before 9 months of age.

**Management of 370 UAP in 295 dogs**

- ☑ Conservative management in **68** cases
- ☑ Surgical treatment in **283** cases:
  - Screw fixation of AP and pDUO in **180** cases
  - pDUO only in **47** cases
  - Excision of AP only in **26** cases
  - Excision of AP and pDUO in **35**
- ☑ Surgery advised but refused by the owner in **19** cases



**Surgical treatment in 283 cases of UAP**

**Outcome in 229 cases with FU (81%) related to AP fusion**

UAP stage	No.	Treatment	Outcome	Success %	Failure %		
Stage 1	61	- DUO only	26	AP fusion	20	77%	23%
		- AP fixation and DUO	35	AP fusion	31	89%	11%
				<b>84%</b>	<b>16%</b>		
Stage 2	86	- DUO only	2	AP fusion	0	0%	100%
		- AP fixation and DUO	84	AP fusion	66	79%	21%
				<b>77 %</b>	<b>23%</b>		
Stage 3	82	- DUO only	4	AP fusion	0	0%	100%
		- AP fixation and DUO	16	AP fusion	5	<b>30%</b>	<b>70%</b>
		- Excision only	26				
		- Excision and DUO	36				

In adult dogs, treatment of UAP becomes necessary when the anconeal process is suddenly dislodged from its fibrocartilaginous attachment by severe elbow extension. In such cases, removal of the free anconeal process is the only treatment. In contrast, chronically degenerated joints with long-standing elbow incongruity and UAP do not benefit from any surgical treatment,

apart from total elbow replacement (prosthesis), when conservative management is no longer acceptable.

### Treatment of elbow dysplasia (MCPD-OCD and MCD) with PAUL after 12 months of age



For dogs aged 1 to 9 years, not responsive to conservative management and having arthroscopically confirmed MCD (without significant pathology in the lateral compartment), we performed Proximal Abducting Ulna (PAUL) osteotomy. Arthroscopic confirmation is done immediately before PAUL surgery or at a previous operation at the time of conventional joint debridement. PAUL is offered to dog owners as a palliative treatment of MCD. We do not recommend PAUL when arthroscopy shows MCPD without significant involvement of the remaining medial compartment or when there is cartilage erosion of the lateral compartment too or in dogs > 9 years of age. In 2010, Ingo Pfeil and Slobodan Tepic theorized that proximal osteotomy of the ulna fixed by a special plate would shift, abduct and rotate the ulna, which would lead to lateralization of the paw, thus, unloading of the medial compartment. The proposed biomechanics of PAUL are similar to high tibial osteotomy for treatment of varus deformity of the knee and medial

compartment syndrome in humans as an alternative to unicompartmental knee joint replacement, which may be carried out later on in cases with progressive OA. This procedure in people consists of medial open wedge osteotomy of the tibial plateau and elevation of the tibial plateau medially to allow the distal limb to move laterally. This loads the lateral knee compartment and unloads the medial compartment. The PAUL plate produced by Kyon is a straight plate with a step of 2 to 3 mm and is applied to the lateral surface of the proximal ulna. This is theorized to raise the ulna on the medial humeral condyle and result in a lateral shift of the distal limb with increased load on the lateral compartment and decreased load on the medial compartment. According to the manufacturer of PAUL plate, the amount of achieved abduction is about 4° with the 2mm step plate and 6° with the 3mm plate, plus 4° to 5° attributable to the natural curvature of the ulna, which is straightened by the plate. The final lateral shift is about 8° with the 2mm step plate and 11° with the 3mm step plate.

The cranio-caudal radiographic view was used to evaluate the mechanical medial elbow angle (mMEA), which has a normal range of  $81.5^\circ \pm 2.5^\circ$  (Pfeil 2010). In cases with an mMEA  $\leq 80^\circ$ , a 3 mm step PAUL plate was used, and in cases with an mMEA > to  $80^\circ$ , a 2 mm step PAUL plate was used. In older dogs with severe OA, a 2 mm step plate was used because stiffening of the interosseus ligament was expected. A caudolateral approach to the ulna was used to expose the lateral side of the ulna, where the plate was to be fixed. The ulnar osteotomy line was marked and measured 4 cm from the radial head, which was easily palpated. Ulnar osteotomy was carried out perpendicular to the bone with a straight thin saw blade, from lateral to medial, after protecting the medial muscles with wet sponges and the radius cranially with a thin periosteal elevator. The PAUL plate was fixed with temporary compression screws then replaced by definitive locking screws according to the plate manufacturer's recommendations.



Among 88 elbows treated with PAUL in our Hospital from 2010 to 2016, 76 were rechecked with a minimum clinical and radiographic FU of 6 months. Lameness detected before surgery was grade 1 in 8% of the cases, grade 2 in 58% and grade 3 in 33%. Lameness detected in the FUs was grade 0 in 51% of the cases, grade 1 in 39%, grade 2 in 9% and no one with grade 3. Although operated dogs had been unresponsive to conventional treatment for advanced OA, overall improvement was seen in 78% (83% in dogs up to 5 years of age and 67% in older dogs), which is rewarding for a palliative treatment. The risk of complications after PAUL in terms of severity and frequency of surgical revision was small (6%) and easily solved. Pfeil (2010) in second arthroscopy look observed the formation of fibrocartilage in the medial compartment 7 months after PAUL in a Bernese Mountain Dog. Similarly, in second arthroscopy look we observed the formation of fibrocartilage in the medial compartment 12 months after PAUL in a German Shepherd Dog, where full erosion was present before surgery. The follow-up period of our experience with PAUL is limited to 6-7 years. Therefore, further long term evaluations are needed to determine whether lateral compartment overload attributable to abduction of the lower limb has detrimental effects. Similar to the situation in people in relation to varus knee corrective osteotomy, PAUL does not stand in the way of total elbow replacement should this become necessary.

## CONCLUSIONS

Elbow dysplasia is a potentially devastating joint disease because of the risk of severe osteoarthritis, which usually leads to life long chronic pain and functional impairment of the affected elbow. Early diagnosis and treatment of this condition is fundamental to restore joint congruity and prevent or limit further osteoarthritis.

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# Breeding against elbow dysplasia -BLUP indexes

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In Finland, dog breeders are highly health-conscious when choosing breeding material; the Finnish Kennel Club (FKC) supports efforts to fight against hereditary diseases by providing a special health programme (PEVISA). The PEVISA programmes are voluntary, but when a breed club enters a programme, preconditions for registration of a litter can be set. Screening the sire and dam for HD and ED are the most common obligatory examinations, and several breed clubs have also set limits on accepted dysplasia grades (Lappalainen, 2013).

Radiographic screening for canine elbow dysplasia (ED) began several decades ago, but genetic improvements have been modest. (How, Y. et al. 2013, Lappalainen, 2013). This indicates that across breeds, the selection intensity against ED has been low (How, Y. et al. 2013). ED is regarded as a quantitative genetic trait with an environmental influence. Heritabilities for hip and elbow dysplasia have been estimated in several dog populations with various methods. A wide range of estimates has been reported. This indicates that even phenotypic selection, if done systematically, could result in genetic improvement in these traits. But genetic progress could be hastened if selection is based on estimated breeding values (EBVs) rather than phenotype (Mäki et al., 2000, Lewis et al., 2013, Oberbauer et al., 2017).

Screening is useful only if the disease or fault is hereditary and the trait is measurable. The method used should be objective and measure the trait in question. Compulsory hip dysplasia screening of breeding dogs, which formed the beginnings of the so-called PEVISA health program of the FKC, was established in 1984 for the retriever breeds, 1986 for the German Shepherd, 1987 for the Rough Collie, 1991 for the Bernese Mountain Dog, and in 1994 for the Rottweiler. The PEVISA program was later expanded by official screening for elbow dysplasia that started in 1994 for the Rottweiler and the Bernese Mountain Dog, and became mandatory in 2001 for the German Shepherd and the retriever breeds. The decision on joining the health program is up to the individual breed associations (Mäki, 2004).

## What is BLUP index

The BLUP (best linear unbiased prediction) EBV is an estimate of animals breeding value and it is affected by results of all the relatives of the dog available in data. For a dog to get an EBV, it must be in a pedigree of a dog with a screening result, or it must have own screening result and at least one of the parents known.

EBVs are estimated using the BLUP animal model method, where the screening results are modelled using a regression analysis. The hip and elbow phenotype consist of both the influences of genes (genotype) and the environment. The calculation equation contains those phenotype affecting factors that can be found in the Finnish Kennel Club database or can be defined there:

*phenotype = gender + age + birth year + scrutineer + litter + + other environmental + genes.*

In calculating everything affects everything, so all factors in the equation are taken into account simultaneously.

BLUP-EBVs are standardized per breed so that their mean value is 100 and the standard deviation is 10. The ten index points correspond to the difference between one letter in the hip results and the half-digit difference in elbow results. The breeding value of the dogs with an EBV less than 100 dogs are worse and over 100 dogs better than the breed average. The higher the EBV is, the better the genetic level of the dog is. Between 90-110 is about 70% of dogs and between 80-120 about 95% of dogs. Thus, a better index than 120 is only about 2.5% of dogs. Almost all dogs' EBVs are within normal distribution. So, between values 70 to 130, and outside these figures are only particularly good or particularly bad breeding value dogs.

The difference between a few points in the indexes is insignificant and is due to the fact, that the index of each dog is re-calculated in each update.

The genetic level of the breed for hip and elbow joint improves when combinations are selected for breeding in which the average of the bitch and male EBVs is better than the average of the whole breed: more than 100. Genetic progress leads to a decline in the EBVs of the older generations.

EBVs are always calculated for each breed and population, so the values estimated for the different breeds or in different countries are not comparable. They reflect only the dog's level relative to the average level of the population.

The heritability also affects the difference between EBVs in different breeds: the higher the heritability in breed, the more the dog's own score affects its' EBV. When the heritability is lower, the scores of the dogs' relatives have a larger influence on the EBV. Heritability is a predictor of the value of the dog's own result as a breeding value and it also describes the genetic variation in breed. The more genetic variation, the more there are genetic differences between dogs and the easier the breeding is. If the heritability is zero, there are no differences and no progress can be made by breeding, as all dogs have identical alleles.

In addition to the dog's EBV, the accuracy of the EBV is also shown in the Finnish Kennel Club database. It can have values between 0 and 100% and is affected by the number of results obtained from a dog and its close relatives as well as the heritability. The higher the heritability is, the higher the accuracy is. The accuracy is improving on each update if more screening results has arrived in the database. (Mäki 2009, Mäki, 2013).

### **Elbow indexes in Finland**

The most effective selection against hip and elbow dysplasia could be conducted using BLUP breeding values. The heritability estimates for hip dysplasia in the Rottweiler, the Bernese Mountain Dog and the Finnish Hound, as well as for elbow dysplasia in the Rottweiler, were even high enough to make efficient selection based on phenotype information (mass selection) only. The FKC has started breeding value estimation with the BLUP method for hip and elbow dysplasia in 2002, based on the genetic parameters estimated and the models defined in this study. However, the accuracy of the breeding values could be improved if more dogs were screened for hip and elbow dysplasia (Mäki, 2004).

Today we have about 148533 ED results in the Finnish Kennel Club database since 1988 and the BLUP EBVs are being routinely estimated for ten breeds. EBVs are estimated once a month for breeds that have EBV requirements for breeding and every other month for other breeds.

There must be quite a lot of screening results available in a breed, to make the EBV estimation possible, because the heritability estimates for elbow dysplasia are smaller than

for hip dysplasia. This could be associated with the fact that the animals in the most severe cases suffer from elbow dysplasia already before the official minimum screening age of one year and thus do not enter the database of the FKC. This is a problem of incomplete data. False negative diagnoses of elbow dysplasia have been reported to be as frequent as 12 percent of all diagnoses and some radiographs showing dysplastic joints are not being sent to the FKC for official evaluation. Also, the different conditions causing elbow arthrosis may have divergent modes of inheritance and may be regulated by different genes (Mäki 2004). It has been reported that FCP (fragmented coronoid process) was by far the most frequent form of ED in this multiple-breed data set, with 94% of positive ED cases diagnosed with FCP, followed by INC (elbow incongruity) (18%) and OCD (osteochondritis dissecans) (10%). UAP (united anconal process) was rarely reported (1.5%). Four percent of dogs were diagnosed with OA (osteoarthritis) of the elbow joint without any signs of primary disease. In total, 26% of all cases were diagnosed with multiple forms of ED (Lavrijsen et al., 2014)

The positive, although mainly low, estimates of genetic correlations between hip and elbow dysplasia allow simultaneous breeding against both traits (Mäki, 2004).

**ED Statistics in Finland** (Golden Retriever, German Shepherd, Saint Bernard and Labrador Retriever)

This table shows, what ED results Golden Retrievers have gained in using different phenotypic breeding combinations. It shows that Golden Retrievers could reduce elbow dysplasia by phenotypic breeding choices. It is clear, when the proportion of breeding dogs with 0-elbows is increasing, the share of 0-elbows in the whole population is also increasing. Statistics show that the use of 1-elbows in breeding adds on average more degrees 2 and 3.

Golden Retriever, year of birth 2006-2011

All dogs, that have parents with ED result

0	2224	78 %		
1	437	15 %		
2	137	5 %		
3	54	2 %		
	2852			

Dogs, with both parents ED 0

0	1699	80 %		
1	308	14 %		
2	84	4 %		
3	35	2 %		
	2126			

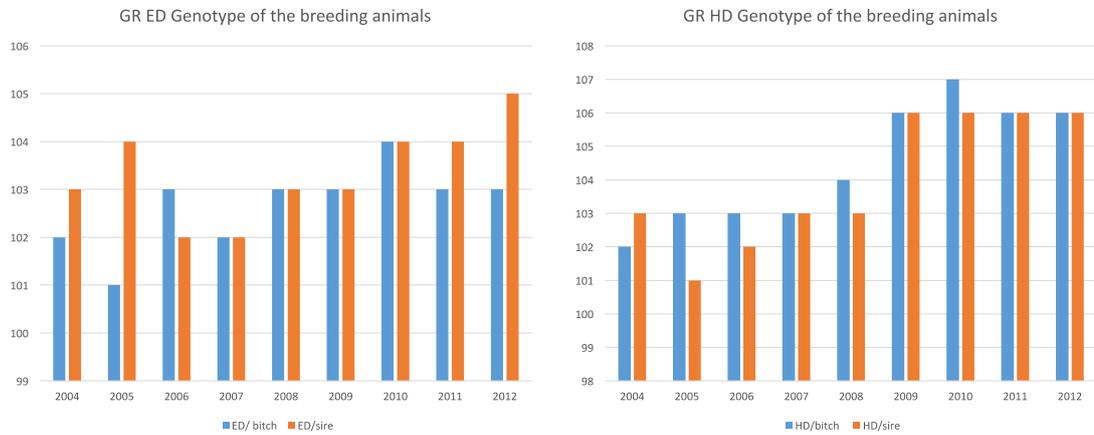
Dogs, with other parent ED 0 and other ED 1

0	463	73 %		
1	111	18 %		
2	44	7 %		
3	16	3 %		
	634			

Dogs, with both parents ED 1

0	34	71 %		
1	7	15 %		
2	6	13 %		
3	1	2 %		
	48			

These statistics show the average genotypic breeding value in ED and HD for the Golden Retrievers used for breeding in Finland 2004-2012



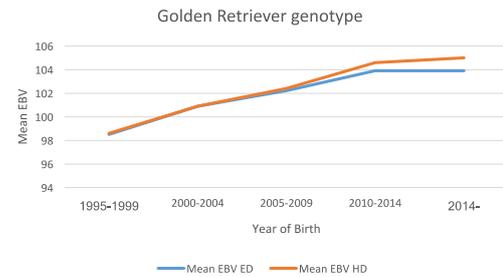
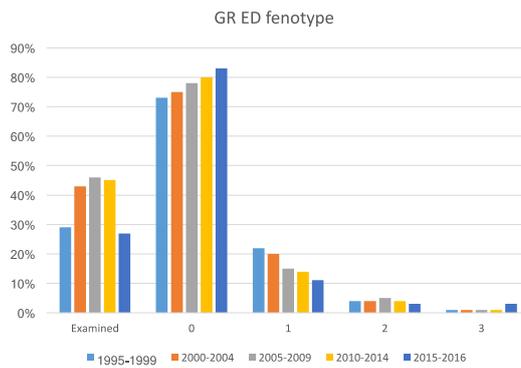
EBVs of the breeding dogs affect offspring EBVs and hence the EBVs of the breed with a few years delay as descendants are screened. It should be noted that the average EBV of males affects much more than females, as males have usually more offspring. In addition, the significance of an individual male may in some years be quite high if the index has been exceptionally good or poor and a lot of offspring have been born.

The following tables and graphs show the mean EBV of some breeds (relative to baseline index), which illustrates the genetic improvement in decreasing elbow dysplasia. The charts show that the use of genetically better dogs has led to genetic improvement in the same proportion.): GR= Golden Retriever, GSD= German shepherd, St. Bern. = Saint Bernard, LB= Labrador Retriever.

# Statistics GR ED 1995-2016 28205/11218

Year	Examined	0	1	2	3
1995-1999	29 %	73 %	22 %	4 %	1 % 1800/6112
2000-2004	43 %	75 %	20 %	4 %	1 % 2354/5512
2005-2009	46 %	78 %	15 %	5 %	1 % 3273/7157
2010-2014	45 %	80 %	14 %	4 %	1 % 3101/6897
2015-2016	27 %	83 %	11 %	3 %	3 % 690/2527

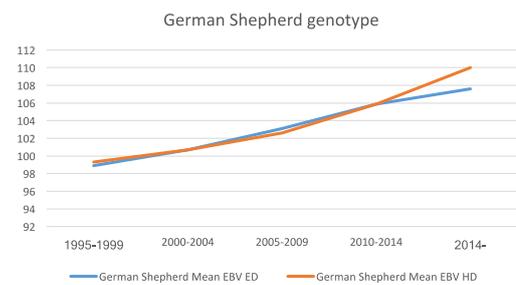
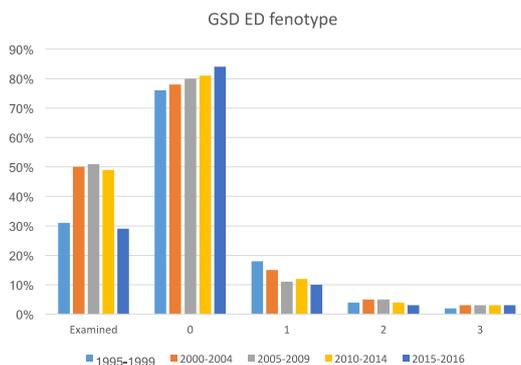
Golden Retriever	Mean EBV ED	Mean EBV HD	n
Year of Birth			
1995-1999		98,5	98,6
2000-2004		100,9	100,9
2005-2009		102,2	102,4
2010-2014		103,9	104,6
2014-		103,9	105



# Statistics GSD ED 1995-2016 40062/17550

Year	Examined	0	1	2	3
1995-1999	31 %	76 %	18 %	4 %	2 % 3069/9896
2000-2004	50 %	78 %	15 %	5 %	3 % 4340/8670
2005-2009	51 %	80 %	11 %	5 %	3 % 5080/9925
2010-2014	49 %	81 %	12 %	4 %	3 % 4197/8586
2015-2016	29 %	84 %	10 %	3 %	3 % 864/2985

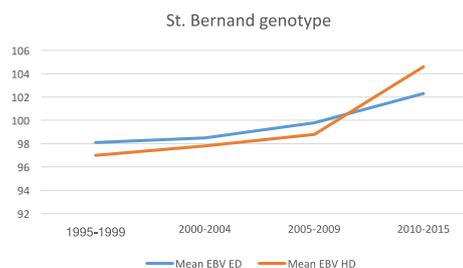
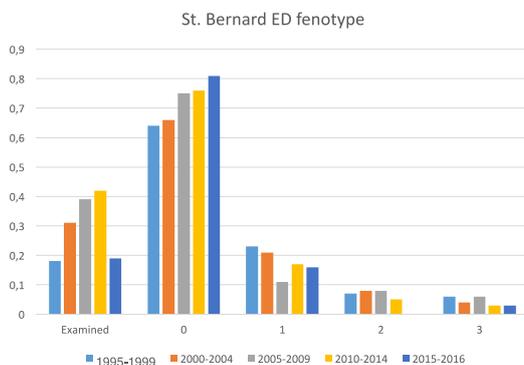
German Shepherd	Mean EBV ED	Mean EBV HD	n
Year of Birth			
1995-1999		98,9	99,3
2000-2004		100,7	100,7
2005-2009		103,1	102,6
2010-2014		105,9	105,9
2014-		107,6	110



## Statistics St. Bern. ED 1995-2016 2971/869

Year	Examined	0	1	2	3
1995-1999	18 %	64 %	23 %	7 %	6 % 213/1161
2000-2004	31 %	66 %	21 %	8 %	4 % 155/498
2005-2009	39 %	75 %	11 %	8 %	6 % 216/547
2010-2014	42 %	76 %	17 %	5 %	3 % 254/604
2015-2016	19 %	81 %	16 %	0 %	3 % 31/161

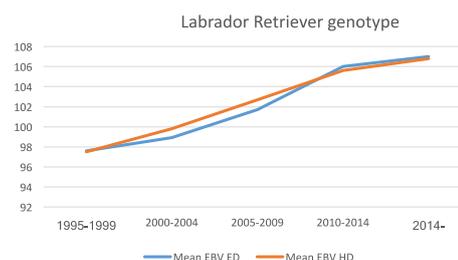
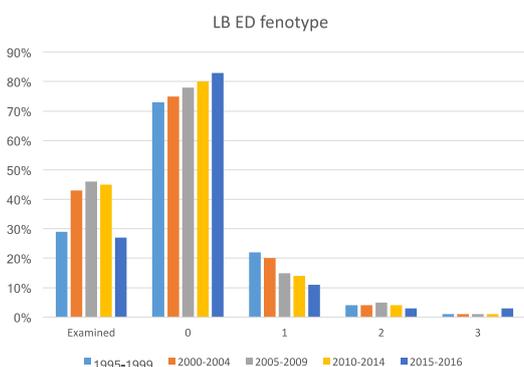
St Bernard	Mean EBV ED	Mean EBV HD	n
Year of Birth			
1995-1999		98,1	97
2000-2004		98,5	97,8
2005-2009		99,8	98,8
2010-2015		102,3	104,6
			298



## Statistics LB ED 1995-2016 28205/11218

Year	Examined	0	1	2	3
1995-1999	29 %	73 %	22 %	4 %	1 % 1800/6112
2000-2004	43 %	75 %	20 %	4 %	1 % 2354/5512
2005-2009	46 %	78 %	15 %	5 %	1 % 3273/7157
2010-2014	45 %	80 %	14 %	4 %	1 % 3101/6897
2015-2016	27 %	83 %	11 %	3 %	3 % 690/2527

Labrador Retriever	Mean EBV ED	Mean EBV HD	n
Year of Birth			
1995-1999		97,6	97,5
2000-2004		98,9	99,8
2005-2009		101,7	102,7
2010-2014		106	105,6
2014-		107	106,8
			1445



The change of ten EBV points corresponds to the shift from one letter to the other, and in the elbows a change of one class equals up to 20 index points. This is breed-specific, because it depends on what is the phenotypic standard deviation of each breed. One phenotypic deviation unit of ED is 0.49 points for Golden Retrievers (10 index points correspond to 0.49 digits in ED, when the score in elbows varies from 0 to 3), 0,55 for German Shepherd, 0,66 for Saint Bernard and 0,53 for Labrador Retriever.

The heritability estimates for elbow dysplasia used in Finnish Kennel Club EBVs are 0,24 for Golden Retriever, 0,24 for German Shepherd, 0,28 for Saint Bernard and 0,15 for Labrador Retriever.

Genetic improvement is also influenced by the accuracy of the EBVs. When the only information for a dog is its own screening results, the accuracy of the dog's EBV is the square root of the heritability. As the heritability of ED is 0.24 for Golden Retrievers, the accuracy of the EBV of a dog is therefore 49%, based on only the own screening result. It is very difficult to get for a hundred percent reliability in practice, as it requires dozens of screened offspring. Accuracy of the EBV is the best in those dogs with the largest number of screened descendants and other close relatives. The smallest accuracies are in dogs, that do not have their own screening results at all, and have only got their EBV based on their distant relatives. Imported dogs' EBVs are also often inaccurate as the results of their relatives screened abroad are not available in Finnish Kennel Clubs database.

For Labrador retrievers screening for ED has been mandatory for breeding animals since 2000, for German Shepherds since 2001, for Golden Retrievers since 2005 and for Saint Bernard since 2012.

Genetic progress occurs when breeding dogs are better than the breed average. Thus, combinations should be selected for breeding, where the mean EBV of the bitch and male is better than the mean of the whole breed, that is minimum 101. This average of the combination corresponds to the expected value of the puppies' EBVs. In addition to the EBVs, attention should be paid to phenotypic results. Breeding dogs should have ED 0. The breeding use of 1-elbows should not be done in Labrador Retrievers (Lappalainen et. Al., 2013) at least it should be well-grounded (at least a good EBV). 2- and 3-elbows should not be used for breeding at all.

A significant difference between the breeds on the hip and elbow scores has been detected in our dataset. The reported disparity of breeds might reflect the breed-specific nature of susceptibility to HD and ED (How, Y. et al., 2013). The large differences within and between breeds might in part be due to population differences (due to genetic drift), but other contributing factors are the large differences in screening protocols between countries, including sedation requirements during radiography, number and orientation of radiographic views required for scoring, percentage of the total population screened and the scoring system itself. A universal scoring system for both disorders with higher efficacy would be required in order to compare results across populations. Implementation of the use of EBVs as well as genome-wide association mapping and quantitative trait loci mapping to elucidate the genetic basis of both entities (Malm et al., 2008) could bring the effect of screening on prevalence on a higher level. (Lavrijsen et al., 2014).

A breed-specific breeding strategy has been mandatory in Finland for all breeds and has to be updated every five years for each breed since late 1990's, if the breed club wants to have any breeding restrictions (PEVISA). It analyses widely the whole breeding population and gives instructions and recommendations for breeders.

The Finnish Kennel Clubs open Database: Koiranet has also an English version <https://jalostus.kennelliitto.fi/frmEtusivu.aspx?Lang=en&R=111> . It is an essential database for Finnish breed clubs and individual breeders. You can find there for example the official health data for breeds and individual dogs and get all kind of statistics about a breeding dog or a whole breed.

This presentation has been done in co-operation with Finnish Kennel Clubs breeding specialist Katariina Mäki.

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# Explanation of grading according to IEWG and discussion of cases

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## Learning objectives

The diagnosis of canine elbow dysplasia (ED) in screening programs is based on the evaluation of radiographs according to the protocol of the **International Elbow Working Group (IEWG)**. The most recent update of this protocol is available on the IEWG website (<http://www.iewg-vet.org>). A mediolateral flexed projection of each elbow joint is mandatory for interpretation and an additional craniocaudal pronated view is highly recommended. The IEWG protocol allows for both registration of **arthrosis** and the presence of the major forms of **primary lesions**: FCP, OCD, UAP, INCONGRUITY. Radiographs are evaluated in a two-tiered procedure: joints are evaluated and graded according to the presence of arthrotic changes first and assessed for signs of a primary lesion in a second step. Any other abnormal finding should be reported too.

Arthrosis scores are assigned as **normal** (Grade 0) in the absence of arthrotic lesions or according to the height of osteophytes as either **mild** (Grade 1, osteophytes less than 2 mm in height), **moderate** (Grade 2, osteophytes 2 – 5 mm) or **severe** (Grade 3, osteophytes higher than 5 mm). In the updated protocol the severity of joint incongruity has been included.

The primary lesions **FCP, OCD, UAP, INCONGRUITY** have been defined by the IEWG (for details see the table below and IEWG website).

## Scoring (last updated 2010)

The elbow findings are scored according to the severity of the arthrosis (DJD) **and/or** the presence of a primary lesion

Elbow Dysplasia Scoring		Radiographic Findings
<b>0</b>	Normal elbow joint	Normal elbow joint, No evidence of incongruity, sclerosis or arthrosis
<b>1</b>	Mild arthrosis	Presence of osteophytes < 2 mm, sclerosis of the base of the coronoid processes - trabecular pattern still visible
<b>2</b>	Moderate arthrosis or suspect primary lesion	Presence of osteophytes 2 - 5 mm Obvious sclerosis (no trabecular pattern) of the base of the coronoid processes Step of 3-5 mm between radius and ulna (INCONGRUITY) Indirect signs for other primary lesion (UAP, FCP/Coronoid disease, OCD)
<b>3</b>	Severe arthrosis or evident primary lesion	Presence of osteophytes > 5 mm Step of > 5 mm between radius and ulna (obvious INCONGRUITY) Obvious presence of a primary lesion (UAP, FCP, OCD)

A Borderline (BL) score between ED 0 and ED 1 is allotted to dogs with minimal anconeal process modelling of undetermined aetiology in some countries (i. g. Germany, France, Italy).

ED scoring based on the combination of arthrotic changes and presence of primary lesions is used non-uniformly throughout Europe and overseas. In Scandinavia, UK and USA/Canada for example classification is based on the degree of arthrosis mainly, whereas the UAP is the only primary lesion recorded.

### **Radiographic views**

The minimal requirement for elbow joint scoring is a true ML projection of each elbow. As has been reported before two ML-projections, a flexed (40°) and a neutral (100° - 120°) position provide the best information regarding the medial coronoid process, incongruity, and presence of osteophytes. With high image quality even OC lesions may be recognized on ML views with reasonable consistency. With modest image quality many OC lesions go undetected on ML views. The by far best view to highlight medial trochlear OC lesions is the Cr Cd 15° pronated projection. Protocols lacking this view – as conducted in many European countries - approve the flaw of missing potential OC lesions depending on image quality.

### **Conclusion**

The IEWG scoring system is a two-tiered procedure, a) assessing the degree of arthrosis and b) registering any signs indicative of a primary lesion of ED. Bear in mind that various countries in Europe and overseas only rely on step a). Both concepts have proven to be useful in reducing ED in a population. However scoring systems based on step a) only are presumed to be less efficient and problems arise when dogs are to be used for breeding in countries with differing scoring system. In such a case it is advised to re-score the dog again according to the local scoring mode. It will be the aim of IEWG to harmonize the scoring systems in the future.



# International Elbow Working Group

The International Elbow Working Group [IEWG] was founded in 1989 by a small group of canine elbow experts from the USA and Europe to provide for dissemination of elbow information and to develop a protocol for screening that would be acceptable to the international scientific community and breeders.

The annual meeting is organized for the purpose of exchanging information and reviewing the Protocol. All interested persons are invited to attend the meeting and to participate in its activities.

The IEWG is an affiliate of the WSAVA.

## IEWG meetings were held in

Davis	1989
San Francisco	1990
Vienna	1991
Rome	1992
Berlin	1993
Philadelphia	1994
Konstanz	1995
Jeruzalem [cancelled]	1996
Birmingham	1997
Bologna	1998
Orlando	1999
Amsterdam	2000
Vancouver	2001
Granada	2002
Estoril	2003
Bangkok	2003
Rhodes	2004
Amsterdam	2005
Mexico	2005
Munich	2005
Prague	2006
Munich	2007
Dublin	2008
Sao Paulo	2009
Bologna	2010
Amsterdam	2011
Birmingham	2012
Cape Town	2014
Bangkok	2015
Vienna	2016
Verona	2017

## IEWG 2017

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