Canine Elbow Dysplasia

Ununited Anconeal Process, Osteochondritis Dissecans, and Medial Coronoid Process Disease

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KEYWORDS

- Elbow dysplasia • Medial coronoid process disease (MCPD)
- Ununited anconeal process (UAP) • Elbow OCD

KEY POINTS

- The genetic component that underlies the individual predisposition to develop elbow dysplasia is polygenic, involving multiple genes and without direct transmission.
- In association with medial coronoid process disease and persistent elbow incongruity, cartilage and subchondral bone changes involving the entire medial coronoid process and medial humeral condyle can be observed.
- Early diagnosis is possible in growing dogs; warning signs of dysplasia owing to medial coronoid process disease are represented by subtrochlear sclerosis of the ulna in the area of the affected medial coronoid process.
- In affected puppies and young dogs, the association of ulnar dynamic osteotomy to joint debridement is intended to improve the elbow congruity.
- Early treatment of ununited anconeal process has been widely shown to be effective in restoring the congruity, integrity, and biomechanics of the joint.

INTRODUCTION AND DEFINITION

Dysplasia of the elbow is a group of diseases involving the humeroradioulnar joint, including the injury or fragmentation of the medial coronoid process of the ulna (also referred to as fragmented medial coronoid process, osteochondritis dissecans (OCD) of the medial humeral condyle, the nonunion of the anconeal process of the ulna (ununited anconeal process [UAP]) and the joint incongruity, usually associated with medial coronoid process disease (MCPD), OCD, and UAP.[1–3] These orthopedic conditions can occur individually or in association with each other, further aggravating joint disease and affecting the long-term prognosis. Joint incongruity often accompanies the diseases listed, not only as a condition in itself, but also as a contributing factor to their development, in particular MCPD and UAP.[4–6]

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ETIOLOGY

The etiology of elbow dysplasia is considered to be multifactorial, with various causes, which determine its development to varying degrees. Incongruity, involving all 3 joint components, humeroradioulnar, asynchronous growth of radius and ulna and an endochondral ossification disorder, represent the most important pathogenetic factors in the determination of the different forms of elbow dysplasia.[2,3,7,8–10] The genetic component that underlies the individual predisposition to develop elbow dysplasia is polygenic, involving multiple genes and without direct transmission. Therefore, dysplasia is not expressed in all genetically predisposed subjects.[7,11–13] Environmental factors such as diet and type and amount of exercise which can worsen, but not cause dysplasia, are also involved in the expression of the severity of the disease. To date, the most recently published literature is not able to provide reliable data about the classification, etiology, or treatment of elbow dysplasia. One of the largest concerns is in regard to incongruity, because this is not necessarily a manifestation of elbow dysplasia, occurring also as a consequence of growth plates diseases, rather than being a main cause.[14–18]

In addition to the dysplastic forms, the elbow of the growing dog can be affected by other diseases, not included in the elbow dysplasia complex. Incomplete ossification of the humeral condyle, failed fusion of the medial condyle of the humerus, which is also described as ossification of the tendons and flexor muscles of the forearm.[2,3]

EPIDEMIOLOGY

Elbow dysplasia begins to occur in growing dogs, aged between 4 and 7 months of age, particularly in medium, large, and giant breeds. In adult dogs, the clinical signs are secondary to the osteoarthrosis that follows. Among the most affected breeds are the Labrador Retriever, Golden Retriever, German Shepherd Dog, Rottweiler, Bernese Mountain Dog, Great Dane, Dogue de Bordeaux, Chow-Chow, and Newfoundland.[9,19,20]

MEDIAL CORONOID PROCESS DISEASE AND OSTEOCHONDRITIS DISSECANS

By MCPD, we mean the formation of a separate osteocartilaginous fragment or a fissure or abrasion involving the cartilage and subchondral bone of the apex or incisor of the medial coronoid process[8] (**Fig. 1**). MCPD represents the most common form of elbow dysplasia; it can be observed as an isolated pathology or in association with OCD or less frequently with UAP.[21] The medial coronoid process of the ulna, completely cartilaginous at birth, reaches complete ossification around 20 weeks of age.[27] The disease becomes evident between the fourth and the seventh months, with differences regarding the species and the individuals. Both joints are commonly affected, many times with differing severity. Although the etiology is not fully known, most agree in considering joint incongruity in the early growing phase as a pathogenetic basis for the development of MCPD.[4–6]

In case of radioulnar incongruity with short radius and long ulna, the medial coronoid process is located slightly above the articular surface of the radius creating a step of 1 to 3 mm. In 2006, Lozier introduced a new pathogenetic theory, where it is possible to observe MCPD even if the ulna is shorter, because it develops later in growth.[23] According to the angular vector model, the radius (longer than the ulna) would cause an inclination of the humeral condylar axis to cause an increase in the load at the level of the medial humeral condyle and the medial coronoid process of the ulna. The radial head would dislocate proximally the lateral portion of the humeral condyle, forcing it

Fig. 1. Anatomic specimen of an elbow affected by MCPD, showing fragmentation of the apex of the medial coronoid process. Also shown are chondromalacia and erosion of the medial humeral condyle and of the trochlear notch of the ulna.

against the anconeous process, thus creating a fulcrum for rotation of the medial portion of the humeral condyle on the apex of the coronoid process. Regardless of the type of incongruity, the consequence is a maldistribution of the load forces, which are mainly directed toward the medial coronoid process of the ulna. In association with MCPD, cartilage and subchondral bone changes involving the entire medial coronoid process and medial humeral condyle can be observed, resulting in a "compartmental syndrome," [24]the maximum expression of an incongruent elbow joint (**Fig. 2**). The presence of MCPD is not always accompanied by an obvious joint incongruity at the time of diagnosis; the explanation could depend on an incongruity before fragmentation that resolved spontaneously during the residual growth of the dog.[24]

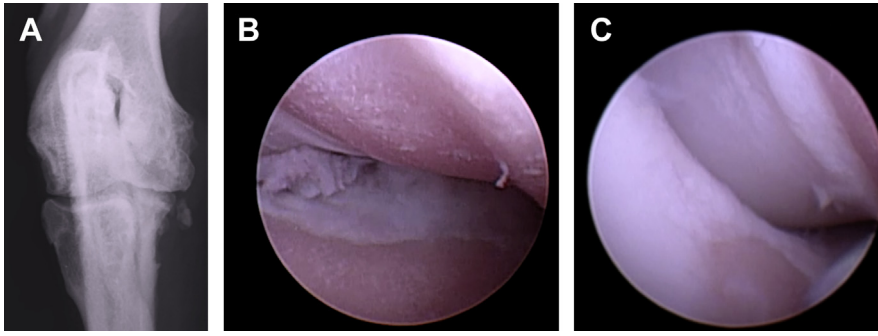

Fig. 2. Medial compartment disease of the elbow with severe erosion and subchondral bone exposure of the joint surfaces in the medial aspect of the joint. [*A*] Radiographic Cr-Cd view showing flattening of the medial condyle. [*B*] Arthroscopic view of the medial compartment with exposure of the subchondral bone. [*C*] Arthroscopic view of the neat separation between the lateral compartment with preserved cartilage and the medial compartment without cartilage.

Dissecting osteochondritis of the medial humeral condyle (OCD) is a manifestation of osteochondrosis (OC), or an enchondral ossification disorder, which results in a focal failure of the normal calcification process and vascular penetration into the epiphyseal cartilage.[25] This process results in cartilage thickening owing to a lack of evolution in bone tissue. Chondrocytes, given the lack of vascular supply, undergo necrosis and progressive weakening. At the articular level, this condition is manifested with initial cartilage fissure and formation of an osteochondral flap. The etiology is attributable to a set of genetic and environmental factors (rapid growth, nutrition, hormonal balance, physical activity, and microtrauma). The role of joint incongruity in the formation of elbow OCD is still unclear.[13] Often it overlaps with joint incongruity owing to a short radius, which causes an increase in weight loads at the medial humeral condyle level. The exposure of the subchondral bone in the synovial area and the degradation of the devitalized cartilage flaps trigger a series of reactive biochemical mechanisms that lead to synovial inflammation and arthritis. The breeds most likely to develop this disease are the Dogue de Bordeaux, Golden Retriever, Labrador Retriever, Bernese Mountain Dog, and Newfoundland.[19,20] Reported more often in males, OCD becomes evident between the fourth and the eighth months of life and affects both joints most frequently. When OCD is coexisting with MCPD and elbow incongruity, the prognosis is guarded (**Fig. 3**).

Diagnosis is made by palpation of the joint and radiographic examination. The prognosis varies from poor to good in relation to the severity of the lesion and the timeliness with which the treatment is initiated. In both MCPD and OCD, a medial collapse of the joint develops. Considering the offset of the ground reaction force with respect to the elbow, a straightforward conclusion follows that a medial larger offset will generate a larger moment in the frontal plane, which as an unavoidable consequence will cause compression of the medial compartment and tension on the lateral collateral ligament, leading to further medial friction.

Clinical Signs in Growing Dogs

The clinical presentation of dogs with MCPD and/or OCD is generally represented by lameness of varying degrees; the onset is progressive or acute. The first symptoms

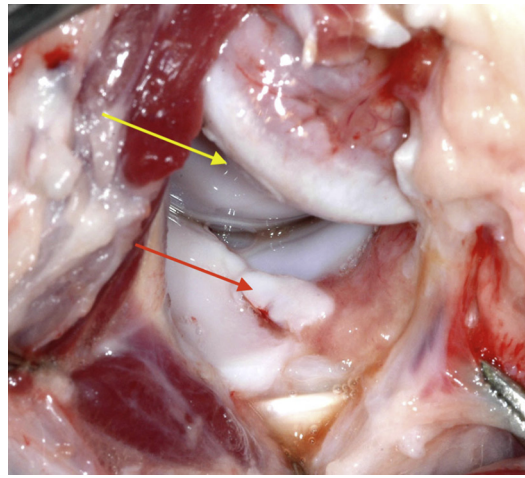

Fig. 3. Anatomic specimen of an elbow affected by both MCPD (*red arrow*) and OCD of the medial humeral condyle (*yellow arrow*).

Fig. 4. (*A*) Dogue de Bordeaux, male, 8 months, affected by bilateral OCD of the humeral condyle, showing an alteration in posture in the standing position with external rotation of the distal limbs, as an analgesic behavior (pseudovalgus). (*B*) Labrador, male, 7 months, with left elbow MCPD, showing a shift of the center of gravity on the healthy right limb.

can appear during the first 4 to 6 months of life of the dog. An alteration in posture in the standing position can be observed, represented by analgesic behaviors, such as external rotation of the distal limb (Fig. 4A), which mimics limb alignment defects, or in case of unilateral involvement a shift of the center of gravity on the healthy limb is observed (Fig. 4B). When the pathology affects both joints, lameness becomes less evident, with exercise intolerance, until one of the elbows get worse and lameness occurs.[9] Bilateral conditions, which are frequent, have a more subtle symptomatology, characterized by the absence of a discreet lameness in the initial phase and by an uncertain gait with a tendency to sit; in these dogs, joint pain then becomes more evident with time, with the progression of joint inflammation and the appearance of lameness.

The clinical presentation and findings of the orthopedic examination in OCD cases can be superimposed on what is described in the paragraph relating to the MCPD. It is important to understand that the extent of synovitis depends on the degree of exposure of the subchondral bone. In the event that the osteochondral flap has not yet occurred, and this happens only in the initial stages of OC, clinical signs could be silent.[24]

Physical Examination in Growing Dogs

At the orthopedic examination, the affected dogs show a painful response to external rotation of the carpus of the affected limb. Swelling of the lateral joint capsule under the anconeal muscle can be observed, in relation to the amount of synovitis owing to exposed subchondral bone (Fig. 5A). In the most chronic forms, thickening of the medial compartment of the joint will be palpated (Fig. 5B). As the lesions become chronic, one will appreciate the rearrangement of the bony prominence typical of

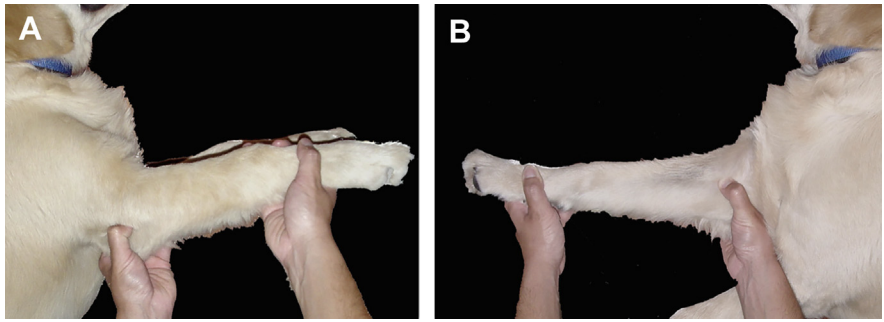

Fig. 5. (*A*) Swelling of the lateral joint capsule under the anconeal muscle can be observed in relation to the amount of synovitis owing to exposed subchondral bone. (*B*) In the most chronic forms, thickening of the medial compartment of the joint will be palpated.

the medial humeral epicondyle, which will be rounded and no longer pointed like in normal elbows. Variable reduction in joint excursion and crepitus during flexion and extension will be found related to the severity of the osteoarthritis that has developed. The physical findings of the orthopedic examination in OCD can be superimposed on what is described relating to the MCPD, elsewhere in this article. It is important to understand that the extent of synovitis depends the degree of exposure of the subchondral bone; therefore, of the osteochondral flap has not yet risen, and this happens only in the initial stages of OC, synovial ectasia could not be seen.[9]

Radiographic Findings in Growing Dogs

An early diagnosis is possible in growing dogs where the first warning signs of development of dysplasia owing to MCPD are represented by subtrochlear sclerosis (STS) of the ulna in the area of the affected medial coronoid process. STS is a bone reaction to joint inflammation and/or overloading. Owing to the frequency of bilateral disease, both elbows must always be examined, even in the case of apparent involvement of only 1 joint.

The following radiographic views are required:

- Mediolateral (ML) neutral view with the elbow at 120° (**Fig. 6**)
- ML neutral view with the elbow at 45° (**Fig. 7**)
- Craniocaudal (Cr-Cd) oblique view with pronation by 15° (**Fig. 8**)

It is necessary to carefully evaluate every detail regarding joint anatomy (**Fig. 9**) and congruity, subchondral sclerosis, and osteophytosis, taking into consideration that

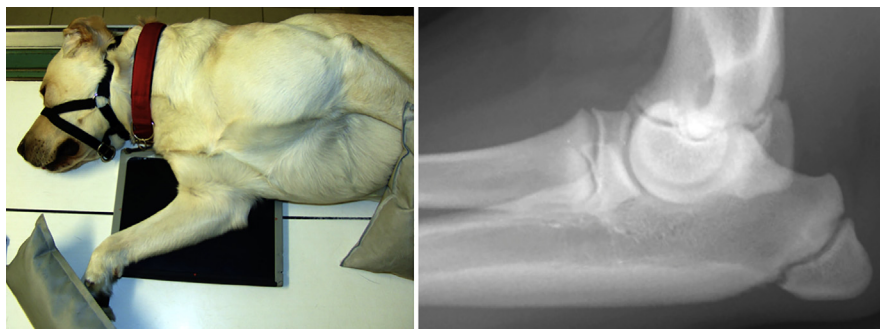

Fig. 6. ML neutral view with the elbow at 120°, keeping the carpus flexed to avoid supination.

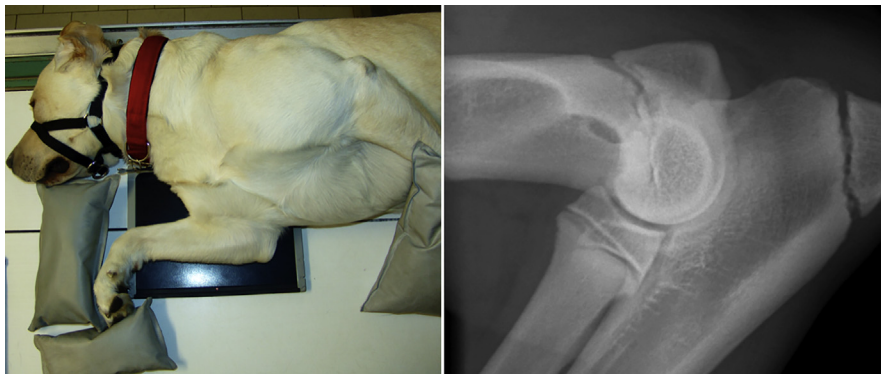

Fig. 7. ML flexed view with the elbow at 45°, keeping the carpus flexed to avoid supination.

slight signs during growth are most of the time a prelude to a dysplastic form that inevitably leads to more pronounced osteoarthritis signs.

ML view (Fig. 10)

- STS of the subtrochlear notch with loss of the trabecular pattern, obscured by a less defined increase in density.
- Loss of definition of the projection of the lateral coronoid process, obscured by the STS.
- Irregular silhouette of the projection of the medial coronoid process in the ML view
- Osteophytes formation starts over the profile of the anconeal process, the cranial border of the radial head, and on the profile of the lateral humeral condyle.
- Incongruity between the radius and ulna owing to a shorter radius can be seen in the neutral ML view. It is evidenced with a wider and uneven joint rim between the radial head and humeral condyle, and with a step between the radial head and the lateral coronoid process.

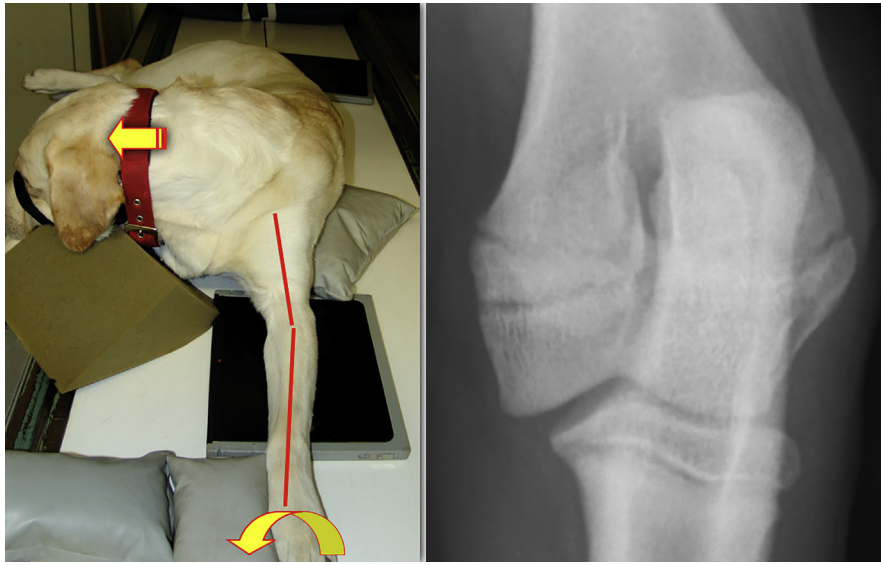

Fig. 8. Cr-Cd oblique view with protonation by 15°.

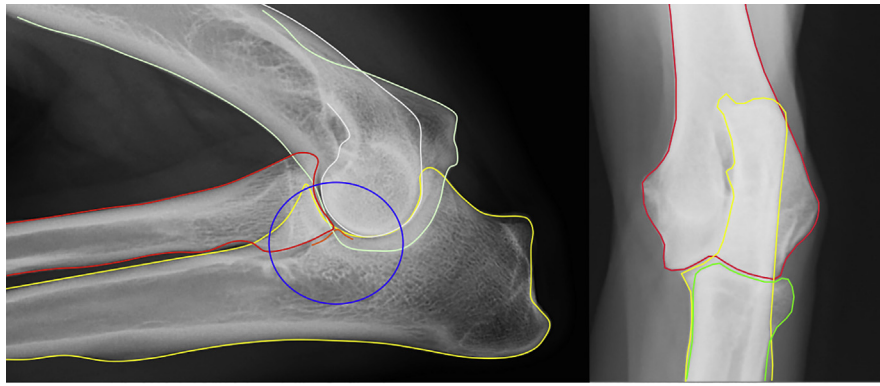

Fig. 9. Profiles of the bones in the elbow joint and their superimposition in the ML and Cr-Cd views. ML view: The *red line* delineates the radius; *yellow line* delineates the ulna, with medial coronoid process and anconeal process; *orange line* delineates the lateral coronoid process; and the *blue circle* indicates the subchondral trabecular pattern. The *pale green line* delineates the medial condyle and the *gray line* the medial humeral condyle. Cr-Cd view: The *red line* delineates the humerus, the *green line* the radius, and the *yellow line* the ulna.

- Less frequently, excessive narrowing of the radiohumeral joint associated to shorter ulna can be seen.

Cr-Cd oblique view (Fig. 11)

- Loss of density of the MCP projection and irregular profile
- Osteophyte formation with irregular profile over the profile of medial humeral condyle
- Incongruity between the radius and ulna owing to a shorter radius can be seen in the Cr-Cd view, with a step between the profile of the radial head and the profile of the ulnar articular surface

In normal elbow joints (in the neutral ML view) the subchondral area of the trochlear notch has a regular trabecular pattern without any bone sclerosis. In addition, the joint rim between the radius and the humeral condyle is thin and even (Fig. 12A). In the Cr-Cd view of normal elbows, the radial joint profile is continuous with that of the ulnar articular surface, without any step (Fig. 12B). The profile of the medial coronoid

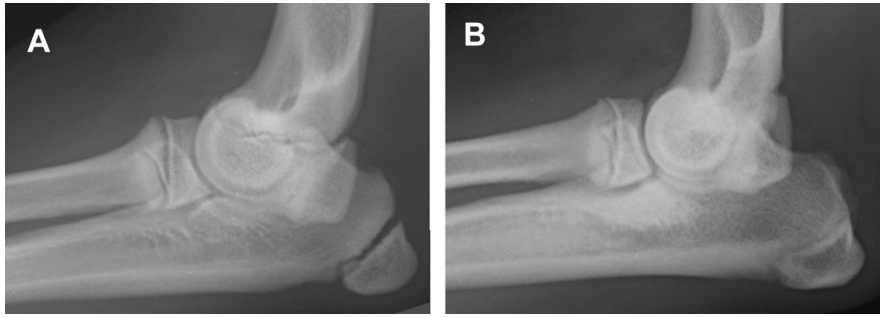

Fig. 10. (*A*) Normal trabecular pattern in the subchondral area of the ulna. (*B*) Subchondral sclerosis as a first sign of developing elbow dysplasia during growth.

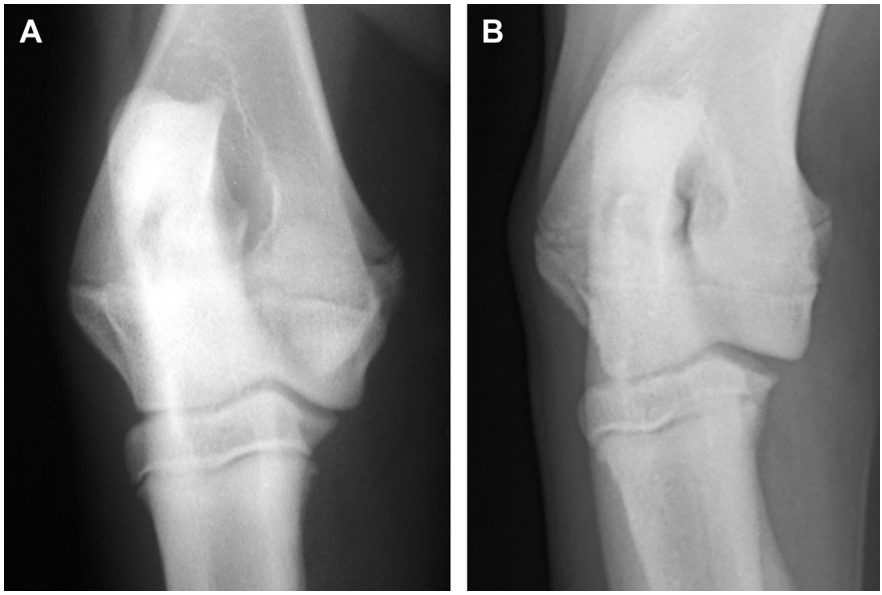

Fig. 11. (*A*) Normal profile of the medial humeral condyle and of the MCP of the ulna. (*B*) Loss of density of the MCP projection and irregular profile.

process and of the medial humeral condyle is well-defined and with a uniform radiographic density. Abnormalities, however minor, must be seriously considered because in most cases, these lesions will worsen as the dog grows.

Radiographic STS can be evaluated both visually and with objective measurement with digital assessment of bone mineral density using computer applications like the public domain application Image J (National Institute of Health, Bethesda, MD) (**Fig. 13**).[26–28] This process has been validated against dual energy x-ray absorptiometry studies in human studies,[29] comparing the bone density of 3 standard regions: the air, a metal bullet, and the subtrochlear region of the medial coronoid. Subtrochlear bone sclerosis is a consistent and direct sign of MCPD, owing to joint incongruity or malformation, as a consequence of joint inflammation and overloading of the MCP. In the elbow joint, it represents a very early and distinct sign of elbow dysplasia, regardless of whether incongruency is detected. Because elbow congruity can be altered by radiographic positioning, owing to physiologic joint laxity in growing dogs, subchondral bone sclerosis as a secondary sign of elbow incongruity is a more reliable sign that joint incongruity itself. As the lesion becomes chronic, the first osteophytes will become evident on the dorsal profile of the anconeal process of the ulna, on the head of the radius, on the medial coronoid process of the ulna in the ML view, and on the medial and lateral condyle in the Cr-Cd view (**Fig. 14**). In some cases, conventional radiology allows the observation of a fragment (**Fig. 15**). In questionable conditions, repetition of the radiographs after 2 to 3 weeks is usually diagnostic owing to the progression of the disease. A computed tomography scan, in contrast, provides a diagnosis of certainty in cases of doubtful radiographic diagnosis (**Fig. 16**).[30–32] A study is in progress correlating visual and digital evaluations of subtrochlear region in puppies and the final score of elbow dysplasia at adulthood. In **Fig. 17**, an example of a normal elbow joint at left of a 4-month-old Labrador (see **Fig. 17**A) is shown, compared with early signs of subtrochlear bone sclerosis in the center of a dog of

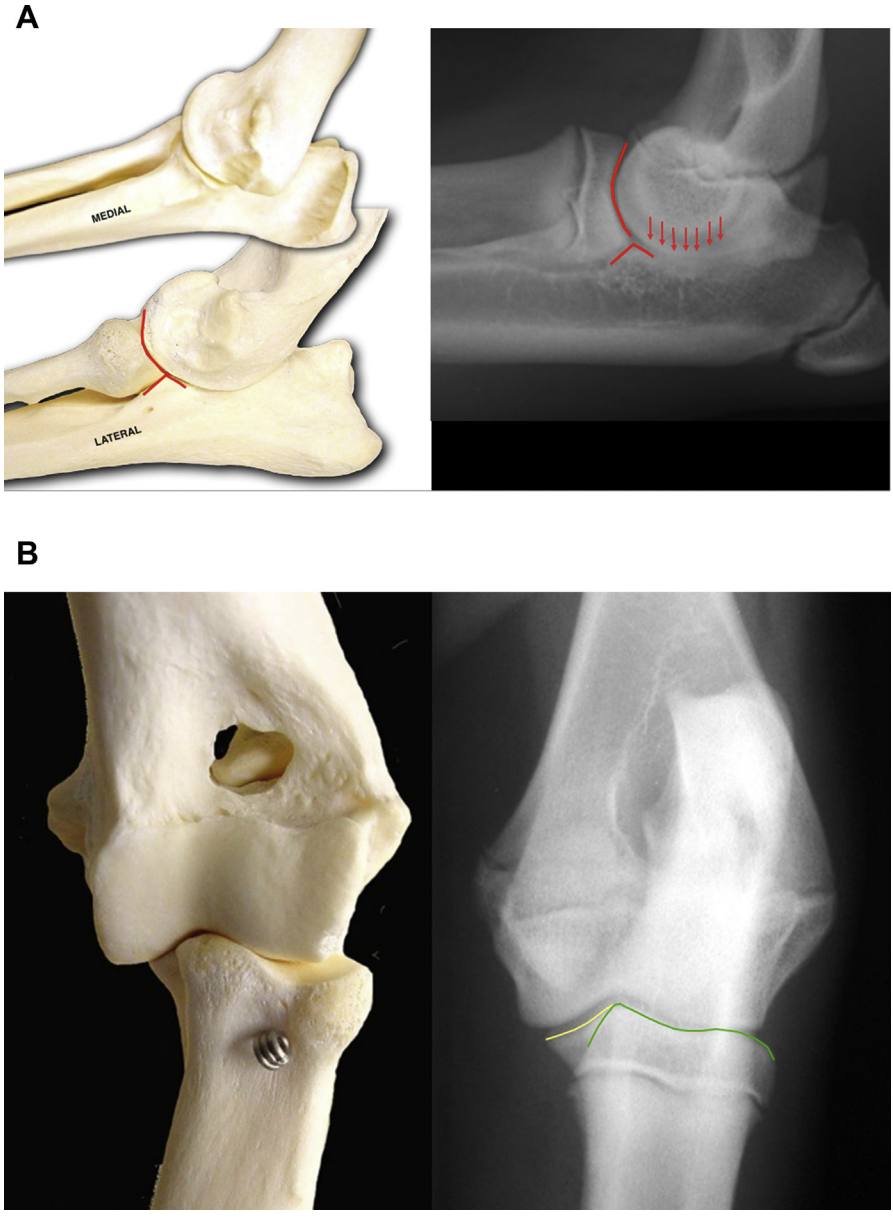

Fig. 12. (*A*) In normal elbow joints (in the neutral ML view) the subchondral area of the trochlear notch has a regular trabecular pattern without any bone sclerosis (*red arrows*). In addition, the joint rim between the radius and humeral condyle is thin and even, with congruity between the radial head and the lateral coronoid process (*red lines*). (*B*) In the Cr-Cd view of normal elbows, the radial joint profile is continuous with that of the ulnar articular surface, without any step.

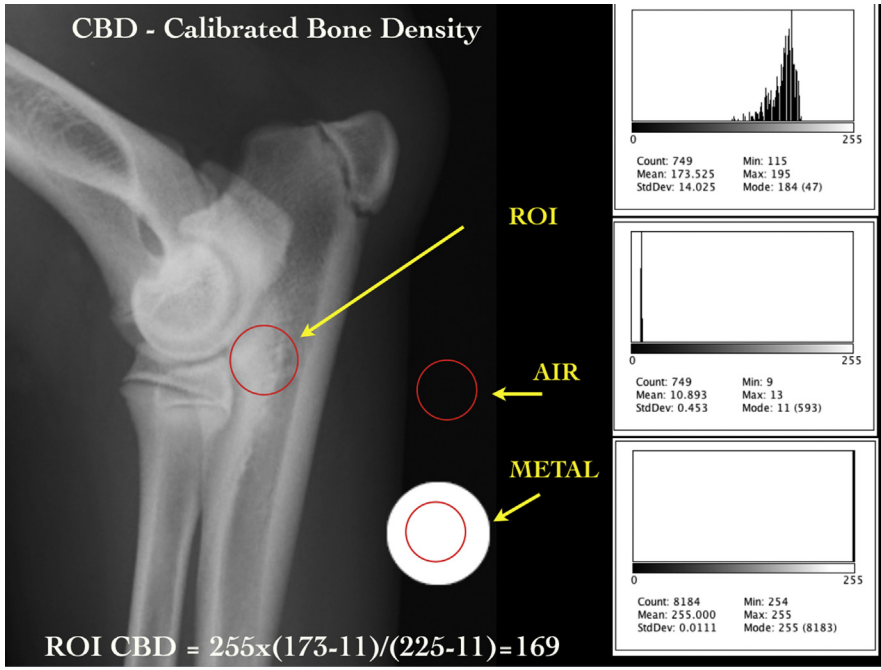

Fig. 13. Radiographic STS can be evaluated both visually and with objective measurement with digital assessment of calibrated bone mineral density using computer applications like the public domain application Image J. ROI, region of interest.

the same age and breed (see Fig. 17B), and a more advanced subtrochlear bone sclerosis at right of a 5-month-old Labrador (see Fig. 17C).

The radiographic study of OCD involves the execution of the same views described for the MCPD. Generally, the radiographic diagnosis of OCD of the medial humeral condyle does not present any difficulties.[33,34] We consider it extremely important to differentiate the initial forms of OC that do not require sudden treatment from forms

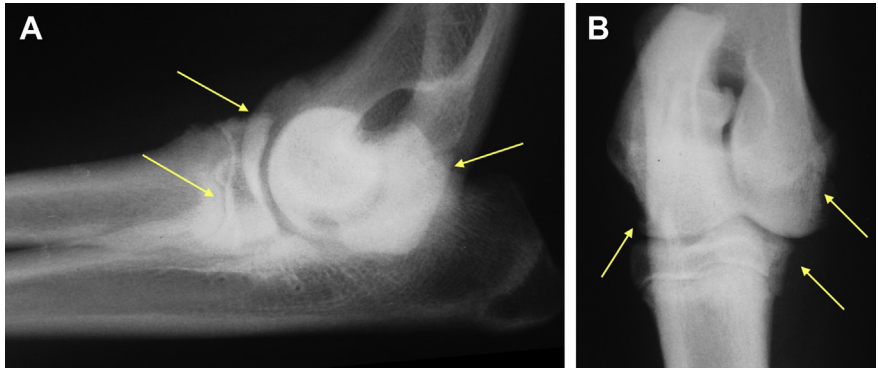

Fig. 14. As the MCPD becomes chronic, the first osteophytes will become evident on the dorsal profile of the anconeal process of the ulna, on the head of the radius, on the medial coronoid process of the ulna in the ML view, and on the medial and lateral condyle in the Cr-Cd view (*yellow arrows*). [*A*] ML view. [*B*] Cr-Cd view.

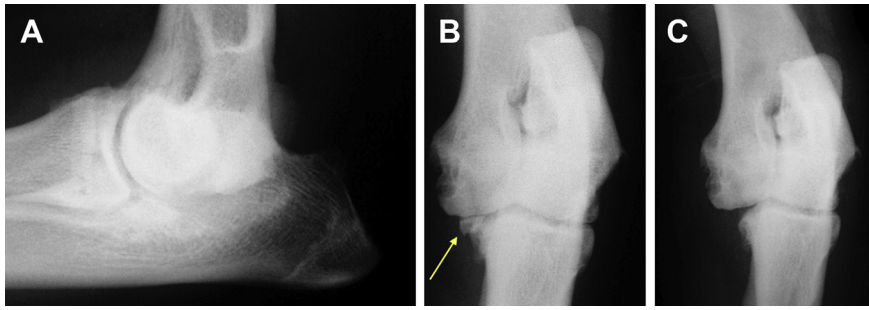

Fig. 15. In this case, conventional radiology allows the observation of a fragment of the coronoid process. [*A*] ML view with irregular shape of the MCP. [*B*] CrCd view showing the coronoid fragment. [*C*] CrCd view of the same elbow after removal of the coronoid fragment.

of OCD, in which a true osteocartilaginous flap has formed and is partly raised or still in place. In cases of OC, which can be seen in puppies 4 to 5 months of age, the only observable alteration is represented by the flattening of the profile of the medial humeral condyle, in the absence of radiolucency areas. In some cases, it is possible to highlight a real osteochondral flap associated with an underlying cuneiform

Fig. 16. A computed tomography scan provides a diagnosis of certainty in cases of doubtful radiographic diagnosis like in this Saint Bernard, female, 8 months, with doubtful STS in the radiograph, whereas the computed tomography scan shows the irregular shape and density of the MCP. (*Courtesy* Federica Rossi.)

Fig. 17. (*A*) Normal elbow joint of a 4-month-old Labrador. (*B*) Early signs of subtrochlear bone sclerosis in a dog of the same age and breed. (*C*) More advanced subtrochlear bone sclerosis of a 5-month-old Labrador.

radiolucent area, whereas in other cases only the irregularity of the joint profile of the humeral condyle and slight radiolucency are observed (Fig. 18).

Treatment of Medial Coronoid Process Disease and Osteochondritis Dissecans in Growing Dogs

In view of a preventive medicine approach for all developmental skeletal diseases—other examples include hip dysplasia and patellar luxation—early diagnosis is critical for successful treatment.[27] Early diagnosis, when the dysplastic process is just starting, could intercept the disease process at its early stage, even before clinical signs have manifested. Thereafter early diagnosis of MCPD allows prompt surgical treatment, which is aimed at restoring joint congruity. MCPD is assumed to be underlying the observed sclerosis, such that the progression of the disease and osteoarthrosis may be prevented or reduced. Because MCPD starts developing at 3.5 to 5.0 months of age in the medium to large breeds, and approximately 1 month later in giant breeds, early diagnosis of elbow dysplasia is possible if a routine orthopedic examination is carried out in susceptible breeds at 4 months of age in medium to large breed dogs and at 5 months of age in giant breed dogs, and immediately when the first signs of forelimb lameness or abnormal gait occur in any breed of dog. The early orthopedic evaluation can be planned to be coordinated with vaccine protocols. The goal is to detect the disease as early as possible, without waiting for clinical signs. When no elbow dysplasia is detected, further evaluation 1 month later is advised because elbow disease can develop slightly later on. When elbow dysplasia is detected, the disease is confirmed, and proper countermeasures can be undertaken.[27]

Early treatment of developing mild elbow dysplasia medial coronoid process disease and osteochondritis dissecans at 4 to 5 months of age with distal dynamic ulnar ostectomy

In 4- to 5-month-old dogs, initial MCPD is suspected when subchondral bone sclerosis of the subtrochlear notch is observed on the ML radiographic view, with or without lameness.[35] OCD is diagnosed when flattening of the medial humeral condyle is seen in the Cr-Cd radiographic view. In affected dogs, a distal dynamic ulnar ostectomy only can be performed without joint treatment. It is believed that this practice releases the pressure on the medial and lateral coronoid processes (definitive peer-reviewed data to support this observation in vivo are lacking at this time). The distal dynamic ulnar ostectomy procedure is performed subperiosteally by removing 4 to 5 mm of ulna with a rongeur, bite by bite, approximately 2 to 3 cm proximal to the distal ulnar physis (Fig. 19A, B). The operated puppies are rechecked clinically and radiographically 3 to 4 weeks later. In cases with persistent clinical signs and worsening radiographic lesions with osteophyte formation or with development of

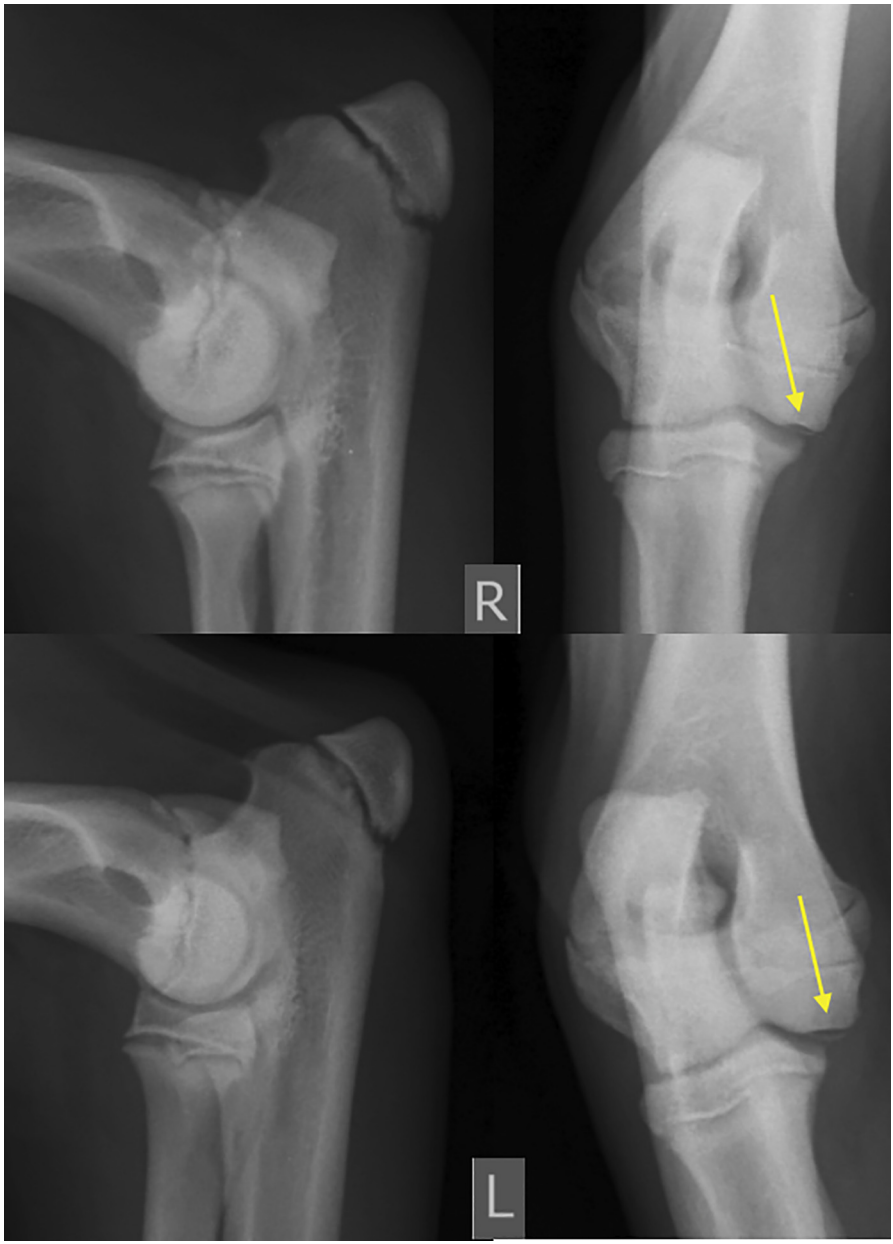

Fig. 18. Golden Retriever, female, 5 months, with a real osteochondral flap associated with an underlying cuneiform radiolucent area (*yellow arrows*).

an osteochondral flap, indicative of progression of the elbow dysplasia, conventional joint inspection and MCPD treatments are carried out with arthroscopy. In 4- to 5-month-old dogs with more severe clinical and radiographic signs suggesting advanced MCPD, we perform joint inspection and treatment with arthroscopy in

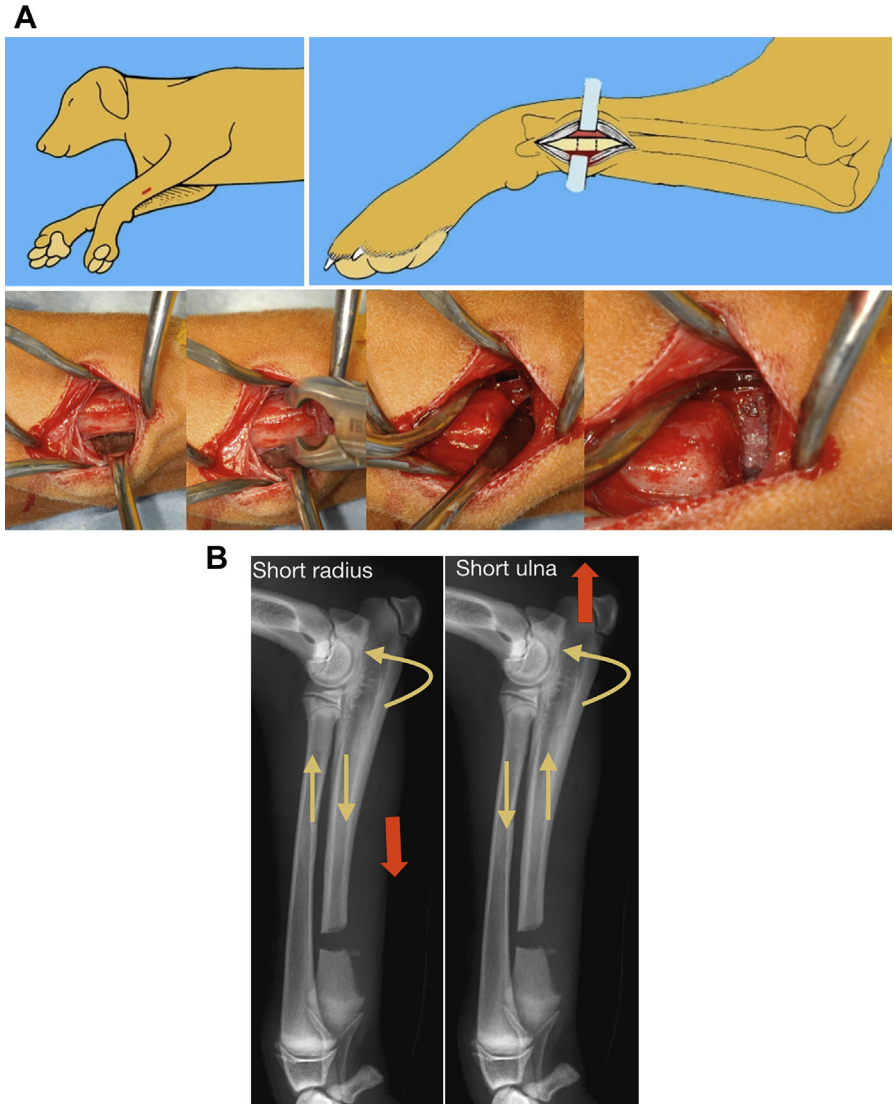

Fig. 19. (*A*) The distal dynamic ulnar ostectomy procedure is performed subperiosteally by removing 4 to 5 mm of ulna with a rongeur, bite by bite, approximately 2 to 3 cm proximal to the distal ulnar physis. (*B*) Spontaneous self-assessment of the joint congruity after distal dynamic ulnar ostectomy. In case of elbow incongruity owing to short radius, the weight bearing forces will lower the proximal ulna at the level of the radial head inside the joint. In case of short ulna, the pull of the triceps muscle will raise the ulna at the level of the radial head inside the joint. Torsional forces applied by muscles will improve joint congruity after distal dynamic ulnar ostectomy (*curved arrows*). [*A*] *Adapted from* Schultz KS, Hayashi K. Management of specific fractures. In: Fossum TW, editor. Small Animal Surgery. 2nd edition. Philadelphia (PA): Mosby; 2002:901-1022; with permission.

conjunction with proximal dynamic ulnar osteotomy (which we feel is more effective than distal dynamic ulnar ostectomy in advanced cases of elbow dysplasia).

In the authors personal unpublished data of 136 elbows with STS at 4 to 5 months of age, a follow-up evaluation revealed that in most cases osteoarthritis continued to progress to a varying degree according to the International Elbow Working Group[36] classification in 3° of severity (41% grade 3, 33% grade 2, 24% grade 1, and 2% grade 0) after conservative management alone (**Fig. 20**). In contrast, in 141 elbows with the same early radiographic signs and treated very early with distal dynamic ulnar ostectomy, there was less severe (or no) progression of osteoarthritis in most cases (4% grade 3 and 4% grade 2 requiring further surgical treatment, 80% grade 1, and 12% grade 0). Distal ulnar ostectomy is 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. Damage to the interosseous vessels 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 with moderate to severe medial coronoid process disease with bioblique dynamic proximal ulnar osteotomy at 5 to 12 months of age

In more severely affected puppies and in young dogs up to 12 months of age, presenting with different degrees of lameness, our approach is intended to improve elbow congruity and possibly decrease the unavoidable progression of osteoarthritis caused by the cartilage and subchondral bone lesions. Since 2012, the author has added a bioblique dynamic proximal ulnar osteotomy as suggested and later described by Fitzpatrick and colleagues[37] to the arthroscopic treatment of MCPD whenever cartilage damage is seen in the medial compartment. Oblique proximal osteotomy of the ulna, without fixation, will tend to lateralize the paw and thus unload the medial compartment. When the medial coronoid process fragmentation is the only lesion

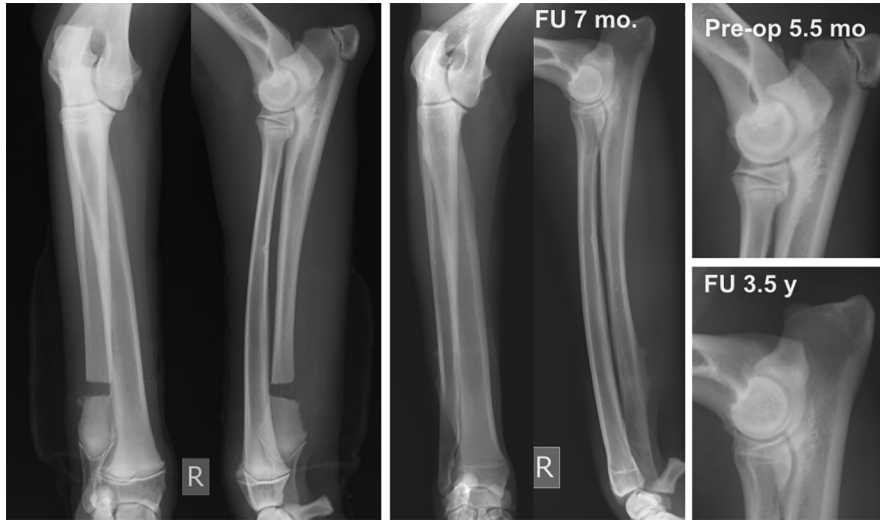

Fig. 20. Labrador, male, 5.5 months, with marked STS and treated with distal dynamic ulnar ostectomy. At 7 months, the STS is cleared and in the follow-up (FU) after 3.5 years the elbow has only minimal signs of osteoarthritis.

found in the joint, which is unusual, the treatment is limited to the arthroscopic removal of the fragments.[36]

In dogs up to skeletal maturity, between 5 and 12 months of age, without any medial compartment disease assessed at the arthroscopic inspection, being an unusual finding, fragmented coronoid process removal or regional debridement only is performed. In the more frequent condition where MCPD is associated with even mild medial compartment disease, bioblique dynamic proximal ulnar osteotomy can still improve joint congruity and the outcome. To decrease the morbidity and prolonged healing time associated with transverse proximal ulnar osteotomy, a maximal obliquity of the osteotomy (**Fig. 21**A, B) should be executed in the proximal midshaft of the bone, as described by Fitzpatrick and associates,[37] with a bioblique direction (caudoproximal to craniodistal and proximolateral to distomedial). This practice limits caudal and varus tilting of the proximal ulna under the triceps pull. With this bioblique dynamic proximal ulnar osteotomy performed at this range of age, we observed a quick healing of the osteotomy 1 to 2 months after surgery, with complete remodeling at 4 to 8 months. Although joint degenerative signs persisted at the follow-ups, a significant decrease of subtrochlear bone sclerosis and improved function were observed consistently. The varus deformity of the proximal ulna decreases the load on the ulnar joint surface.[37–39]

The author performed arthroscopic MCP debridement with bioblique dynamic proximal ulnar osteotomy on 117 dogs with MCPD with medial compartment disease between July 2012 and June 2015.[36] Eighty-three cases were reevaluated with a minimum of 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, and 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%,

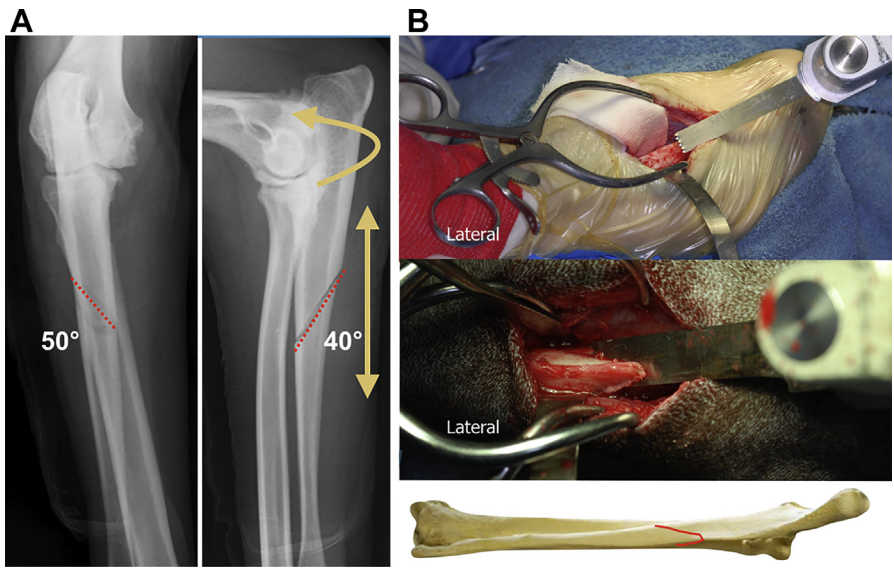

Fig. 21. (*A*) Bioblique dynamic proximal ulnar osteotomy with maximal obliquity of the osteotomy should be executed in the proximal midshaft of the bone, as described by Fitzpatrick and associates,[3] with a bioblique direction: at the left proximolateral to distomedial and at the right caudoproximal to craniodistal. (*B*) A long and narrow oscillating saw blade is required to perform the osteotomy with maximal obliquity in the 2 planes.

and a poor outcome in 5% of the cases. The poor outcome was seen in dogs with combined a fragmented coronoid process and OCD. Nevertheless, the long-term prognosis remains reserved and the owners should be instructed to perform regular rechecks, decrease high-impact physical activity, avoid any type of sporting or working activities, and maintain a slim body habitus.[36]

Complications after Dynamic Ulnar Osteotomies

- Complications in cases of distal ulnar ostectomy
  - Premature closure of distal ulnar physis can occur when the ostectomy is too close to the growth plate (<2 cm). In such a case, antebrachial deformity could occur with distal radial deviation in valgus and procurvatum, possibly requiring radial corrective osteotomy.
  - Synostosis can occur when the ostectomy involves the transcortex periosteum and the radial periosteum. This complication is more likely to occur when the ostectomy is performed with an oscillating saw blade instead of using a rongeur. Radioulnar synostosis impairs pronation and supination of the distal forelimb and can be a cause of lameness. When synostosis is limited to a small area and causes lameness, it can be removed surgically, but with the risk of secondary new synostosis.
  - Caudal tilting of the proximal segment could occur when the ostectomy is performed too proximal (>3 cm from the physis), favored by uncontrolled physical activity.
  - Nonunion or delayed union could occur when the ostectomy is performed in older dogs (>6 months of age).
  - A lack of efficacy in restoring joint congruity when the osteotomy is performed at 6 months of age or later, requiring further surgery (proximal dynamic bioblique ulnar osteotomy, proximal abducting ulnar osteotomy, etc).
  - Wrong case selection, without indication for dynamic ulna osteotomy because of misinterpretation of early signs of elbow dysplasia.[40]
- Complications in case of proximal ulnar ostectomy
  - The risk of causing excessive caudal and varus tilt and dislocation of the proximal ulnar segment can be secondary to the lack of owner compliance and consequently an excessive and uncontrolled physical activity or to surgical error, represented by a short oblique, or even worse, to a transverse ulnar cut. The use of a narrow and long blade, usually 9 cm long and 9 mm wide, is needed to obtain the required obliquity, which should be from 40° to 30° to the caudal ulnar surface. Severe tilt of the proximal segment could be associated with radial head luxation. This complication could result in a similar condition as a Monteggia fracture. The treatment of this type of complication depends on the amount of dislocation and on the timeline of diagnosis; reduction and fixation with an intramedullary pin, with or without tension band wiring, is required in the case of an early and severe dislocation. The cortical nature of the proximal ulnar segment predisposes this type of osteotomy to an increased risk of delayed healing in mature dogs. It is for this reason that the proximal dynamic bioblique osteotomy is not recommended after 12 months of age (skeletal maturity). Single session bilateral treatment dramatically increases the risk of proximal ulnar dislocation and for this reason, must be avoided. In case of bilateral condition, the 2 surgical interventions should be staged about 3 or 4 weeks apart, depending by the age of the dog.
  - Synostosis between radius and ulna could occur if the long interosseus ligament is involved, particularly in immature dogs.

- Inadvertent radial osteotomy could occur, either partial or complete. A proper surgical technique that protects the radius with a malleable retractor eliminates the risk of performing a radial cut and of radioulnar synostosis. A modest (15°) lateromedial direction of the osteotomy will help to avoid the radius distally. In cases of a partial radial incision, immediate radial plating could be required.
- Too rapid of healing of the osteotomy could prevent adequate improvement of joint congruity. It could occur in the case of an incomplete osteotomy or without cause, requiring a repeat of the osteotomy.
- Delayed union could occur in more mature dogs (>9 months of age), requiring 2 to 3 months to heal completely.
- Nonunion is unlikely to occur in dogs up to 12 months of age, but it could be a serious complication in adult dogs, requiring strong plate fixation and bone grafting, with a reserved prognosis.[40]

MEDIAL CORONOID PROCESS DISEASE AND OSTEOCHONDRITIS DISSECANS IN ADULT DOGS

Chronic osteoarthritis as a consequence of MCPD and OCD of the elbow is very frequent in dogs belonging to the breeds predisposed to develop elbow dysplasia. As with all degenerative joint diseases, the progression of osteoarthritis is correlated to the time and intensity of physical activity as well as increases in body weight. The main predisposing condition for the progression of osteoarthritis in elbow dysplasia is the persistence of joint incongruity with persistent uneven joint loading, leading to medial compartment disease. The collapse of the joint space in the medial compartment leads the dog to bring the limb into adduction, increasing the erosion of the medial compartment over time. Subchondral bone exposure owing to continuous contact and overloading of the joint surfaces causes heat with synovial necrosis and permanent stimulation of the biochemical factors of osteoarthritis.[24,41,42]

Clinical Signs in Adult Dogs

Forelimb lameness can be evidenced as an exacerbation of a chronic latent condition in relation to physical activity, stressful movements, or an increase in body weight. Bilateral conditions could be overlooked for several years owing to severe worsening of osteoarthritis in one of the elbows, leading to 1-sided lameness. In elderly dogs the condition could worsen to end-stage elbow dysplasia, with persistent lameness.

Physical Examination in Adult Dogs

On palpation, the elbow joint will seem to be thickened because of periarticular fibrosis and osteophytes. On manipulation, the amplitude of the range of motion will be decreased, especially in flexion. Crepitus could be present during flexion and extension, because of the osteophytes.

Radiographic Findings in Adult Dogs

The standard radiographic examination of the elbow joint involves 2 ML views, with the elbow in neutral position (about 110°) and flexed (about 45°), and a Cr-Cd view with about 15° of protonation the radiographic examination will show all the typical osteoarthritis changes induced by the underlying MCPD and/or OCD.[31]

In the ML views, the usual findings are (**Fig. 22**) as follows:

- Osteophytes on the ridge of the anconeal process
- Osteophytes on the cranial margin of the radial head
- Osteophytes on the ridge of the lateral condyle

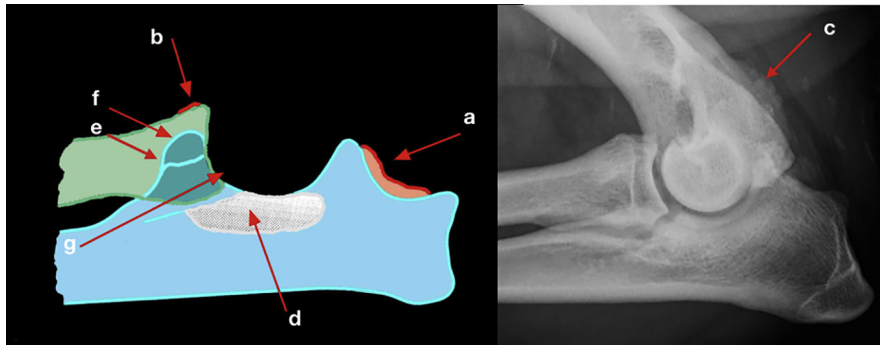

Fig. 22. In the ML views, the usual findings of MCPD are (a) osteophytes on the ridge of the anconeal process, (b) osteophytes on the cranial margin of the radial head, (c) osteophytes on the ridge of the lateral condyle, (d) STS, (e) abnormal silhouette of the medial coronoid process, (f) tip of the medial coronoid missing (blunting), and (g) uneven joint space between radius and ulna and between radius and humeral condyle.

- STS
- Abnormal silhouette of the medial coronoid process
- Tip of the medial coronoid missing (blunting)
- Uneven joint space between radius and ulna and between radius and humeral condyle

In the Cr-Cd view with 15° of protonation, the usual findings are (Fig. 23) as follows:

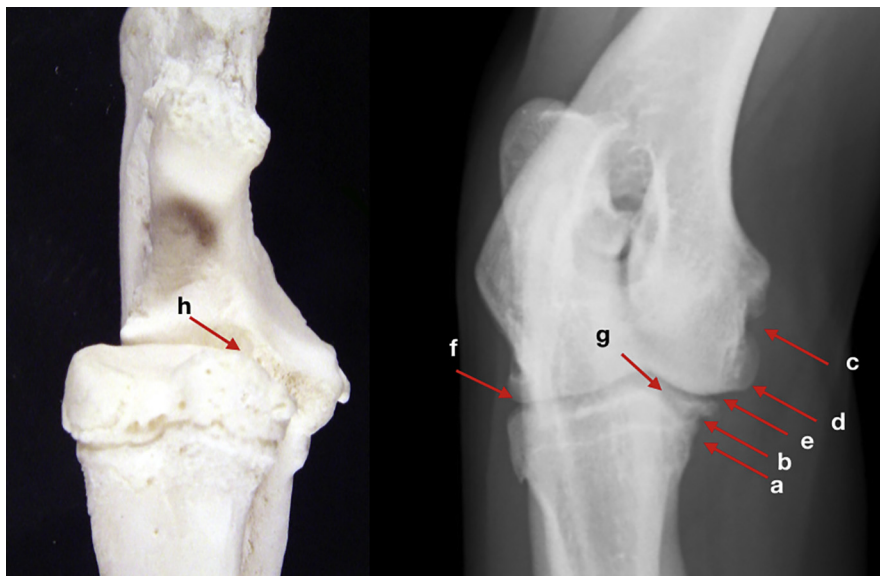

Fig. 23. In the Cr-Cd view with 15° of protonation, the usual findings of MCPD are (a) irregular profile of the medial coronoid process, (b) osteophytes on the medial surface of the medial coronoid, (c) irregular profile of the medial condyle, (d) loss of convexity (flattening) of the medial humeral condyle, (e) reduced joint space in the medial compartment, (f) increased joint space in the lateral compartment, (g) dislocated fragment of the medial coronoid process, and (h) incongruity between the radial head surface and the medial coronoid.

- Irregular profile of the medial coronoid process
- Osteophytes on the medial surface of the medial coronoid
- Irregular profile of the medial condyle
- Loss of convexity (flattening) of the medial humeral condyle
- Reduced joint space in the medial compartment
- Increased joint space in the lateral compartment
- Dislocated fragment of the medial coronoid process
- Incongruity between the radial head surface and the medial coronoid

The severity of the radiographic signs is variable according to the chronicity and severity of the disease. With MCPD, a real fragment is not always radiographically evident; more frequently, signs of secondary osteoarthritis are seen. Flattening of the medial humeral condyle can be due to chronic OCD or to erosion of the joint surface owing to medial compartment disease with medial collapse.[24,31,42]

Treatment of Medial Coronoid Process Disease and Osteochondritis Dissecans in Adult Dogs

The therapeutic approach differs based on the age of the dog, the degree of osteoarthritis present, the type of injury, and the choice of the surgeon.[43,44] The following is the approach used by the authors.[36]

- Conservative therapy is considered first in adult dogs with symptoms related to osteoarthritis evolution: weight reduction, limited activity and nonsteroidal anti-inflammatory drugs in cycles as needed. 15% reduction of body weight has been shown to be equivalent to nonsteroidal anti-inflammatory drug daily administration in a study published by Impellizzeri and colleagues.[45]
- Surgical treatment is performed when the conservative management is unsatisfactory. Joint inspection and local treatment can be performed by arthroscopy or traditional surgery. Arthroscopy allows one to view the joint in full, evaluate the extent of the cartilage damage associated with the MCPD and medial compartment disease, to distinguish different types of fragmentation, and to choose the best therapeutic approach. To date, the joint treatment involves the removal of the osteochondral fragment pertaining to the medial coronoid process or total/subtotal coronoidectomy. The MCPD, for the purposes of its treatment, should be considered not a pathologic form in its own right, but the symptom of a much more complex pathology, which unfortunately is still unclear to date. Persistent joint incongruity of the joint surfaces could be the end result. Whatever the treatment (removal of the fragment, coronoidectomy) and the method of execution (arthroscopy or arthrotomy), in most cases the osteoarthritis evolution secondary to the primary pathology will not be stopped, but only decreased at best.[44,46]
- In cases of OCD after the removal of the diseased cartilage, the sclerotic bone underlying the lesion can be activated by micropicking (few punctures with an awl, for a depth of 2 mm, spaced 2–3 mm apart) to favor the exit of mesenchymal cells and the formation of reparative fibrocartilage. It is not recommended to do this procedure when spurs of fibrocartilaginous tissue are already present.
- New surgical proposals for medial compartment disease are discussed in other sections of this issue. A number of different corrective osteotomies have been proposed and practiced to treat the condition. Most recommendations are based on observing incongruities within the joint, and are always meant to avoid the medial component of the ground reaction:
  - Elongation of the radius by an oblique proximal osteotomy (proposed by Slocum in 1998),[47] stabilized by a plate, will tend to lateralize the paw and thus

decrease the medial offset of the ground reaction and hence unload the medial compartment. This process will only occur if the interosseous ligament is sufficiently compliant—if not, the outcome may be the opposite.

- Sliding humeral osteotomy, proposed by Mason and Schulz in 2008[48] and originally based on shifting the action of the triceps, incidentally, results in lateralization of the distal forelimb; Fitzpatrick and colleagues[49] have published a report suggesting a significant clinical improvement, but the risks of the procedure may be limiting its wider acceptance.
- Proximal abducting osteotomy of the ulna proposed by Pfeil and Tepic in 2007.[50] Stabilized by a stepped plate, imposing a shift with abduction and incidental rotation of the ulna, which adds to lateralization of the distal limb and thus to unloading of the medial compartment (**Fig. 24**).

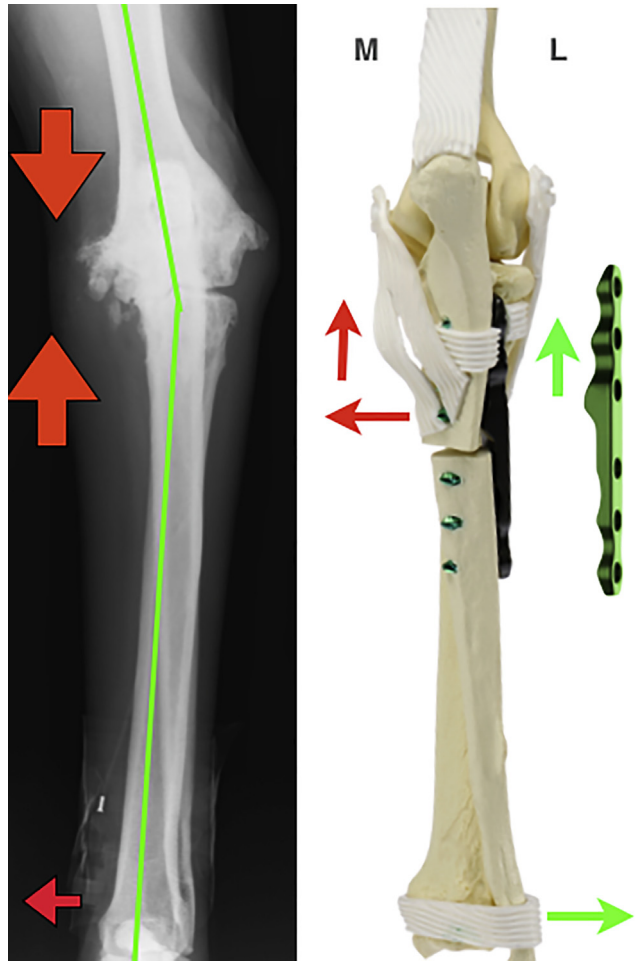

Fig. 24. Proximal abducting osteotomy of the ulna proposed by Pfeil and Tepic in 2007. Stabilized by a stepped plate, imposing a shift with abduction and incidental rotation of the ulna, adds to the lateralization of the distal limb and thus to unloading of the medial compartment.

- Rotational osteotomy of the humerus (proposed by Tepic in 2011) aims at shifting the distal limb laterally—in vitro demonstration has yet to be confirmed by surgery in clinical cases.[51,52]
- Midshaft radius abducting and elongating osteotomy (proposed by Tepic in 2011) fixed by medial plating is independent of the condition of the interosseous ligament and should, in all cases, led to lateralization of the distal limb and may be the method of choice in cases of the short radius.

- Resurfacing techniques and joint arthroplasties will be presented in another section of this issue:, the most common being as follows:
  - Canine unicompartmental elbow developed by Cook and Schulz in 2014[53,54]
  - Total elbow arthroplasty (Randy Aker, 2007, Tate, BioMedtrix)[55]
  - Partial elbow arthroplasty, involving the medial compartment only (Kirk Wendelburg, 2011, Kyon, still in clinical trials)[56,57]

End-stage medial compartment disease, occurring in older dogs, unresponsive to medical management as often seen in elderly age, can be treated with radiotherapy with a single application of 10 Gy with improved function for several months.[58] In another study lower dosage was used, 3 application every 48 hours of 2 Gy. Clinical improvement was observed in 92% of patients with median benefit duration of 356 days after the first treatment, and 418 days after the second treatment. No side effects were recorded.[59]

NONUNION OF THE ANCONEOUS PROCESS

UAP is a well-recognized disease affecting young growing dogs of several large and giant breeds. A high incidence has been reported in the German Shepherd Dog, and moderate to low incidence in Great Dane, Newfoundland, Black Russian Terrier (Tchorny Terrier), Saint Bernard, Basset hound, Greyhound, Italian Spinone, and Italian Cane Corso.[19,20,60] Unlike small breed dogs, which do not have a separate center of ossification,[61] a separate center for the anconeal process does exist in breeds such as the ones listed.[62,63] The anconeal process fails to unite with the proximal ulna during the first months of skeletal growth. In Greyhounds, this is ossified by 14 to 15 weeks but takes longer to ossify (16–20 weeks) in German Shepherd Dogs.[22,64] Failure to ossify after 20 weeks of age is termed “ununited.” In a personal study performed in German Shepherd Dog puppies, the anconeal process was fused with the ulna at 15 weeks of age in females and at 16 to 17 weeks in males.[60] Nonunion of the anconeal process and persistent joint incongruity lead to joint instability, cartilage erosion and degenerative joint disease. An ununited anconeal process is the oldest known cause of elbow dysplasia and it was first described by Steirn, albeit under the term *patella cubiti*, in 1956.[65,66] The term UAP was first reported in 1959.[61] Several hypotheses regarding its pathogenesis have been proposed. The most accepted is asynchronous growth of the radius relative to the ulna in the early growing phase, which causes proximal displacement of the radial head and subsequent abnormal pressure on the anconeal process by the humeral trochlea when ulna is shorter than radius.[67] This process prevents bone union of its ossification center. Asynchronous growth may be related to genetic regulation and to rapid body growth. The antebrachial growth plates are different in the radius and ulna, with 2 distinct physes in the radius (proximal and distal) and 1 physis in the ulna, distally. Asynchronous growth of the radius and ulna can result in a shorter than normal ulna in the first phase of growth (up to 4–5 months of age) and a shorter than normal radius in the subsequent growth phase (5–6 months of age). Both may occur in the same dog, resulting in different diseases at different times of development (UAP and fragmented coronoid

process).[21,64] Excision of the ununited process does not prevent the progression of degenerative joint disease because the permanent joint instability and incongruity are not corrected.[69,70] Screw fixation alone of the process without correction of the joint incongruity is not successful and usually leads to fixation failure. In accordance with the pathogenesis of UAP, a lengthening osteotomy of the proximal ulna has been shown to relieve the pressure on the anconeal process. This procedure allows the process to unite with the ulna, with or without screw fixation, depending on the stage of disease and different practitioners' preferences.[71,72] To achieve the same result without screw fixation, the anconeal process should still be firmly connected to the ulna by fibrocartilaginous tissue. The younger the dog, the greater the possibility that the process will fuse. With time and physical activity, the process will eventually become very loose or completely free in the joint, eliminating the possibility of fusion. The goals of treatment are fusion of the anconeal process and restoration of joint congruity before the establishment of osteoarthritis. Thus, an early diagnosis is essential for successful treatment of this condition and for preventing secondary degenerative joint disease associated with UAP.

Ununited anconeal process with persistent joint incongruity is a potentially devastating joint disease because of the risk of severe osteoarthritis over the time, which usually leads to chronic pain and functional impairment of the affected elbow. Early diagnosis and treatment of this condition is fundamental to obtain fusion of the anconeal process, restore joint congruity and prevent further osteoarthritis.[60] A complete understanding of the evolution of UAP aids in choosing the best treatment, which is aimed at fusion of the process and correction of joint incongruity.

Clinical Signs in Growing Dogs

The UAP manifests itself with a variable degree of lameness that occurs around 4 to 10 months of age of the dog. The symptoms could occur later in life, with acute onset without a previous history of lameness. In a standing dog, a constant shift of the center of gravity in unilateral cases and the abduction of the elbow is observed.[67,68]

Findings at Physical Examination in Growing Dogs

Lateralized joint effusion and distention is appreciated, and pain is observed at manipulation of the elbow, more with extension of the joint.[67,68]

Radiographic Findings in Growing Dogs and Staging the Disease

Early diagnosis of UAP is based on radiographic evidence of nonfusion of the anconeal process in the ML flexed view. This difference can be determined by comparing radiographs of the diseased and opposite elbows. In cases with bilateral disease, comparing the radiographs with those of healthy puppies of the same age and breed can be informative. Incongruity caused by a shorter than normal ulna can be better assessed in the extended (neutral) ML 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 ML 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 with previous reports,[22,62–64] in most breeds, including German Shepherd Dogs, the anconeal process should be fused at 4 months of age, whereas in giant breeds, including Great Danes and Saint Bernards, union occurs between 4 and 6 months of age.[60]

UAP has different stages and clinical entities that can be differentiated by radiography and joint inspection (arthroscopy or miniarthrotomy) as suggested by Bardet in 1998.[73] In growing dogs, the disease can be differentiated into 5 entities according to radiographic aspects and intraoperative findings:[60]

1. The process is not fused but is still firmly attached; the joint can be congruent or incongruent with a longer than normal radius. Radiographically, the separation line of the anconeal process does not have a complete radiolucency zone and the anconeal process seems to be in its correct position. Intraoperatively, the anconeous process is strictly connected to the ulna by interposing fibrous tissue and does not seem to be mobile on palpation, with a minimal separation line (**Fig. 25**).
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. Radiographically, the separation line has a complete radiolucency zone, but the process seems to be in place. Intraoperatively, it is possible to appreciate minimal mobility by means of palpation or by flexion and extension of the joint, and the anconeous process still seems to be in good condition and partially connected to the ulna (**Fig. 26**).
3. The process is not fused, but in place, with a radiolucent line of separation, with normal joint congruity and no signs of MCPD (**Fig. 27**).
4. The process is not fused and is completely loose; the joint is usually incongruent with a shorter than normal ulna. Radiographically the radiolucency area seems to be wider and is accompanied by bone resorption of the anconeal process and ulna, which shows irregularities. At this stage, the execution of 2 radiographs, in a midlateral neutral and midlateral hyperflexed position, allows to evaluate the mobility of the anconeal process. In surgery, a wide mobility of the anconeal process is appreciated (**Fig. 28**).
5. 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) (**Fig. 29**).

Treatment of Ununited Anconeal Process in Growing Dogs

Early treatment of UAP with dynamic ulnar osteotomy and screw fixation of the anconeal process has been widely shown to be effective in restoring the congruity, integrity and biomechanics of the joint. Personal experience confirms that, compared with

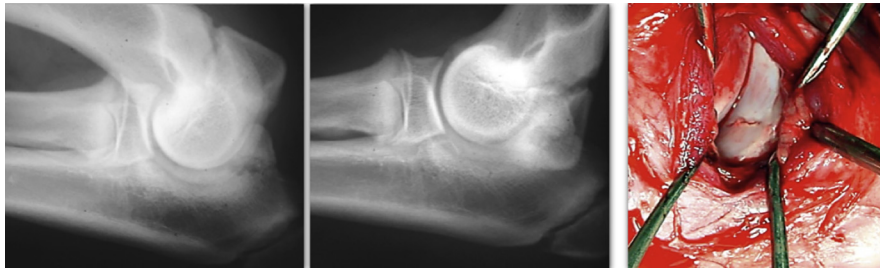

Fig. 25. UAP stage I. The process is not fused, but is still firmly attached. Radiographically, the separation line of the anconeal process does not have a complete radiolucency zone and the anconeal process seems to be in its correct position, not dislodged by the humerus in the extended elbow view. Intraoperatively, the anconeous process is connected to the ulna by interposing fibrous tissue and does not appear mobile on palpation, with a minimal separation line.

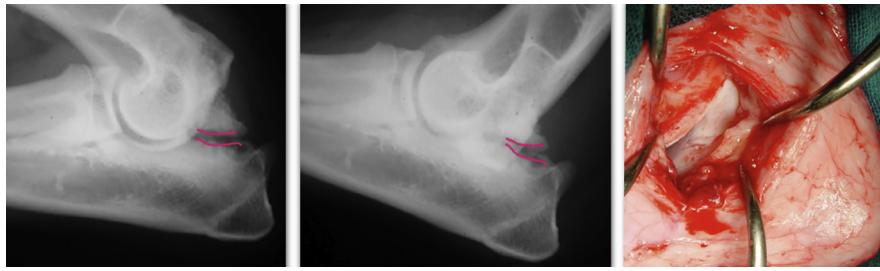

Fig. 26. UAP stage II. The process is not fused and moves slightly. It is hinged at its caudal part, creating a small cranial gap. The joint is usually incongruent, with a shorter than normal ulna. Radiographically, the separation line has a complete radiolucent zone, increased in the extended view under pressure by the humeral condyle, but the process seems to be in place. Intraoperatively, it is possible to appreciate minimal mobility by means of palpation or by flexion–extension of the joint, and the anconeal process still seems to be in good condition, partially connected to the ulna.

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 osteoarthritis progressed, the range of motion was decreased and function was impaired. Reattachment of the UAP by means of a lag screw inserted from the ulna or from the process without dynamic ulnar ostectomy has been described.[75] However, this procedure does not eliminate the elbow incongruity that most likely caused the UAP in the first place, and, ultimately, fixation failure is highly likely. 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, in term of months, the greater the likelihood that the UAP will heal, which emphasizes the importance of early diagnosis and treatment.[60] We found, as a general rule, that the prognosis in large breeds, such as German shepherd dogs and Rottweilers, was better when the surgery was done at 4 to 6 months of age. After 6 months of age, the prognosis deteriorates; in our own

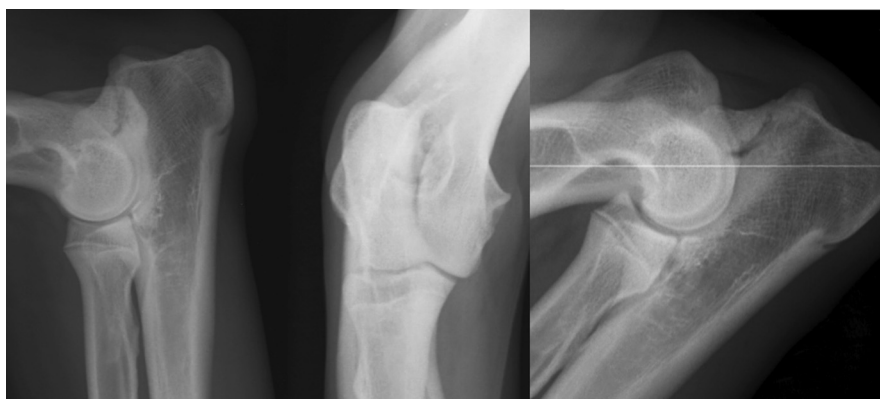

Fig. 27. UAP stage III. The process is not fused, but in place, with a radiolucent line of separation, with normal joint congruity and no signs of MCPD.

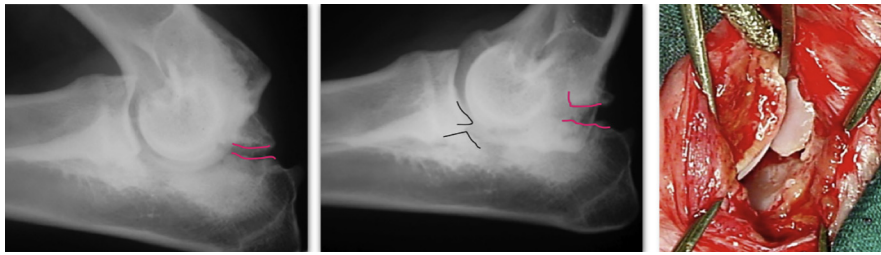

Fig. 28. UAP stage IV. The process is not fused and is completely loose; the joint is usually incongruent with a shorter than normal ulna. Radiographically the radiolucency area seems to be wider and is accompanied by bone resorption of the anconeal process and ulna, which shows irregularities. The execution of 2 radiographs, in a midlateral neutral and midlateral hyperflexed position, allows evaluation of mobility of the anconeal process. In surgery, mobility of the anconeal process is appreciated.

cases, we had only few successful outcomes in dogs in this older age group. In giant breeds, we found that an UAP can heal provided that surgery is carried out before 9 months of age.[60]

When dealing with lesions in both elbows, the patient will be more comfortable when 2 separate surgeries are carried out 2 to 3 weeks apart. However, by doing so, the dog will bear its weight after the first operation on the nonoperated leg, which increases the risk of loosening of the anconeal process. In selected cases of bilateral UAP at a very early age and with good owner compliance, both elbows can be operated at the same time. These dogs need more assistance during their daily routines and the owners should be made aware of this. However, it is critical to treat both elbows at an early age.

Concerning the osteotomy procedure, we have carried out osteotomies at different angles to determine which one was safest and most effective. Ideally, osteotomy should not change the final conformation of the ulna or its position relative to the radius in the joint. A cast or pin to stabilize the osteotomy should not be applied and weight bearing should be limited to promote physiologic realignment of the joint without unnatural or forced positioning. Because of the tension exerted by the triceps muscles on the olecranon and to avoid cranial tilting of the proximal ulna, an oblique osteotomy

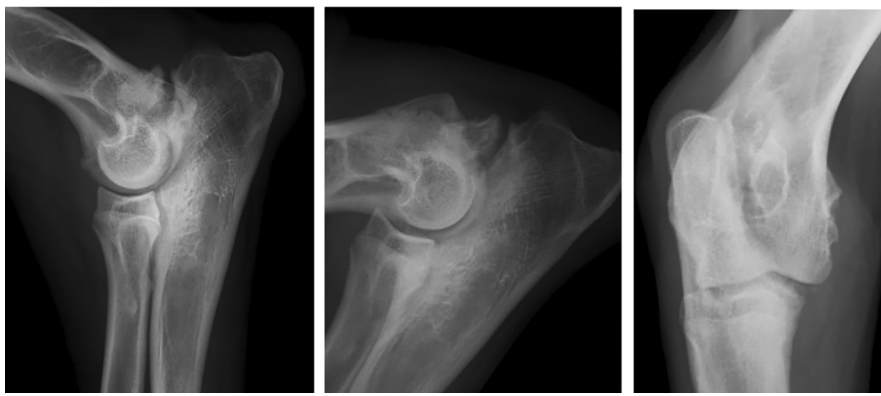

Fig. 29. UAP stage V. The process is not fused, the coronoid process is fragmented, and there is reversed joint incongruity (a longer than normal radius becomes a shorter than normal radius).

is preferred because the distal part of the proximal ulnar segment is stabilized by its contact with the distal ulnar segment. Moreover, an oblique osteotomy promotes bone healing because of the larger surface of bone interface. In contrast, a transverse osteotomy offers a smaller contact area, which prolongs the healing time, particularly in older puppies, and increases the risk of inclination of the proximal ulna. Driving a small smooth K wire from the tuber olecranon down the medullary canal across the osteotomy gap and into the medullary canal of the distal ulna has been suggested to reduce the cranial deviation of the proximal ulna and the instability of the osteotomy. In the author's experience, this is not necessary except in short legged dogs such as Basset hounds and in older dogs. In these cases, the pin must be removed after 3 to 4 weeks to prevent it from breaking owing to cycling fatigue. To decrease the risk of too rapid a bone healing, particularly in very young dogs, the removal of a thin segment of bone to create a wider gap and the insertion of an autologous fat graft into the defect have been described.[33] However, in our experience, these procedures are not necessary in most dogs and could lead to permanent nonunion. Dogs of giant breeds, such as the Saint Bernard, in which the growth period is much longer, should be closely monitored to determine whether additional procedures, such as repeated dynamic ulnar ostectomy or shortening of the radius, are required.

The osteotomy procedure can be accomplished using Gigli wire, an oscillating saw or an osteotome on a predrilled line.[61,75] Gigli wire is the safest and quickest, but only a transverse osteotomy can be easily achieved. With the oscillating saw, an oblique osteotomy can be made, but the risk of accidently notching the caudolateral cortex of the radius, which is very close to the ulna, must be considered.[70] With an osteotome, even when it is hammered on a predrilled line, the risk of causing a fissure in the cranial ulnar cortex is considerable.[73] In our experience, the use of an oscillating saw with a narrow long blade and isolating the entire circumference of the ulna with wet gauze sponges medially and with a malleable retractor laterally is the better choice.[74] The bioblique ulna osteotomy described by Fitzpatrick and colleagues[37] in 2013 for MCPD can be used for UAP too, at the level of the proximal third to the central third of the ulna.

The likelihood of finding concomitant lesions in the elbow of older puppies with elbow dysplasia is high, and a complete joint evaluation, possibly with computed tomography or arthroscopy/arthrotomy, is recommended.

Proximal dynamic ulnar ostectomy

A dynamic and lengthening ulnar osteotomy was shown to allow the anconeal process to unite spontaneously to the ulna in a varying percentage of cases.[60,71] The success rate was related to early treatment (4–7 months in large breed dogs and 6–9 months in giant breed dogs) and to the presence of a strong fibrocartilaginous connection between the process and the ulna. Varying angulations of the osteotomy line have been described. Transverse osteotomy is the simplest procedure and can be performed with Gigli wire. Because of the small osteotomy surface, the instability of transverse osteotomy is marked, resulting in greater morbidity for the patient. It can result in delayed bone union and in an excessive inclination of the proximal ulnar segment owing to the tension of the triceps brachii muscle and possible radial head subluxation.[70,73] 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 a very oblique osteotomy is decreased, resulting in less morbidity for the patient.[74] Bone union is faster and excessive inclination of the proximal ulnar segment is inhibited by bone contact of the cut surfaces. Some surgeons place a small intramedullary pin proximally to provide

some stabilization.[76] However, fixation is not routinely undertaken to allow a spontaneous anatomic realignment of the proximal ulna in the elbow joint, except in dogs that are more than 8 months of age and in Basset hounds. Although pin fixation of the osteotomy may speed recovery and decrease callus formation, it can also inhibit complete anatomic joint congruity and if not removed soon (after 3–4 weeks) it could break. A light padded bandage to protect soft tissues is applied for 10 days to make the patient comfortable. Joint inspection, via arthroscopy or arthrotomy, is done before the dynamic ulnar ostectomy to ascertain the condition of the anconeal process.

Fixation of the anconeal process

Combining both dynamic ulnar ostectomy and lag screw fixation of the process has been shown to increase the probability of bony union of the anconeal process.[60,74–78] Fusion of the process can be achieved even when it is no longer firmly connected. Bone healing can be enhanced by curettage of the fibrous tissue in the gap and by filling it with a cancellous bone graft. 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 (**Fig. 30**). One or 2 cortical 2.7-mm or 3.5-mm screws in lag fashion or one 4.0-mm partially threaded cancellous screw is inserted. With the latter, it is usually necessary to remove some of the proximal threads of the screw that would be engaged in the proximal ulna and thus, inhibit the lag effect. In a study by Meyer-Lindenberg,[42] a proximal dynamic ulnar ostectomy in association with screw fixation was carried out in all cases in which joint incongruity was evident radiographically and surgically. Otherwise, a middle or distal ulnar osteotomy was chosen. In the authors' experience, a proximal ulnar osteotomy was always carried out when the anconeal process was fixed with a screw. When the treatment is successful, radiographic evidence of union of the anconeal process and ulna is seen within 5 to 8 weeks (**Fig. 31**). Several months are required for complete healing of the osteotomy and remodeling of the spontaneous hypertrophic callus. Dynamic ulnar osteotomy results in much better function because of the resulting improvement in joint congruity, even when anconeal bone union is not achieved. Fixation of a completely loose process is unlikely to be successful, and the failure of implants can be anticipated because of bone resorption of the process and remodeling of the trochlear notch, which causes an abnormal cycling load on the process by the

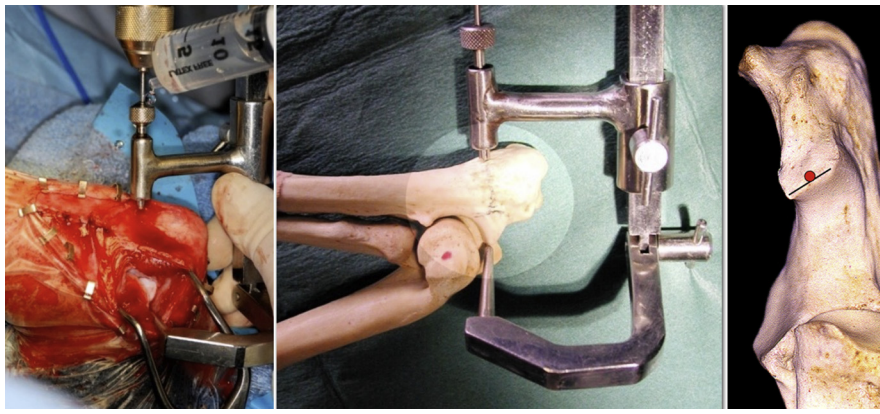

Fig. 30. Internal fixation of the anconeal process is achieved via a caudolateral approach, using an aiming device to drill the screw hole from the caudal ulnar cortex to the tip of the process.

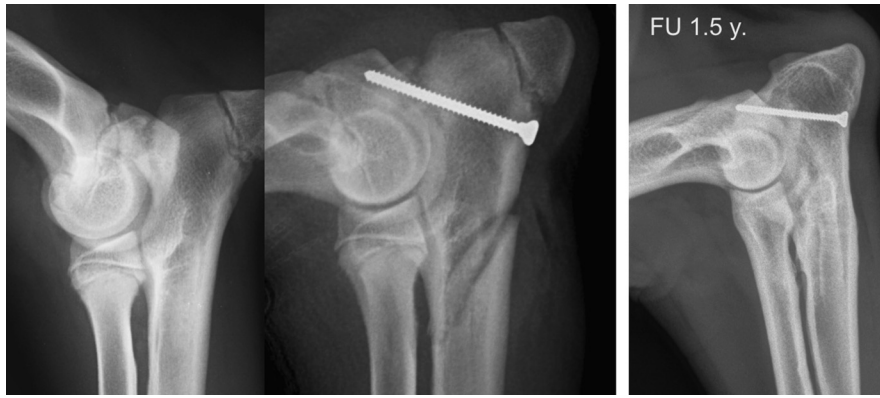

Fig. 31. When the treatment with proximal ulnar osteotomy and screw fixation of the anconeal process is successful, radiographic evidence of union of the anconeal process and ulna is seen within 5 to 8 weeks. FU, follow-up.

humeral condyle. In these cases, the loose anconeal process is removed together with the broken or loose implants. When a fragmented coronoid process is also present in growing dogs, the coronoid fragments are removed, the anconeal process is fixed, and proximal dynamic ulnar ostectomy is performed to improve joint congruity.

Clinical Signs in Adult Dogs

As for other forms of elbow dysplasia, front limb lameness can be evidenced as an exacerbation of a chronic latent condition in relation to physical activity, stressful movements, aging, or an increase in body weight. Bilateral conditions could be overlooked for several years owing to severe worsening of osteoarthritis in one of the elbows.[67,68]

Findings at Physical Examination in Adult Dogs

In adult dogs, it is possible to highlight hypomyotrophy of the affected limb, incomplete load and external rotation of the distal limb, reduction of the amplitude of the range of motion of the affected elbow, and pain and joint crepitus owing to osteophytes.[67,68]

Radiographic Findings in Adult Dogs

The radiographic examination of the elbow joint involves performing 2 ML views, with the elbow in extended position and flexed as much as possible, compatible with the decreased range of motion owing to osteoarthritis, and a Cr-Cd view with about 15° of protonation. The radiographic examination will show all the typical osteoarthritis changes induced by the underlying UAP and sometimes of concurrent MCPD. The severity of the osteoarthritis will be correlated to the age and to the persistency of short ulna incongruity (see **Fig. 33**). It is not unusual to find a UAP without severe osteoarthritis and without elbow incongruity (see **Fig. 27**).[60,67,68]

Treatment of Ununited Anconeal Process in Adult Dogs

In adult dogs, treatment of UAP becomes necessary when the anconeal process is loose or when it is suddenly dislodged from its fibrocartilaginous attachment by forced elbow extension. In such cases, removal of the free anconeal process is the only treatment.[60] In contrast, chronically degenerated joints with long-standing elbow

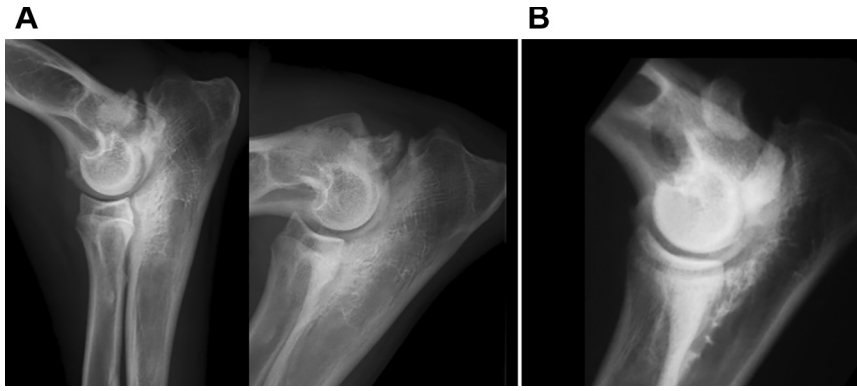

Fig. 32. Loose anconeal process, or sudden detachment and proximal dislodgment of the anconeal process owing to forced hyperextension in dogs with UAP without persistent joint incongruity, where the anconeal process is not fused but is firmly attached, causing acute lameness. Removal of the anconeal process is required.

incongruity and UAP do not benefit from any surgical treatment, apart from total elbow replacement (prosthesis) when conservative management is no longer feasible.

In adult dogs, the 4 most common conditions are:

1. UAP without persistent joint incongruity; the anconeal process is not fused but is firmly attached and there is no or only mild signs of osteoarthritis. This condition does not cause clinical problems and is incidentally diagnosed on routine radiographic examination. Usually, surgical treatment is not required (see **Fig. 27**).
2. Loose anconeal process, or sudden detachment and proximal dislodgment of the anconeal process owing to forced hyperextension in dogs with the condition described in point 1, causing acute lameness. Removal of the anconeal process is required (**Fig. 32**).
3. UAP with persistent joint incongruity with a shorter than normal ulna and severe osteoarthritis. Conservative management is recommended (**Fig. 33**).

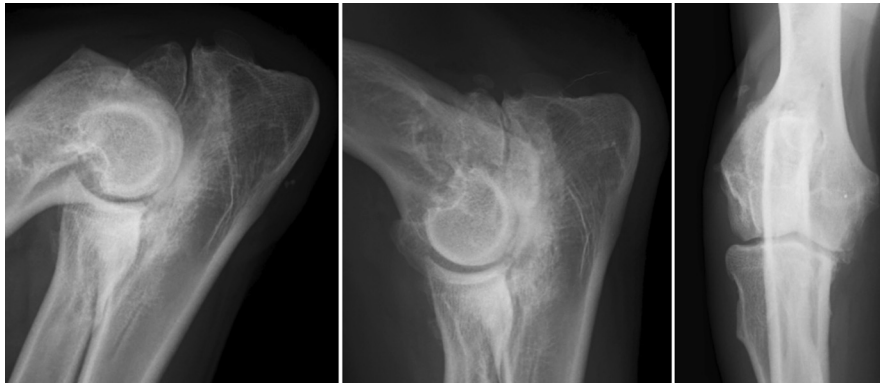

Fig. 33. UAP with persistent joint incongruity with a shorter than normal ulna and severe osteoarthritis. Conservative management is advised because the removal of the anconeal process will not improve elbow function.

4. UAP and severe degenerative joint disease with complete joint alteration such that joint incongruity can no longer be distinguished and with medial compartment alteration too. Conservative management is met with a poor prognosis.

PROGNOSIS FOR ELBOW DYSPLASIA

Elbow dysplasia has always had a variable prognosis depending on the severity of the disease. Nevertheless, the prognosis is always guarded because of the tendency of this disease to cause progressive osteoarthritis with time, exercise, and body weight increase. Early treatment of all forms of elbow dysplasia in the growing phase, before the development of osteoarthritis, looks to be the best way to mitigate the lifelong consequence of the disease.

CLINICS CARE POINTS

- The expression of elbow dysplasia is multifactorial, composed of both genetic aspects (polygenic involving multiple genes) and influenced by environmental factors such as diet, excessive exercise, and weight gain.
- A radiographic early sign of elbow dysplasia in the juvenile dog is STS of the ulna in the area of the medial coronoid process, this is in response to overloading of the medial compartment and inflammation.
- In many cases of juvenile dogs with MCPD, a dynamic ulnar osteotomy can improve elbow congruity and possibly decrease the progression of osteoarthritis.
- Early detection and treatment of elbow dysplasia (juvenile) is the key and in some cases can decrease the long-term degenerative changes seen with this debilitating disease.

DISCLOSURE

Dr A. Vezzoni is a paid instructor at PAUL Courses organized by Kyon. No other financial conflicts. Dr K. Benjamino has no commercial or financial conflicts.

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