Review of the literature

Elbow incongruity in the dog

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Summary
Elbow incongruity is the term to describe bad alignment of the joint surfaces of the elbow. Two features illustrate incongruity of the elbow: an abnormal shape of the ulnar trochlear notch and a step between the radius and ulna, caused by either a short radius or a short ulna. It has been suggested that both an elliptical notch, and a step, can cause increased local pressure within the joint, resulting in loose fragments at different locations: ununited anconeal process (UAP), fragmented coronoid process (FCP), osteochondritis dissecans of the humeral condyle (OCD). These lesions are grouped under the term ‘elbow dysplasia’ and are the most frequent causes of front leg lameness in the dog. Although several radiographic features to diagnose incongruity have been described, the ‘scoring’ of incongruity is subjective because there is currently no objective method to measure the degree of incongruity. Because superimposition is avoided, CT is suggested as a standard technique to measure incongruity. Arthroscopy on the other hand, allows the direct visualisation of the intra-articular structures and their abnormalities. Information on both techniques are still relatively new. Several surgical techniques have been proposed to restore joint congruity; the one most frequently used is an ulnar osteotomy. But because of possible complications, other techniques are being developed. Reports evaluating the results of the different techniques are not yet available.

Keywords
Elbow incongruity, literature, scoring, diagnosis, dysplasia

Introduction

The elbow joint is a complex, accurately matching joint, formed by the distal humerus and the proximal radius and ulna. Incongruity refers to a mal-alignment of these three bones within the joint (Fig. 1) (1–8).

Over the last two decades, elbow incongruity has become considered as a cause of elbow dysplasia. This term combines three disorders of the elbow, which are all characterised by loose fragments within the joint and which result in lameness and arthritis (5, 6, 8–10). The three disorders are: ununited anconeal process (UAP), fragmented coronoid process (FCP) and osteochondrosis dissecans of the medial part of the humeral condyle (OCD). According to the International Elbow Working Group (IEWG), incongruity is a fourth disorder which falls under the term elbow dysplasia. These disorders occur most frequently in juvenile, large breed dogs. Compared with female dogs (4), fast growing, male dogs are more often affected.

This article is an overview of what is known in the literature about the significance, diagnosis and treatment of elbow incongruity.

Anatomy of the elbow joint

The elbow joint is formed by the humerus, the radius and the ulna, which articulate accurately (Fig. 2). The distal part of the humerus is the humeral condyle and articulates with the incisura trochlearis, also known as the trochlear notch of the ulna. The medial part of the condyle is the trochlea humeri, often incorrectly named the medial humeral condyle, and contributes to the stability of the elbow joint. The capitulum is the lateral part of the condyle and is responsible for more than 80 percent of the weight bearing.

The most important movements of the elbow are flexion and extension. The additional movements are pronation and supination, as a result of the articulation between radius and ulna.

In a congruent elbow, the joint surfaces are well aligned. Therefore, coordinated growth from metaphyseal and articular growth plates is necessary during the development of the elbow joint.

Definition and aetiology of incongruity

In an incongruent elbow, the joint does not fit well and the joint space is not parallel.

Eckstein et al. distinguished physiological from pathological incongruity in human elbow joints. In 1993 they studied the characteristics of physiological incongruity in healthy joints and found a limited concave incongruity between the humerus and ulna in the unloaded position (11) (Fig. 3C). This contact pattern optimizes stress distribution during gait; the joint fits better when loaded (Fig. 3D). Moreover, it ensures better nutrition of the articular cartilage. Several veterinary studies also refer to a physiological incongruity. Wind’s opinion is that a mild degree of incongruity without clinical signs or arthrosis should not be judged as pathological. Preston et al. and Maierl looked at the effect of stress on contact areas in normal dogs. They demonstrated the same concave physiological incongruity as did Eckstein et al. in their study of the human joint.

Apart from the physiological form, there are two pathological forms of incongruity in which incongruity is much more pronounced. The first form is the unequal growth between the radius and ulna (short ulna / short radius) (Figs. 1C, D). This un-
equal growth may be caused by trauma of the growth plate, hypertrophic osteodysplasty, or a persistent cartilage core within the distal ulnar growth plate (10, 12). These disorders are well recognised as a cause of valgus, or varus, deformity in growing dogs of different breeds. However, the same disorders are not commonly seen in dogs with the more discrete form of incongruity, which leads to ED. An explanation for this more discrete form of incongruity is still not clear.

A second form of incongruity is the elliptical shape of the trochlear notch of the ulna (Fig. 1B). According to Wind’s hypothesis, the proximal part of the ulna is relatively longer in large breed dogs, when compared to small breed dogs. This has been confirmed following measurements in dogs of different breeds. In large breed dogs, the growth rate of the proximal part of the ulna should be quicker in order to keep up with the growth rate of the humeral condyle. If, for some reason, the growth of the proximal part of the ulna is disturbed, the size of the ulnar trochlear notch is too small to encompass the humeral condyle. A breed predisposition for an elliptical notch was seen in the Bernese Mountain dog, in a comparative study with Rhodesian Ridgebacks, which had a round notch. The development of an elliptical notch in the Bernese Mountain dog was seen throughout aging from three months of age (1, 7).

**Biomechanics and significance of incongruity as cause of elbow dysplasia**

It is well-known that a pronounced growth retardation, of either radius or ulna (short radius or short ulna) leads to limb deformity, i.e. varus or valgus (12). The consequences of a more discrete form of a short radius or short ulna causes less pronounced external changes. Several authors state that incongruity causes elbow dysplasia by an increased pressure within the joint (4, 13, 14). This theory is supported by biomechanical studies that describe the pressure pattern within the joint, as well as studies that evaluate the consequence of an iatrogenically created incongruity.

In case of incongruity caused by a ‘short ulna’ (Fig. 1D), the humeral condyle has a tight fit between the anconeal process and the radius. This causes increased pressure on the anconeal process, which leads to fragmentation of the anconeal process or a non-union in case of a separate ossification centre; a condition that has been described in several breeds (15). In a clinical series of 22 dogs, Sjöström proved the correlation between a short ulna and an ununited anconeal process (10). According to Wind, this growth retardation can be compensated for at a later stage, which explains the presence of fragments without a clear incongruity (8).

In case of incongruity caused by a ‘short radius’ (Fig. 2), there is increased pressure on the medial part of the humeral condyle and the medial coronoid process (4). In an experimental study, a radial osteotomy was performed in seven dogs, so as to create a short radius incongruity. All of the dogs became lame and one developed a fragmented coronoid process (16). In a study of 17 joints (17), the contact patterns within the joint were measured after shortening the radius in
cadaver limbs. An increase in pressure was measured at the level of the medial coronoid process. In contradiction to these findings, CT-absorptiometry did not demonstrate an increase of pressure in joints affected by FCP, when compared to normal joints (18).

In cases of incongruity caused by an elliptical trochlear notch, the diameter of the notch is too small to encompass the humeral condyle. This increases the pressure on the anconeal process and medial coronoid process. Measurements in 55 dogs with elbow dysplasia, demonstrated a small, elliptical notch, and a larger proximal part of the ulna (8). In contrast to these findings, Collins et al. compared the results of 13 Rottweilers with a control group of 14 Greyhounds and did not find any correlation between the prevalence of elbow dysplasia and an elliptical notch (2). Kirberger also opposed this theory because of the low prevalence of simultaneous FCP and UAP in the same joint, which is to be expected as a consequence of an elliptical notch (4).

Another explanation for abnormal loading of the joint is a growth deformity originating from the humerus. Fujita and Shulz studied the effect of varus deformity on contact patterns within the elbow. They performed a lateral ‘sliding’ and medial ‘opening’ wedge osteotomy of the humerus so as to create a varus. The result was an overall decrease of intra-articular pressure and a lateral displacement of the contact areas. A humeral osteotomy could possibly resolve the pressure on the medial coronoid process and also prevent the development of a fragmented coronoid process. However, abnormal high pressures were not found in these artificially deformed joints, which questions a humeral osteotomy as being an efficient treatment for incongruity (19).

In general, younger animals have a greater risk of developing loose fragments, because ossification has not yet completed and their bones are more fragile and less dense (9).

**Signs of incongruity**

The significance of incongruity (IC) as a cause of lameness is unclear, since incongruity is almost always accompanied by UAP, FCP or OCD. It is not possible to distinguish whether pain originates from the consequences of the fragmentation or from the incongruity itself, as often seen in valgus deformity (9). Joint effusion and pain are common findings. In chronic cases there is also muscle atrophy and a decreased range of motion due to arthrosis and inflammation. The severity of the lesions are correlated to the degree of incongruity: mild incongruity is not likely to cause fragmentation and lameness, while in more clear incongruity there is often lameness and/or loose fragments (8, 9).

![Fig. 3](image-url) Schematic representation of stress distribution within the joint with and without loading, and for a congruent and a physiological incongruent joint. In the congruent joint the humerus and ulna ‘match’ perfectly (A). Under a high load the stress increases in the central part of the trochlear notch (B). In the physiologically incongruent joint there is a small concave incongruence (C) that ensures a more equal stress distribution under high load (D) (after Eckstein et al. 1993).

**Diagnosis of incongruity**

Radiography is the standard imaging technique for the diagnosis of elbow disorders in the dog. Three recommended views are a mediolateral, flexed, and extended view and an oblique cranio-medial-caudolateral view (1, 5, 7, 20). Based on those projections, Wind (8) described four main radiographic features of elbow incongruity: a ‘step’ between radius and ulna, an elliptical shape of the trochlear notch, an increased joint space, and a cranial displacement of the humeral head (Fig. 4). These features were determined on the extended lateral and the cranio-medial caudolateral views (Fig. 4). A) Mediolateral radiographic projection of a congruent joint. B) Severe incongruent joint with step (↕) and comma-shaped joint space (←). The medial coronoid process (↑) has an irregular aspect. There is arthrosis on the anconeal process (▼) and the proximal part of the radius and there is sclerosis on the trochlear notch (▼).
The size of this ‘step’ is variable and can be up to 5 mm and is best seen on a mediolateral projection. However, the radiographic assessment of incongruity is not simple; it is difficult to visualize a three-dimensional structure on a two-dimensional projection.

The mediolateral flexed view was not useful for the evaluation of incongruity because the joint is compressed in this position. Although Wind stated that the degree of incongruity could not be influenced by the positioning of the joint, Murphy (23) and Mason (5) concluded that radiography was not sufficiently sensitive to evaluate incongruity because of superposition and influence of positioning (16, 19). A false positive diagnosis of a ‘step’ was seen in normal joints by performing pronation and supination (23). In an in vitro study (5), an artificial ‘step’ was created by progressively shortening the radius (5–40 mm). The elbows were judged on the three standard radiographic projections by four different radiologists (ACVDI diplomates). The sensitivity and specificity for diagnosing IC were rather low for all radiographic projections and depended upon the radiographic projection. When evaluating the lateral projection, the specificity was 86% with a sensitivity of 78%. On the craniocaudal views, the values were 82% and 79%, respectively. The radiologists required a minimum ‘step’ of 1.5 to 4 mm, depending on the experience of the radiologist, to reach a sensitivity of 90%. The larger number of ‘false negative’ diagnosis of IC was contributed by the fact that clear parameters were not previously defined and because of the difficulty in visualizing a three-dimensional structure on a two-dimensional view. The conclusion of this study was that a ‘step’ cannot be clearly determined on radiography.

Brünnberg and Viehmann measured the radiographic parameters determined by Wind using computerized measurements. Three methods were established to measure the radioulnar ‘step’ and the humeroradial joint space (Figs. 6, 7). The ‘step’ measured on the craniocaudal view was underestimated, probably due to beam direction or joint positioning. The cranial displacement of the humeral condyle and the shape of the trochlear notch were measured by surface and angle measurements (1, 7). These methods of measurements are not practical for routine use.

According to Collins et al. (2) the shape of the trochlear notch is not valuable for the evaluation of incongruity because of breed variation and also because an elliptical shape can be physiological as well. The shape of the notch can also be influenced by the position of the joint (23).

Arthrosis is a secondary radiographic sign of elbow incongruity. A good correlation was found between the severity of incongruity and the degree of secondary arthrosis (21, 24). Incongruity leads to instability which causes secondary changes in the bone and cartilage. Additionally an increased tension of the joint capsule can induce arthrosis (9).
Because superimposition is avoided, computed tomography was suggested as a more accurate technique for the evaluation and measurement of elbow incongruity (1, 3, 7, 25, 26). Sagittal and dorsal reconstructions are very informative for diagnosing incongruity. Reichle et al. described a clear radioulnar ‘step’ and an increased humeroradial joint space on the sagittal reconstruction images (Fig. 8B) (25). The dorsal reconstruction (Fig. 8D) shows the ‘step’ and often concomitant pathology of the medial coronoid process (3). Studies in this field are still preliminary (27, 28).

Evaluation of incongruity by direct inspection of the joint surface can be obtained by arthroscopy or arthrotomy (8, 29). While arthrotomy permits only a limited view, arthroscopy permits direct inspection of a large part of the joint surface, and thus provides additional information for diagnosing incongruity (29). Several arthroscopic features were seen in incongruent joints: a lower level of the radial head at the end of the trochlear notch and in the lateral compartment, an irregular cartilage border between the ulna and radius, discoloured, irregular or loose cartilage on the radial head and the trochlear notch. In the authors’ experience, in a total of 1500 cases with the exception of three cases (a Rottweiler, a Bernese Mountain Dog and a Saint Bernard Dog), arthroscopic examination showed that incongruity in lame dogs was always accompanied by fragmentation of the medial coronoid process.

Studies that compare radiography, CT and arthroscopy for the diagnosis of elbow incongruity have yet to be published.

**Treatment**

**General considerations**

Since elbow incongruity is seen in combination with other elbow lesions (FCP, UAP, OCD), surgical treatment of these joints not only aims to restore congruity, but also to remove, or re-attach, the loose fragments. Besides causing ED, incongruity is suggested to worsen the prognosis after sur-
Surgical treatment of elbow dysplasia (removal of loose fragments) (9). This could partially explain why 30 to 40 percentage of dogs, treated for ED, still show some degree of lameness after surgery (30, Van Ryssen, personal communication, 2001).

Ulnectomy, without removal of the fragment, is only supported by one author without any clinical study (4). An ulnar osteotomy permits the proximal part of the ulna to shift and/or tilt, so pressure within the joint is more evenly distributed (6).

The goal of the correction of incongruity is to improve the prognosis, after surgical treatment of FCP, OCD or UAP, by a more equal distribution of the intra-articular loads.

Ulnar osteotomy

The most frequently performed procedure for the correction of incongruity is an ulnar osteotomy. It is a generally accepted procedure for the treatment of UAP (31) as an alternative to the surgical removal of the loose fragment. In young dogs, it may be used as a ‘stand alone’ procedure, to induce spontaneous fusion of the anconal fragment. A perpendicular or oblique proximal ulnar osteotomy can relieve abnormal pressure within the joint and restore congruity (Fig. 9) by allowing the proximal part of the ulna to move proximally and tilt cranially. The chances are good, particularly in young dogs, that the anconal process will fuse after the stress is relieved. An oblique osteotomy prevents extreme tilting of the ulna and reduces the mobility of the proximal part of the ulna, thus avoiding abundant callus and delayed healing; it also avoids the necessity of an additional intramedullary pin to prevent varus deformation. Pin breakage is a frequently reported complication when an intramedullary pin is used (32–34). Thomson was the first to describe the use of an oblique osteotomy in three joints with UAP, of which two healed (35). Sjöström et al. applied a perpendicular osteotomy in 20 dogs (22 joints) with UAP (10). The anconal fragment fused in 21 out of 22 joints. Seventy percent of the dogs regained full function, while in 30% residual lameness was attributed to different factors such as arthrosis, too early healing of the ulnar osteotomy, or an abnormal shape of the trochlear notch. Since fusion of the anconal process is not always achieved, several authors recommend a combination of an ulnar osteotomy with lag screw fixation of the fragment (31, 36).

Osteotomy of the ulna has also been described as an additional procedure to the surgical treatment of FCP (removal of the fragment). In a series of 10 dogs, all younger than 10 months, Ness performed a transverse, proximal ulnar osteotomy 25 mm distal to the elbow joint (Fig. 10) in combination with removal of the fragments via arthroscopy. The use of an intramedullary pin alone seemed to be redundant since a mild varus deformity did not cause any functional complications. After surgery, nine out of ten dogs showed clear improvement after two months: five were completely normal, four had occasional stiffness and one remained significantly lame (33).

Bardet and Bureau reported the combination of arthroscopic removal of the coronoid fragment with a proximal ulnar osteotomy, regardless of the animal’s age. A 93% success rate was obtained following the treatment of 83 adult dogs (mean age of 12.7 months), despite an increased degree of arthrosis (32).

In a study of 10 specimens, restoration of joint congruity was studied after experimental shortening of the radius. Congruity was best achieved by a proximal oblique osteotomy combined with an intramedullary pin, while, due to the strong interosseus ligament between radius and ulna, a distal ulnar osteotomy did not have any effect. A proximal oblique osteotomy, without intramedullary fixation, caused varus deformity (17, 26). This is in contradiction to previously described clinical studies where intramedullary fixation was not inserted and a varus deformity was not seen (10, 32, 33). A second contradiction to the study of Preston and Schulz is the recommendation for the use of a distal ulnar osteotomy in dogs younger than nine months suffering from a FCP and incongruity (34). They also recommended that after surgical removal of the fragmented coronoid process, a partial osteotomy (5 mm) at the distal third of the ulna should be performed. The results of this treatment were reported to have been good in 77.5%, of a large number of patients (70% of 117 dogs) (34).

Radial lengthening

A more recently developed technique is the lengthening of the radius to reduce the ‘step’ within the joint (37). In an earlier preliminary study of five dogs, Olsson performed a radial lengthening after artificial...
closure of the distal radial growth plate by irradiation of the growth plate. He was able to restore the congruity and lameness resolved in all of the dogs. Incongruity and the clinical signs reoccurred after several weeks in three dogs, and the treatment had to be repeated. Despite the recurrence, Olsson recommended treatment for a short radius in order to limit clinical, radiographic and pathological changes (16). The promising results of a clinical study of 40 cases were presented in 2004 in a short communication at the 12th ESVOT Congress, Munich, Germany, after an oblique proximal radial osteotomy, joint congruity was restored and the radius was fixed with a plate. The preliminary results are comparable with those of the dynamic ulna-osteotomy, but further research was recommended (37).

Although several complications of an ulna-osteotomy are possible (delayed union, non-union, etc.), none are mentioned in the literature.

Humerus osteotomy

In an experimental study, the effects of humeral osteotomy on the contact pattern within the elbow were studied in five specimens (19). Two types of humeral osteotomy were performed: a lateral ‘sliding’ osteotomy and a medial ‘opening wedge’ osteotomy. In both types the results were that of a general decrease of the intra-articular pressure and a lateral displacement of the contact areas. The conclusion of this limited study was that osteotomy of the humerus does not seem to be a solution to optimize the pressure within the elbow joint.

Coronoidectomy

In a recent report of Puccio, coronoidectomy was performed in 17 dogs for the treatment of incongruent elbow joints without FCP. In order to restore congruity, arthroscopy via an osteotomy was performed to remove 4 mm or more of the medial coronoid process. All of the dogs were sound following surgery (38). The large number of incongruent joints without a coronoid lesion in Puccio’s study, is contradictory to the authors’ findings.

Arthroscopic treatment

In a study currently being performed by the authors, the results of the arthroscopic examination, followed by broad removal of the coronoid process, are described in 40 dogs with severe incongruity. Although the treated joints showed obvious arthrosis, inflammation and cartilage damage, 80% of the dogs were free of lameness or markedly sounder after surgery.

Prevention

Measurements to prevent the development of incongruity and consequent elbow dysplasia can be taken at different stages. Breed selection, based on early screening of the elbows, is already being performed in the context of ED prevention. The elbows are scored based on the size of the osteophytes and the presence of a primary lesion, in accordance with the guidelines of the International Elbow Working Group. The weak points in this system are that there are not any objective parameters to define incongruity, and that radiography does not seem to be an accurate diagnostic technique for this purpose (cfr. ‘diagnosis’).

In the growing dog, weight control and limited exercise are suggested in order to prevent the abnormal development of the trochlear notch (8).

If incongruity is indeed a crucial aspect in the existence of elbow dysplasia, an early ulnar osteotomy in young dogs, with incongruity, prevents the formation of loose fragments (16). Vezzoni supports this hypothesis: young dogs have the capacity to adapt the joint surface and their ligaments are more elastic. He performed an ulnar osteotomy in dogs of four to six months of age with incongruity, whether they are lame or not, in order to prevent the formation of loose fragments. The osteotomy was located proximal when incongruity was ‘severe’ and distal when ‘mild’. A limited number of dogs still developed FCP despite the osteotomy. In most dogs development of elbow dysplasia and arthrosis was prevented. The number of dogs included in this study, and the success rate are not mentioned (34).

Conclusion

Over the last decade, elbow incongruity has received more and more attention because...
of its role in the development of loose fragments in the elbow, especially FCP.

Although several studies have been performed, a method for an objective measurement of incongruity has not yet been described, nor has a comparative study been performed to determine which imaging technique is the most reliable. Until now, all of the studies performed refer to the radiographic evaluation of elbow incongruity. There is still some discussion as to which projection should be used. Most studies are based on models and are very limited in number (5). Two studies describe the measurement of the ‘step’ on radiographs, but are not available for practical use (1, 7). Computer tomography avoids superimposition and allows direct measurement, but an objective evaluation or a comparison with radiography is yet to be published.

Because of the malformation of the elbow joint, it has been suggested that incongruity worsens the prognosis of FCP after treatment. Should this be true, the removal of the fragment (FCP) should be combined with a correction of the incongruity. Until now there have not been any reports which compare the classical treatment with an osteotomy. Some confusion still exists regarding the ideal technique to correct the incongruity, and also the results and possible complications. Although several techniques have been described, none of the above has proved to be fully effective. The best technique to treat incongruity, based on a large number of patients and a long time follow up, has yet to be determined.

References

29. Van Ryssen B. Role of arthroscopy in elbow diseases in the dog. Proceedings 12th International Small Animal Arthroscopy workshop, refresher course, 2001; University of Ghent, Belgium.

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