Clinical Communication

Radiographic evaluation of osteotomized ulnar segments following arthroscopic treatment for canine medial coronoid disease

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Keywords
Ulnar osteotomy, medial coronoid disease, radioulnar incongruity

Summary
Objective: To assess movement of ulnar segments radiographically, following proximal and mildshaft ulnar osteotomy or ostectomy after arthroscopic treatment for dogs diagnosed with medial coronoid disease.

Methods: Fragmentation and cartilage wear were treated arthroscopically and the presence of incongruity confirmed. Osteotomies were performed at the mid-point or proximal third of the length of the ulna. The distance of separation between the ulnar segments and the adjacent radius were measured and followed by serial radiographs postoperatively until healing had occurred.

Results: Proximal oblique osteotomies located at one-third the length of the ulna were associated with the most movement of the ulnar segments, most notably of the proximal segment. Osteotomies or ostectomies performed in the middle demonstrated less segmental movement and on average, slightly longer time to heal. Movement of the ulnar segments in both groups occurred immediately, and then peaked at two to four weeks postoperatively, tending to plateau thereafter.

Clinical significance: Radioulnar incongruity is considered a facet of the aetiopathogenesis of canine medial coronoid disease. This creates abnormal loads and focal wear along the medial coronoid process. Performing an oblique osteotomy at a location measured at the proximal third of the length of the ulna allows increased movement of the proximal segment, which may result in unloading of the medial compartment. Performing an osteotomy or ostectomy distally dampens segmental movement due to constraint of the interosseous ligament. These findings suggest that a proximal oblique osteotomy at this location creates immediate favourable movement with low morbidity.

Introduction
Fragmentation of the medial coronoid process of the ulna has been classified as an entity of elbow dysplasia, separate from ununited anconeal process and osteochondritis dissecans; all of which affect large breed dogs (1–3). Several causes of fragmentation and wear of the medial coronoid process have been suggested, yet a definitive cause remains to be proven (4). Proposed theories include: a) radioulnar incongruity due to a short radius or long ulna; b) trochlear notch dysplasia; c) pre-mature radial or ulnar physeal closure; or d) traumatic fracture of the medial coronoid process (5–7). Due to the varied physical and histological changes which may occur in the region of the medial coronoid process, we have chosen to use the term medial coronoid disease (MCD) to denote subchondral or bony changes to the ulna, excluding the diagnosis of fracture or ununited anconeal process.

Various diagnostic modalities have been used to achieve a diagnosis of MCD, each with variable sensitivity or specificity (8). Radiography is readily available, cost effective, and commonly used as a screening tool to aid diagnosis and evaluate risk for elbow disease. Sensitivity of radiography has been estimated to range from 10–60% compared with other modalities used to diagnose incongruity or fragmentation (5, 8–11). One study found that greater than 2 mm of step disparity is required to appreciate radioulnar incongruity radiographically (10). Additionally, another study stated 90% sensitivity amongst radiographers using measured ranges of 1.5–4 mm of incongruity amongst cadaver models (11, 12).

Computed tomography also assists diagnosis of incongruity and fragmentation, but may be less specific due to a possible positioning artefact of the antebrachium (13–16). Magnetic resonance imaging offers similar sensitivity as computed tomography, but is more specific in demonstrating changes to cartilage or subchondral bone. In addition to imaging techniques, arthroscopy has gained popularity since one can visualize the presence of intra-articular incongruity, fissures, cartilage changes, or fragmentation; as well as offer concurrent treatment.

Multiple treatment options for MCD have been presented in the literature com-

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Materials and methods

Fourteen large breed dogs with a mean body weight of 28 kg (range 12–48 kg), and that were six months to 10 years of age (4 dogs <1; 11 dogs ≤3 years; 2 dogs >5 years), were diagnosed with MCD and elbow incongruity. Eleven dogs were male and three were female. In some cases (7/14), diagnosis was assisted by computed tomography in order to gain owner approval for participation in the study. Dogs that were presented with forelimb lameness and additional elbow or shoulder pathology were excluded.

All dogs were anaesthetized with a similar protocol using analgesic pre-medication (morphine 0.25–0.5 mg/kg IM, SQ), anaesthetic induction (propofol\(^a\) 3–6 mg IV to effect), intubation, and anaesthetic maintenance using isoflurane and occasional ventilator assistance\(^b\). An intravenous injection of cefazolin\(^c\) (22 mg/kg) was administered after sedation. An intra-articular injection of 5 ml of 2% lidocaine was administered into the elbow joint prior to arthroscopy, followed by 5 ml of 0.2% bupivacaine intra-articularly after surgery.

Surgery was performed by a single surgeon (ASL), with patient signalment and location of the osteotomy randomized. Each patient was positioned in dorsal recumbency with the forelimb abducted and the antebrachium externally rotated. A medial approach was made for insertion of a 2.7 mm, 30 degree arthroscopic\(^d\) to visualize and document any incongruency, fragmentation, fissuring, or cartilage wear. Focal treatment consisted of removal of any fragments and debridement of areas of subchondral wear. If noted, osteotaxis was performed along areas of severe cartilage wear on the surface of the medial coronoid process or medial humeral condyle.

After arthroscopy, the limb was adducted and extended cranially and a caudolateral approach made at the middle (0.5 x L) or proximal third (0.3 x L) of the length (L) of the ulna as measured from the point of the olecranon to the radiocarpal joint. Proximal and distal to the site of the osteotomy, a 1.14 mm Kirschner-wire was used to drill two small holes into the caudolateral ulnar cortex a distance of 2 cm apart. A small point of radiopaque, biocompatible endodontic filler\(^e\) was placed into each drill hole, achieving a measurement of 2 cm between the biomarkers (19). This endodontic filler is primarily used in root canal procedures in humans and animals and it was chosen due to its radio-opacity and minimal to no adverse tissue reaction, cytotoxicity, or effect on bone healing (20, 21). An osteotomy or ostectomy (removing 2 mm of bone) was performed midway between the two biomarkers.

The location of the osteotomy was randomized regardless of age, sex, degree of arthritis, or severity of arthroscopic findings. Six cases had a transverse (n = 4 of 6) or short oblique (n = 2 of 6) ostectomy or osteotomy performed in the middle of the ulna, located near the region of the interosseous ligament. In seven cases, an oblique

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\(^a\) Propofol (Propofoil\(^a\)) ; Abbott Animal Health, Abbott Park, IL, United States
\(^b\) Engler Model A.D.S. 1000: Engler Engineering Corporation, Hialeah, FL, United States
\(^c\) Cefazolin sodium injectable, 100 mg/ml (1 g bottle): Hanford Pharmaceuticals, Syracuse, NY, United States

\(^d\) Stryker: Stryker Cambridge, MA, United States
\(^e\) Dentasply Caulk 200F Gutta, Percha Point: Dentasply GP Maillofer, Tulsa, OK, United States
ulnar osteotomy was performed along the proximal third of the ulna in two planes: caudoproximal to craniodistal and proximo-lateral to disto-medial. One case of the initial 14 elbows to be studied was excluded, as an osteotomy performed in the middle inadvertently created a fissure and subsequent fracture of the adjacent radius; thus, 13 antebrachii were followed postoperatively.

Postoperative care consisted of placement of a soft padded bandage on the affected limb for three days. Carprofen (2 mg/kg orally twice daily) or meloxicam (0.1 mg/kg once daily) was administered for two to five weeks thereafter. A fentanyl transdermal patch (2–5 mcg/kg/hr) was applied and tramadol (2–6 mg/kg orally twice daily) was administered for two to three weeks during and following recovery. Exercise restriction for six to 10 weeks was followed by controlled activity until the osteotomy had healed.

Radiographs were taken using a digital radiograph system and measurements standardized with a 10 cm calibrated marker. Cranio-caudal and flexed mediolateral views of the antebrachii were taken immediately postoperatively and two, four, six, and eight to 12 weeks thereafter, with follow-up to six to 12 months in most cases. Movement of the ulnar segments was plotted over time by measuring the distance between the biomarkers and the space between the cortices of the proximal ulna and adjacent radius. The time from surgery until union of the osteotomy was determined radiographically.

Statistical analysis

A non-parametric two-tailed test was used to test the hypothesis and follow the difference between the normal distribution of parameters of the distance measured between the biomarkers over time. The null hypothesis was rejected using Pearson’s Correlation Coefficient, followed by formation of an alternative hypothesis since movement of the ulnar segments occurred in most (n = 9 of 13) cases, despite the location of the osteotomy. Theorizing that no movement would occur of the osteotomies or ostectomies that osteotomies were performed were smaller in proportion, measuring from 0–5 mm, and thus smaller in significance (p > 0.01). Values of p < 0.05 were accepted as significant.

Results

The cases in which a midshaft osteotomy or ostectomy was performed (n = 6) showed a small measurable difference of separation larger measurements of distance between the biomarkers (p < 0.001) over time. The standard error of measurement was higher for the oblique osteotomies (SEM = 0.051) versus the osteotomies performed in the middle (SEM = 0.032). The measurements from the biomarkers measuring the distance from the trans-cortex of the ulna to the trans-cortex of the adjacent radius after the osteotomies were performed were smaller in proportion, measuring from 0–5 mm, and thus smaller in significance (p > 0.01). Values of p < 0.05 were accepted as significant.
between the ulnar segments: 1–3 mm (mean = 1.25 mm ± SD 0.79) over time. The distance between the biomarkers remained the same with marginal change during follow-up (Fig. 3). Half of these cases (3 out of 6) did display some movement, but only of the distal end of the proximal ulnar segment, a distance of 1–4 mm away from the trans-cortex of the radius. Two of these three cases showed slightly visible caudal deviation (termed ‘kick down’) of the proximal segment as measured from the trans-cortex of the radius.

In contrast, the majority of the proximal third oblique osteotomies (5 out of 7) showed positive, measurable movement of the ulnar segments with increased distance between the biomarkers of 3–5 mm (mean 3.14 mm ± 0.13), such that the proximal segment on radiographs had visibly moved proximally as well as caudally. This measured movement was termed ulnar ‘kick back’, or proximal translation of the proximal ulnar segment and is likely due to the upward pull of the triceps muscles. Increased distance measured from the trans-cortex of the ulna to the trans-cortex of the proximal radius of 2–4 mm (mean 3 mm ± 0.58) was termed ‘kick down’, or caudal displacement of the proximal ulnar segment (Fig. 2, 5). Two of the proximal osteotomy cases, although documenting increased movement between the biomarkers, showed minimal caudal displacement of the distal end of the proximal ulnar segment (0–2 mm). These smaller measurements were noted in the cases in which the proximal ulnar osteotomy was performed closer to elbow joint and the radial head (Fig. 2).

No complications were noted in any of the cases performed along the proximal third of the ulna. Most of the osteotomies (6 out of 7) performed proximally had healed by eight to 12 weeks postoperatively; whereas those at midshaft appeared to be healed at 12 weeks (4 out of 6) or later (2 out of 6). One middle transverse osteotomy was diagnosed as a functional nonunion at five months postoperatively. No varus deformation was noted of the distal antebrachium with any of the proximal ulnar osteotomy cases, even of those with measured segmental separations ≥4 mm. Overall, the degree of movement despite location of the osteotomy, reached a plateau after two to four weeks postoperatively, with only minimal additional movements of ± 1 mm beyond this time (Fig. 6).

Discussion

The term dynamic ulnar osteotomy describes the gradual sliding motion of the proximal segment along the distal ulnar segment when an oblique osteotomy is performed (22). Since the ulna is under tension, its release causes separation of the osteotomy by the pull of the triceps mechanism. It is our understanding that no other studies have documented the location or measurable movement of the ulnar segments over time, nor compared the location of the osteotomies along the ulna. Exact direction and location of which to perform an ulnar osteotomy for treatment of cases diagnosed with MCD has only been mentioned briefly in a literature search, following ideology for cases diagnosed with an ununited anconeal process. These include: a proximal transverse osteotomy made 2.5 cm distal to the humeroradial joint; a proximal oblique osteotomy.
3 cm below the elbow joint; or an osteotomy 2.5–3 cm distal and 40 degrees caudoproximal to the radial head, performed 50 degrees to the long axis in a proximolateral to distomedial direction (23–26). No specific postoperative measurements or follow-up objective outcomes were stated. It is reasonable that an ulnar osteotomy performed more proximally would contribute more dynamically toward movement of the ulnar segments. The rationale for using an ulnar osteotomy or ostectomy to treat cases with MCD is to create distal displacement as well as caudolateral rotation of the medial coronoid process away from areas of supra-physiological loading (27). Changes at the level of the proximal ulnar segment may be translated to the level of the medial coronoid process, with shift, decreased wear, or adaptive remodelling over time. Our hypothesis was confirmed such that performance of an ulnar osteotomy at the proximal third of the ulna allowed greater release and movement of this segment over time.

Our measurements established that osteotomies performed in the middle of the ulna showed the least movement of the ulnar segments compared to those made more proximally. The direction of the cuts performed in the middle, whether oblique or transverse, was not associated with any large degree of movement. This may be due to the osteotomy being performed distal to or within the length of the constraint of the interosseous ligament. The proximal border of the interosseous ligament is several centimetres distal to the medial coronoid process; however, its location or length may vary individually (28). One supportive in vitro study using cadaver antebrachii did not find any significant difference in displacement of the proximal ulnar segment when ulnar osteotomies were performed with or without release of the interosseous ligament (29). A proximal oblique osteotomy angled in two planes allows movement of the proximal ulnar segment, yet limits excess inclination and displacement due to continued contact of the cortices- making this location and direction more favourable to achieve separation and proximal movement.

Past studies have documented alterations or movements of 2–4 mm to be of sufficient change to allow removal of the coronoid process from continued wear in vivo and in vitro (5, 27, 30–32). One retrospective study noticed clinical improvement in a large subset of cases if 4 mm of the medial coronoid process was removed (30). In vitro measurements of offset of the humeroulnar joint in the longitudinal plane demonstrated less contact wear when a 2–4 mm offset was achieved following a proximal ulnar osteotomy or sliding humeral osteotomy (27, 33). Our radiographic findings showed that up to 5 mm (range 3.6–5.5 mm) of separation between the biomarkers and up to 1.5-5 mm separation from the proximal radius occurred, which may be comparable to offload the medial coronoid when an osteotomy is performed proximally (Figs. 4, 5). However, the exact amount of correction of incongruity within the canine elbow joint remains unknown. Thus, the role of incongruity in relation to MCD may prove more complex than just movement or shift of the affected ulnar segments.

Although the diagnosis of MCD is more common in juvenile dogs, some studies suggest that this condition may remain undiagnosed until an older age when a dog presenting for forelimb lameness may already have underlying degenerative changes (34, 35). Thus, the finite decision of which individual and which type of surgery to perform remains controversial. Our study demonstrated that for those dogs diagnosed with MCD and elbow incongruity, regardless of age; in addition to arthroscopic treatment, performing a proximal oblique ulnar ostectomy yields immediate motion of the proximal segment.

We concluded that an ulnar osteotomy at any site may contribute to motion of the proximal ulnar segment; but if made closer to the elbow joint, this renders more movement of the released segment (24, 25). The authors recognize that although the results were derived from a small number of cases, they suggest that an oblique proximal osteotomy afforded the greatest movement of the proximal segment (Fig. 6). Further studies of intra-articular contact patterns are needed to confirm the exact extent to which unloading occurs. This technique in turn, may then be considered in the subset of cases seeking to accomplish movement of the proximal ulna and offload the medial compartment from continued wear. While our measurements of ulnar movement after an osteotomy may support the decision to locate it proximally, they do not provide any data on when to perform an ulnar osteotomy to improve the long term clinical outcome in patients with MCD.

References