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Functional and cosmetic modification of the facial axial pattern flap for maxillofacial reconstruction in the dog

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Closure of large maxillofacial wounds is often difficult because there is limited loose skin for tension-free primary closure and few regional vascular pedicles available for axial pattern flap reconstruction. In addition, although restoration of function is the surgeon’s primary goal, there is a, more pressing, requirement for cosmetic wound closure than in other areas of the body.

Maxillofacial wounds commonly result from trauma and tumour excision, and may be complicated by oronasal fistulation and dental involvement. Difficulty in the application of bandages and dressings, and the constant motion created by mastication, deglutition and respiration may further complicate wound healing in this area.

Local reconstructive techniques, including advancement and transposition flaps of the lip and cheek, are reported to be successful in the reconstruction of facial defects in dogs. Local flaps available for cosmetic primary closure of facial defects comprising the upper lip, cheek and adjacent maxillary region include the: labial advancement, buccal rotation, upper labial pull-down and inverse tubed skin flaps.

When reconstruction of a larger defect is necessary or a wound is not amenable to local reconstruction, an axial pattern flap may be necessary. Axial pattern flaps reported to be of use in maxillofacial reconstruction include the: superficial temporal, caudal auricular, superficial cervical, angularis oris and facial axial pattern flaps. The facial axial pattern flap is based on the three branches of the facial artery, the angularis oris, and superior and inferior labial arteries. The durability of the facial axial pattern flap was explained by this rich vascular supply in a report of its use in the reconstruction of four large maxillofacial wounds.

The present authors describe a modification of the facial axial pattern flap that facilitates closure of the hard palate and nasal cavity, whilst generating tissue for cosmetic reconstruction of the upper labial fold. This simple modification employs the deep tissues of the flap, including the platysma muscle, for wound closure, preventing the previously described post-operative billowing of the flap with respiration. Complete mucosal coverage of the deep surface of the flap is not attempted, avoiding dorsal or axial distortion of the labial fold. This modification of the facial axial pattern flap, its complications and follow-up after 3 months is described for the closure of extensive maxillectomy in two dogs.

Sacroiliac luxations that are minimally displaced can be managed appropriately with conservative treatment. Surgical fixation is necessary when displacement is severe, when the pelvic canal is narrowed or when neurologic deficits attributable to the luxation are present. Rigid fixation commonly involves insertion of a screw from the ilial wing into the sacral body.

Two cases of sacroiliac luxation are presented. Dog #1 had a minimally displaced left sacroiliac luxation plus a right sacral fracture. Dog #2 had a left sacroiliac luxation plus left ischial and pubic fractures. Both dogs were considered suitable candidates for conservative treatment but responded poorly over time. Given the degree of lameness and pain present, surgical intervention was recommended at two weeks (Dog #1) and six weeks (Dog #2) post-trauma.

Reduction and internal fixation at this point is complicated by chronicity. A minimal approach with fluoroscopy guided lag screw fixation was used with great success. Both dogs were weight bearing and comfortable within one day of surgery.

This presentation describes the technique and highlights the use of fluoroscopic guided fixation as a treatment option for chronic, non-union sacroiliac luxations.
Case Report

An eleven-year-old, female neutered, stumpy tail cattle dog was presented with a right fore-limb lameness of six months duration. Pain and discomfort were initially identified in the right shoulder. Moderate degenerative changes were seen on radiographs. The dog was treated for arthritis with pentosan polysulphate (Cartrophen), carprofen (Rimadyl), firocoxib (Previcox), oral glucosamine supplements, and an intra-articular injection of methylprednisolone acetate (Depo-Medrol). Despite these treatments, the lameness deteriorated and three months later there was frequent knuckling of the right front foot with collapsing episodes.

The dog was referred and on examination there was marked muscle atrophy particularly of the right triceps and extensor carpi radialis muscles. The extensor carpi and triceps reflexes were hyporeflexic. There was hyperaesthesia of the distal right fore leg with loss of some motor function and proprioception. The left forelimb and hind limbs were neurologically normal and there were no other signs of spinal or central nervous system problems. No axillary mass was palpable. No abnormalities were detected on three view thoracic radiography. A mass in the brachial plexus distal to the dorsal horn with no spinal cord compression was detected on contrast enhanced CT- myelogram. This was constant with a diagnosis of a tumour of the right brachial plexus.

A forequarter amputation was performed with particular care to remove the components of the brachial plexus as proximal as possible en block with the limb and the mass in the plexus. C6 to T2 nerves were transected as they exited the vertebral foramina. The axillary lymph node was removed en block with the limb as well.

The proximal ends of the transected nerves were inked with tissue marking dye and together with the 35mm diameter lobular mass within the plexus and the regional lymph node were submitted for histopathology. The diagnosis was a completely excised malignant schwannoma with lymph node hyperplasia.

The dog recovered well with our standard analgesic protocol and remains clinically well three months after surgery.

Malignant Schwannoma

Malignant schwannomas are also known as a malignant peripheral nerve sheath tumours (MPNST) in which the cell of origin is thought to be a Schwann cell. In general, MPNSTs are mesenchymal neoplasms that are included under the general group of soft-tissue sarcomas due to similarities in biologic behaviour. However when these tumours occur in the brachial plexus and other major peripheral nerves they present some specific clinical issues. The classification of nerve sheath tumours has been widely debated. Studies have shown that the most reliable classification is based on a combination of ultrastructural features and immunocytochemical demonstration of cell-specific marker proteins, by which the most appropriate nomenclature would be schwannoma or nerve sheath tumour.

In dogs, these tumours most commonly arise from the brachial plexus nerves (C6-T2), although occurrence in other peripheral nerves, spinal roots and cranial nerves have been documented.

Diagnosis

The time from onset of clinical signs till diagnosis of nerve sheath tumours range from 3 weeks to 3 years. This may be due to the fact that it is difficult to diagnose brachial plexus tumours on the basis of clinical signs alone. Survey radiography, myelography, electromyography (EMG), computed tomography (CT), and magnetic resonance imaging (MRI) are commonly used to detect brachial plexus tumours. The specificity and sensitivity of plain radiography detecting brachial plexus tumours is low. Myelography is useful in determining vertebral canal involvement, but the potential for false negative studies is still high. EMG can be used to detect denervation in muscles; however this is not specific for a tumour, as certain myopathies may show similar findings. In one study, ultrasound was effective in detecting brachial plexus tumours. It is reported that contrast-enhanced CT and MRI provide excellent imaging of the brachial plexus tumours and they are currently considered the best procedures. It appears that MRI is the preferred imaging tool for brachial plexus tumours due to excellent contrast resolution, ability to distinguish nerve bundles from vessels, and primary multiplanar imaging. Overall, however, either contrast enhanced CT or MRI provide imaging which is useful in determining the extent of disease for treatment planning.
Treatment
Metastatic disease has been reported therefore thoracic radiographs should be part of the staging process even though metastasis is a low probability\(^5\), \(^6\), \(^{19}\). The treatment of choice is wide surgical excision. This usually involves amputation, resection of the involved plexus and foraminotomy, laminectomy or hemilaminectomy to remove the proximal nerve root as close to the spinal cord as possible\(^7\). Because this dog’s tumour was quite distal in the brachial plexus, there were normal sized nerves for quite some distance from the cord and the myelogram was normal, foraminotomy was not performed and the nerves were sectioned immediately as they exited the vertebrae. However, if wide excision cannot be achieved due to involvement of the spinal cord, curative treatment may not be possible. Adjuvant radiation treatment is unlikely to be curative because the radiation dose required to treat this soft tissue sarcoma is higher than the tolerable dose for the spinal cord. On the other hand, if the tumour is situated in other peripheral nerves and cranial nerves where a curative dose of radiation therapy is possible, a combination of marginal resection and adjuvant radiation treatment may be useful. Studies have shown that there is a median survival of 1416 days and a 15% recurrence rate with wide excision alone\(^4\), \(^{13}\), \(^{14}\). McKnight et al\(^{13}\) reported a 16% recurrence rate and a 5-year survival rate of 76% for dogs treated with radiotherapy (median dose of 63 Gy) for incompletely resected Grade I and II soft tissue sarcomas which included 28 dogs with MPNST.

Prognosis
Complete excision of malignant schwannoma in the brachial plexus in dogs may be curative and this is likely related to early detection and prompt treatment\(^{13}\), \(^{17}\), \(^{18}\). Potential prognostic factors for malignant schwannomas include size, location, grade, previous treatment, and surgical margins\(^7\). In general, the prognosis for dogs with malignant schwannoma is poor however, because the tumour cells readily spread along the nerves making complete resection difficult resulting in recurrence following incomplete resection\(^4\), \(^{13}\). Prognosis for dogs with tumours confined to the plexus is better than for dogs with tumours affecting a plexus and invading the vertebral canal\(^4\).

References:
Idiopathic inflammatory bowel disease (IBD) is an important and commonly recognised gastrointestinal disorder in cats. Clinical presentation is variable, most frequently associated with chronic gastrointestinal signs including weight loss, vomiting and diarrhoea (Waly, Stokes et al. 2004). Histologically, IBD is characterised by cellular infiltration of the intestinal mucosa and lamina propria with monomorphic or pleomorphic populations of lymphocytes, plasma cells, eosinophils and neutrophils (Jergens, Moore et al. 1992).

Renal transplantation is a well recognised treatment for end-stage renal failure in cats. Criteria for selection of suitable transplant candidates included absence of neoplastic, cardiac, thyroid, infectious or other organic diseases, including inflammatory bowel disease. Diagnostic evaluation of potential candidates includes history, physical examination, extensive serologic testing, thoracic radiography, abdominal ultrasonography, electrocardiography and echocardiography (Bernsteen, Gregory et al. 2000; Kadar, Sykes et al. 2005).

In an attempt to evaluate the prevalence of concurrent gastrointestinal disease (particularly IBD) in cats receiving renal transplants, a full thickness intestinal biopsy was harvested from the small intestine at the time of renal transplantation. The medical records of all cats receiving renal transplants at the Veterinary Medical Teaching Hospital at University of California – Davis between 1996 – 2006 were reviewed. Cats were included in the study only if their medical records were complete and if their intestinal biopsies were available for re-review by a single board certified pathologist. All cats had undergone diagnostic evaluation, as described above, before surgery and were identified as free from apparent gastrointestinal disease.

Of the 80 cases that met the inclusion criteria, 35 had abnormal intestinal biopsies. Nineteen (19/35) were diagnosed with lymphocytic plasmacytic enteritis, 6/35 had lymphoma, 4/35 had pleomorphic enteritis and 2 cats each had neutrophilic or histiocytic enteritis. In 2 cases, it was impossible to distinguish between IBD and early lymphoma. Twenty four cats were alive at the end of the study, 4 had been lost to follow-up and the remainder were recorded as died or euthanized. Allograft rejection was recorded in the medical records of 17/80 cases, with rejection occurring up to 18 months post transplantation (range 5-551 days, median 61 days).

A prevalence of abnormal intestinal biopsies of 45.8% was detected in our sample population, with 36.3% of cats having histologic evidence of IBD. This prevalence was unexpectedly high in a population with no historical information consistent with chronic gastrointestinal disease. The impact of concurrent intestinal disease on cats receiving renal transplants is unknown.

2010 ACVSc College Science Week

ALGORITHM FOR MANAGEMENT OF MEDIAL COMPARTMENT DISORDERS OF THE CANINE ELBOW
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This Overview contains the notes for the following lectures:
1. Aetiopathogenic postulates of developmental elbow disease
2. Treatment algorithm for developmental elbow disease – SCO, BURP, PUO
3. Treatment algorithm for developmental elbow disease – OC implants – autogenous and synthetic
4. Current concepts in management of DED – SHO
5. Experiences with TATE and Iowa TER

Introduction
A historically-grouped triad of pathologies is typically recognized under the umbrella of elbow dysplasia:
1. Disease of the medial aspect of the coronoid process (medial coronoid disease, MCD).
2. Osteochondrosis (OC) or osteochondritis dissecans (OCD) of the medial humeral condyle.
3. Ununited anconeal process (UAP).
Other diseases such as un-united medial epicondyle and elbow incongruity are variably included.

While several diseases may coexist within the same joint, it is apparent from histomorphometric, biomechanical and genetic/heritability data that there is considerable independence in development of these multifactorial disease processes. This is further complicated by the spectrum of clinical signs and macroscopic pathology associated with any single disease process, which has important implications for treatment and prognosis. Clearly, there is no single treatment for all recognized manifestations of elbow dysplasia, so deconstruction of this oversimplified nomenclature is proposed. Furthermore, a working understanding of the etiopathogenesis of these disease processes is needed to define and optimize treatments for a corresponding spectrum of pathologic change.

There is increasing recognition that joint incongruence and associated biomechanical overload is an important factor in the development of canine elbow disease. However, it is important not to overlook biologic aspects of disease, with regard to aetiopathogenesis, disease progression and clinical management. While it is deemed unlikely that many of the elbow diseases commonly recognized result from normal biomechanical forces acting on biologically abnormal bone and cartilage, neither is it likely that they are exclusively characterized by abnormal biomechanical forces acting on biologically normal bone and cartilage.

Since these disease processes may or may not be etiopathogenically related from a biologic and/or biomechanical perspective and since elbow incongruity may be involved in some or all of these manifestations, the author feels that the term elbow dysplasia isn’t particularly helpful with respect to explaining the pathology to dog owners or with regard to treatment, and proposes that developmental elbow disease (DED) may be a more appropriate umbrella for these disparate but inter-related conditions.

Disease of the Medial aspect of the Coronoid Process

Diagnosis
Diagnostic imaging of the MCP may be challenging, and is typically based on identification of secondary markers of degenerative joint disease in the absence of other discernable discrete pathologic changes. Thorough clinical evaluation including evaluation of discomfort on elbow manipulation may be as important as subsequent diagnostic imaging.

Radiographic examination allows more detailed classification of the nature of disease (specifically likely chronicity, radiographic severity of subchondral disease, and presence of OC lesions) and may be a valuable guide to decision making regarding therapeutic intervention, rather than simply to confirm a diagnosis of MCD. This is of particular significance because elbows affected by MCD can be radiographically within normal limits. Degree of osteophytosis is poorly correlated with pathology subsequently identified by direct joint inspection but has close associations with expression of cartilage genes. Particular attention should be paid to identification of opacification in the region immediately caudal to the medial coronoid, sub-trochlear sclerosis (STS), as an early sentinel of disease. (Ref 1) STS may represent trabecular and canalicul remodeling, altered osseous density pattern, periarticular osteophytosis and/or enthesiophytosis at the insertion of the biceps brachialis muscle complex. Diseases involving the shoulder joint and adjacent structures should be rigorously excluded as causes of thoracic limb lameness.
Whilst CT examination is very helpful for assisting identification of subchondral lesions of the medial coronoid process, and high-field MRI may be useful for identifying bone marrow lesions in this region, arthroscopic evaluation constitutes the most important single interrogation directing decision-making for MCD with or without pathology of the medial aspect of the humeral condyle. A spectrum of arthroscopic changes including fragmentation, cartilage fissures, chondromalacia, and cartilage fibrillation affect the medial coronoid process (MCP) and we consider these to be manifestations of a common underlying disease process. (Ref 2)

Etiopathogenesis
Pathologic changes initially affect subchondral bone with formation of microcracks, characteristic of local fatigue failure. Although the precise nature of this fatigue phenomenon remains elusive, several biomechanical hypotheses encompass the disparate range of recognized pathologic changes, all of which may be attributable to humero-ulnar conflict (HUC), with radial incisure or coronoid tip fissuring/fragmentation potentially arising from varying ectopic focal overload phenomena. These may include but are not limited to:
1. Static radio-ulnar length disparity: shortening of the radius relative to the ulna.
2. Dynamic radio-ulnar longitudinal incongruence: relative distal displacement of the proximal radial articular surface compared with the distal aspect of the ulnar trochlear notch during weight bearing or in certain positions within the range of motion of the elbow.
3. Dynamic humero-ulnar incongruence: disparity in relative position of the ulnar trochlear notch and the distal humerus occurring in a torsional fashion, such that MCD and UAP could occur concomitantly.
4. Ulnar trochlear notch geometry incongruence: shape abnormality of the articular contours of either the radial incisure of the medial coronoid or the humeral condyle, or both.
5. Primary rotational instability of the radius and ulna relative to the distal aspect of the humerus.
6. Musculo-tendinous mismatch: rotational instability as a secondary effect of disparity between muscle tensions generated during supination and pronation of the antebrachium relative to the humerus. The biceps brachii/brachialis muscle complex has been identified as a potential contributor in this regard based on its high moment of inertia about the elbow and eccentrically orientated insertion in the region of the MCP, but antebrachial flexor tendons also likely play a role.

Other hypotheses include a primary developmental disease of bone and/or cartilage such as osteochondrosis, supported by thickening of cartilage recorded in some specimens although it seems most probable that such changes are a secondary biological effect of subchondral bone disease or underlying biomechanics. It is likely that fragmentation represents fracture along planes of increased focal load and that the cartilage of the fragment surface is thickened because the fragment moves relative to the distal humerus such that its cartilage surface is not subjected to the same erosive conflict that the remaining portion of the medial coronoid and medial aspect of the humeral condyle may endure. Early hypotheses of incomplete ossification have been largely disregarded in light of the embryonic origin of the MCP by appositional ossification. (Ref 3)

Disease Development
Progression of subchondral microcrack formation to visible cartilage fissuring or fragmentation by coalescence appears variable between dogs and between different regions of the coronoid process. Age of onset of clinical signs attributable to MCD may be associated with underlying pathology precipitated toward clinical manifestation by a relatively minor traumatic event. The “end-stage” of MCD also varies between patients, ranging from formation of free fragments, to cartilage eburnation associated with alteration of canicular pattern of subchondral bone. This may reflect variable patterns of biomechanical overload (regional mechanical variance) or variable biologic response within zones of the medial coronoid process in response to similar biomechanical stimuli (regional biologic variance). Subchondral microcrack formation extends beyond the area of superficial or macroscopic disease. The pattern of visible pathologic change may be dependent on a balance between rate of microcrack formation and healing by fibrous infilling, and on the focal intensity of supraphysiologic forces, which could theoretically radiate outward from a central focus akin to fissure lines created by movement of tectonic plates.

Treatment Options
Considering these proposed etiopathogenic pathways, our preference for local treatment of end-stage MCD is subtotal coronoid ostectomy (SCO) whereby a pyramidal portion of the medial aspect of the coronoid process extending to include the entirety of the articular portion distal to the level of the radial incisure is removed either by osteotome or shaver guided arthroscopically or using a micro-sagittal saw via a mini-medial arthrotomy. (Ref 4) Subchondral microfractures have been found extending to the edge of the osteotomy line, but the excised fragment generally includes the full extent of visible cartilage pathology and subchondral pathology as identified by histomorphometry (Danielson and Fitzpatrick, Vet Surg 2006). Other surgical techniques for focal management of MCD include removal of free fragments alone, and varying degrees of debridement, abrasion, or excision of the visibly diseased portion of the medial aspect of the coronoid process, either
arthroscopically or via arthroscopy.
In the author’s opinion, in general, SCO yields superior clinical outcomes in the medium and long term by comparison with fragment removal alone. However, this is anecdotal opinion and is very patient dependent in the author’s view – i.e. the outcome is dependent on the inciting etiopathogenesis of HUC, in that some patients perform poorly and sustain further erosion of the medial compartment by the cut edge of the medial coronoid, whilst others experience lameness resolution for many years after SCO. Confounding factors are that propensity for periarticular osteophytosis occurs independent of profundity of cartilage pathology and dogs have a variable tolerance for pain associated with cartilage erosion, with some dogs sustaining severe medial compartment erosion but coping well from a functional standpoint. This is particularly the case where bilateral disease is present and in older Labrador Retrievers in the author’s opinion.

If primary joint incongruity is present, often the caudal edge of the osteotomy following SCO may still abrade the opposing aspect of the humeral condyle and clinical lameness may persist. If dynamic joint incongruence or abnormal dynamic loading are deemed potential causes of MCD, then arguably, oblique proximal ulnar osteotomy (PUO) should be considered as a treatment approach; however, without better mechanical understanding, it is unclear what osteotomy configuration might be most beneficial. In our experience, long-term outcome is equivocal in dogs with MCD without substantial humeral condylar pathology. However, when there are frictional abrasion lesions associated with the medial aspect of the humeral condyle or where definitive humeroradial incongruity (>3mm) is evident on CT or arthroscopic assessment, ulnar osteotomy may be justified. We employ a novel 25-40 degree bi-oblique cut trajectory from caudoproximolateral to craniodistomedial. (Abstract 1)

When rotational instability and/or excessive supination loading force is suspected, we employ a biceps ulnar release procedure (BURP) that involves tenotomy of the distal insertion of the biceps brachii/brachialis complex onto the ridge immediately caudal to the abaxial portion of the medial coronoid process, in an effort to ameliorate humero-ulnar conflict. We have used this procedure before development of end-stage disease and although early outcomes have been encouraging with resolution of clinical signs and negligible morbidity, further investigation of indications and outcomes are indicated. It is unknown at this stage whether BURP may reliably be employed for successful palliative treatment of end-stage medial compartment erosion where periarticular fibrosis or profundity of pathology may negate the positive effects of tendon release. (Abstract 2)

Non-surgical management remains the major alternative approach when focal surgical treatment is considered inappropriate or has already been performed without resolution of clinical signs, with the caveat that the authors will frequently perform ancillary surgical intervention in the latter eventuality. Successful non-surgical management plans typically involve simultaneous use of a moderated exercise routine, body weight control, judicious use of non-steroidal anti-inflammatory medication or prescription analgesic agents, and use of nutraceuticals, disease modifying compounds and prescription diets. A prospective and carefully designed study of outcomes following conservative management by comparison with fragment removal and SCO for treatment of confirmed similar MCD grades would yield valuable data. A recent study (Burton NJ, BVOA, 2010) compared outcomes in a small number of dogs treated conservatively with a group treated by fragment removal alone and found no difference at six months postoperatively.

**Disease of the Medial Humeral Condyle**
Osteochondrosis is recognized as a disturbance of enchondral ossification with failure of deeper cartilage layers to mature and mineralize appropriately. There is resultant thickening of articular cartilage which is thought to be associated with malnutrition of the deeper layers of cartilage and subsequent chondrocyte necrosis. Progression of lesions to osteochondritis dissecans (OCD) by cleavage or fracture of abnormal cartilage allows access of synovial fluid to the sub-chondral bone and exchange of inflammatory mediators. Lesions are commonly relatively medially / abaxially located, and diagnosis is usually straightforward, by recognition of a scalloped subchondral defect visible on standard cranio-caudal radiographs of the elbow. Males are approximately twice as likely to be affected as females (although 25/27 dogs in one of our recent studies were male) and the condition is bilateral in about 50% of cases. Labradors and Rottweilers are over-represented, along with various other large or giant breed dogs. Age at presentation typically ranges 5-10 months and overt disease or lameness is typically present before 7 months of age.

Concomitance of OC with MCD is frequent (30/33 elbows in one of our studies). This may reflect a potential role for incongruity in the etiopathogenesis of both diseases, although numerous developmental factors have been implicated including genetic, dietary, growth rate, and endocrine factors, potentially intimating a more biologic etiopathogenesis than that inciting MCD. We often recognize OCD in conjunction with varying degrees of cartilage erosion (kissing lesions) of the medial humeral condyle, apparently associated with HUC and MCD, which may support a role for incongruity in etiopathogenesis of OC. Regional mechanical or biologic variance phenomena likely influence disease manifestation and research targeted at identifying morphologic changes of cartilage and subchondral bone is warranted, but hampered by the degree of pathologic change due to secondary arthrosis by the time of diagnosis in most clinical cases. Abrasive lesions are often centered at or
immediately peripheral to the OCD lesion, but remain distinct in both gross appearance and depth of subchondral defect. The medial aspect of the coronoid process inevitably demonstrates a similar degree of cartilage pathology across some portion of its surface (mirror-image striations), whereas additional presence of macroscopic fragmentation or fissuring, although common, is more variable.

Both surgical and non-surgical management of OCD of the medial humeral condyle (with or without MCD) result in progression of osteoarthritis, yet variation in outcome within the spectrum of identified disease and detailed medium- and long-term outcomes have typically not been reported. In our experience, presence of marked cartilage disease of the medial humeral condyle has been associated with relatively poor clinical outcomes and in some cases, even if MCD is simultaneously treated by SCO, may continue to progress with eventual full-thickness eburnation throughout the medial joint compartment.

**OCD without MCD**

Conventional surgical treatments (including curettage, microfracture, micropick) aimed at stimulation of fibrnocartilage ingrowth are still considered justified for treatment of small (typically <5mm maximal diameter in medium- and large-breed patients), shallow (typically <1mm subchondral bone depth defect) or abaxial lesions where prognosis is anecdotally considered to be relatively positive.

For treatment of more substantial lesions, either of large diameter or with a deep subchondral defect, regeneration of fibrnocartilage has anecdotally been found to be inadequate for appropriate reconstitution of the articular contour. Anecdotally, the author has experienced poor outcomes after conventional debridement of elbow OCD lesions in the medium and longer term. Second look arthroscopic examinations in patients enduring ongoing clinical problems associated with pain or lameness, have revealed progressive medial compartment erosion associated with OCD and HUC.

Reconstruction of the articular contour may be preferable and a range of materials (autografts, allografts, resorbable and non-resorbable filler matrices) have been investigated. Of the procedures potentially available for clinical application, Osteochondral Autograft Transfer (OAT) procedures are most readily applicable for use in dogs. OAT involves harvesting a cylindrical core of bone with an intact cap of healthy cartilage from a non-contact articular surface (typically the medial trochlear and proximo-medial condylar regions of the stifte) and implanting this core into a socket created at the site of the osteochondral defect (Ref 5). OAT procedures are widely used for osteochondral resurfacing in human joints with validated clinical outcomes to 10 years. Putative benefits of OAT procedures over conventional techniques include accurate reconstruction of subchondral and articular contour, resurfacing with hyaline or hyaline-like cartilage and creation of an immediate barrier between synovial fluid and subchondral bone. However, accurate matching of surface topography or split-line divergence pattern is not possible for stifle to elbow procedures, and the resultant surface, whilst potentially being superior to debridement alone, is suboptimal. Nonetheless, clinical outcomes have been positive both on short and long term followup and arthroscopic reassessment where available has revealed robust resilient defect resurfacing.

More recently the author has employed polyurethane ‘cartilage-substitute’ filler-plugs (Synthetic Osteo-chondral Substitute, SOCS) for resurfacing of OCD defects in the canine elbow. This obviates the requirement for a donor site, decreases surgery time and reduces challenges associated with topographical surface-mapping, since the SOCS graft can be contoured in situ. SOCS joint re-surfacing has one-year validated clinical and imaging outcome measures in dogs at the authors’ facility and results are very promising. (Abstract 3)

**OCD and MCD**

Treatment approach is based on the severity of cartilage pathology present, affecting both the coronoid process and the medial aspect of the humeral condyle around or adjacent to the OCD lesion. When MCD is identified in a joint with OCD of the medial humeral condyle, we consider SCO justified, almost without exception, irrespective of the severity of arthroscopic or radiographic pathology. Progression of cartilage pathology was documented post-operatively in 10 of 24 elbows treated for concomitant MCD and OCD by SCO and OAT procedures of the medial humeral condyle. On this basis, we now advocate a combination of OAT or SOCS procedures plus SCO and PUO. Application of PUO directed bi-obliquely as described above (BOD-PUO) has been clinically and arthroscopically documented to provide adequate amelioration of HUC to ensure graft survival, at least in the medium term and helps avoid complications associated with osteotomy instability including incidence of delayed or non-union. (Ref 5) We do not recommend intramedullary stabilization and feel it is in fact contra-indicated when appropriate alteration in surface contact mechanics of the humero-ulnar joint is required.

**Focal Medial Humeral Condylar Kissing Lesions associated with MCD**

Where MCD-associated focal, partial thickness (modified Outerbridge grades 1-3) cartilage lesions are observed on the surface of the medial aspect of the humeral condyle, we consider SCO alone to provide adequate reduction in persistent frictional abrasion due to HUC to support positive clinical outcomes in most cases, unless overt incongruity is detected between the remaining cut edge and the humerus. Where these lesions are recognized in the same joint as an OCD lesion, treatment of the OCD lesion by OAT procedures can still be considered appropriate, but ancillary SCO and BOD-PUO are critical to achieving
a positive outcome. Where deeper (modified Outerbridge grades 3-5) cartilage lesions are identified on the surface of the medial aspect of the humeral condyle, but are focal (i.e. not affecting the entire contact surface of the medial aspect of the humeral condyle) we consider that SCO is unlikely to provide adequate reduction of conflict and adjunctive BOD-PUO is often justified. In vitro biomechanical studies to define indications, elucidate modality of action and document efficacy of BOD-PUO are ongoing.

**MCD and Extensive Medial Humeral Condylar Kissing Lesion**

In some dogs, MCD is associated with severe humeral erosive lesions attributable to HUC. The typical appearance is full thickness (modified Outerbridge grade 4-5) cartilage pathology across the major portion of the medial joint compartment, affecting both the medial aspect of the humeral condyle and the corresponding distomedial ulnar notch contact area. Clinical signs are typically severe and chronic, but can occur in dogs as young as 6-7 months. Long-term prognosis is considered severely guarded after medical management or local surgical treatment. In this scenario, we recommend use of sliding humeral osteotomy (SHO). This involves application of a stepped locking plate on the medial aspect of the humerus and creation of a mid-diaphyseal osteotomy such that the proximal humeral segment is translated laterally relative to the distal segment. Biomechanical unloading of the diseased medial joint compartment is supported by in vitro studies and outcomes of clinical application have been positive, including arthroscopic and histologic documentation of novel fibrocartilaginous cover of previously eburnated regions. Owner perception of outcomes in terms of reduction of pain and improvement of quality of life are uniformly positive and kinetic data supports improvement of lameness grade. Proactive preoperative owner counseling and judicious patient selection are strongly advised prior to this procedure, with cage rest and leash-only walking advocated for six to twelve weeks. We have performed over 100 of these procedures and at 3 to 4 year follow-up, results remain encouraging, reproducible and sustainable such that the technique can be recommended for widespread clinical application (Ref 6). Early problems with the technique have now largely been overcome and recent iterations of technique have suffered few problems and garnered satisfactory clinical improvement.

SHO is still deemed a salvage procedure where full-thickness cartilage erosion of the medial compartment is apparent, but prophylaxis of full thickness erosion may be a justifiable indication if it can be reasonably expected that HUC will progressively result in debilitating OA. With decreased complication rate and experience of positive outcomes, the author has become more willing to perform SHO on juvenile dogs where OCD lesions are not clearly margined, where HUC results in erosive lesions of the medial humeral condyle outside the margins of the deeper OCD “crater” lesion, or where extensive progressive HUC “kissing” lesions are rapidly resulting in destruction of the medial compartment. Whether more recent developments in radial or ulnar osteotomy techniques may prove more or less efficacious clinically than SHO remains to be seen.

**Global Elbow Arthrosis**

In some dogs, both medial and lateral joint compartments may be severely diseased, with extensive eburnation of cartilage and subchondral bone of all major articular structures. Chronic lesions associated with MCD and/or elbow incongruity are frequently responsible, although some cases may have previous documentation of concomitant OCD lesions or other pathologies such as articular fractures and erosive arthropathies.

In this circumstance, salvage procedures like Total Elbow Arthroplasty (TEA) or arthrodesis may represent the only viable options for restoration of comfortable limb function. Whereas elbow arthrodesis may provide marked improvement in comfort for dogs with severe degenerative joint disease, substantial functional lameness inevitably persists with limb circumduction and potential associated disability. TEA is widely considered to be preferable to arthrodesis; however, morbidity and prolonged convalescence associated with currently available implant and instrumentation systems have been concerning. TEA shows real promise for amelioration of discomfort and improvement of quality of life but long-term clinical outcome data is lacking for more recent implant designs. The author does not advocate TER where the lateral radio-humeral joint compartment is still intact. The semi-constrained metal on polyethylene prosthesis developed at Iowa State University by M Conzemius has gained reputation for difficulty of technical application and mixed outcomes. In a very limited number of cases, the author has had reasonable functional outcomes, in that lameness remains but owners report improved quality of life and less apparent pain in their opinion and as assessed by clinical examination. Similar clinical outcomes have been experienced in the author’s facility for a limited number of constrained TATE implanted-dogs. Generally the technique of application for this technique, developed by Randy Acker, is easier to achieve in a standardized fashion that for the Iowa elbow, but outcomes in the authors experience are subjectively only marginally superior. There may be reduced propensity for short-term failure with the TATE elbow in the author’s experience, but the author has experienced challenges with ongoing lameness due to implant loosening or failure of healing of the epicondylar osteotomy, and most animals remain at least mechanically lame. However, the author has also experienced some truly excellent results with TATE application and full recovery of pain-free function. Removal of relative movement of the radius and ulna in pronation and supination is a potential challenge with the TATE cartridge-slipper constrained design. Ongoing kinetic and kinematic studies will document longer term outcome for the TATE elbow prosthesis.
Development of a biomechanically resilient TER which allows more accurately normalized elbow motion is the subject of research by several manufacturers.

**Elbow Incongruity**

Overt incongruity is typically recognised as a step in the articular surface between the radial head and ulnar trochlear notch. Either the radius or the ulna may be reduced in length relative to the other, and in many cases, difference in length is attributable to a specific injury of the growing bone (premature physeal closure, radio-ulnar synostosis, etc.). These are typically associated with a traumatic event, although there may be a lag of several months until incongruity or overt clinical signs develop and the initiating event may not be historically reported. Elbow incongruity almost always develops in the skeletally immature patient.

Incongruity will result in deformation of the respective contact areas of the elbow joint, creating areas of focally-increased load bearing and subsequent disease. The precise pattern of disease depends on the precise conformation of incongruity.

When the radius is shortened relative to the ulna, the most common reason for lameness is MCD. In younger patients, the coronoid process (and to a lesser extent, the humeral condyle) may remodel, with increases in overall dimensions and density, but cartilage erosion and fragmentation will almost inevitably result. When the ulna is shortened relative to the radius, pathology is more variable. UAP may develop in some patients, but focal cartilage eburnation or subluxation of the radial head may be more common.

Due to the tethering effects of the antebrachial bones on each other via the interosseous muscle, complex antebrachial deformities may be recognised concomitant with elbow incongruity, including rotational misalignment, sagittal bowing, transverse misalignment, carpal deformity and limb shortening. While these aspects of disease may justify treatment individually, reestablishment of elbow congruity should be considered the primary aim of any intervention performed. Where overt incongruity is recognised, surgical intervention is almost always indicated and while non-surgical management may resolve lameness in the short-term, long-term progression of degenerative disease is likely to be severely debilitating. Early surgical intervention may offer the optimum prognosis due to potential capacity for immature bone and cartilage to remodel in response to changes in articular morphology.

A range of treatment methods are available for treatment of the various configurations of elbow incongruity. The simplest methods include dynamic proximal ulnar osteotomy which may be sufficient to achieve excellent congruity in many cases with simple radio-ulnar length mismatch, while severe or complex deformities may necessitate methods such as multiple derotation or angular osteotomies, distraction osteogenesis, dynamic radial head relocation and transarticular distraction techniques.

**Ununited Medial Epicondyle (UME)**

UME is no longer considered by the majority of surgeons to be a component of the “elbow dysplasia” grouping of diseases.

This rare condition has been widely debated regarding its aetiopathogenesis and the nomenclature of UME is almost certainly a misnomer. The separate ossification centre of the medial epicondyle usually unites by 10 weeks of age, significantly before development of any associated clinical signs in most patients, and anatomical location does not appear to correlate well with the typical location identified. Currently popular hypotheses are of a chronic avulsion fracture, enthesiophytosis or dystrophic mineralisation associated with the insertion of a number of flexor tendons at that level.

Radiographic appearance is typically one of a relatively large mineralised opacity separate from and medial to the medial condyle of the humerus. While “UME” may be associated with pain or lameness in some patients, it may also be recognised as an incidental finding. Where associated with a clinical problem, surgical removal of the mineralised portion appears to be beneficial.

**References**


ABSTRACTS

1. A NOVEL BIOBLIQUE DYNAMIC CORRECTIVE ULNAR OSTEOTOMY FOR THE TREATMENT OF MEDIAL CORONOID DISEASE IN DOGS

Introduction: Corrective ulnar osteotomies have been employed to restore static humero-ulnar and radio-ulnar incongruency with encouraging clinical results. Osteotomy configuration, orientation, and usage of internal stabilization vary in the veterinary literature. Reported complications of ulnar osteotomies are excessive instability, varus formation, and infection. We proposed an osteotomy of the proximal ulna directed obliquely in both the caudoproximal-to-craniodistal and proximolateral-to-distomedial planes. Our hypothesis was that the stability achieved by the biobliquity of the osteotomy would provide reliable osseous union, facilitate restoration of elbow joint congruency and minimize postoperative complications.

Materials and Methods: A retrospective analysis of clinical, radiographic, and arthroscopic data of dogs affected by thoracic limb lameness attributable to identified humero-ulnar incongruity as a predictor of medial compartment disease was performed. Inclusion criteria required radiographic or arthroscopic evidence of humero-ulnar and/or radio-ulnar incongruity. All cases a bioblique proximal ulnar osteotomy was created using a long micro sagittal saw blade at a level corresponding to the junction of the proximal and middle third of the radius. The blade was held as close as possible to the caudal cortex of the ulna to produce an osteotomy approximating 30° (range 25-40°) to the caudal ulnar cortex in both transverse and sagittal planes. Outcome measures included lameness scores, 2nd look arthroscopy where indicated, and radiographic assessment of humero-ulnar and radio-ulnar congruency.

Results: 42 dogs (46 thoracic limbs) met the inclusion criteria. All dogs in the study underwent subtotal coronoid ostectomy for treatment of concomitant fragmented medial coronoid process. Osteochondritis dissecans was arthroscopically diagnosed in 12 elbows, and osteochondral replacement was performed in 6 of these. In 38 cases (90.5%), lameness scores improved by 6 months postoperatively. In 35 cases (83.3%), arthroscopic and/or radiographic evaluation revealed restoration of elbow congruency in all limbs by 6 months postoperatively. Complications included infection (2 limbs) and delayed union (2 limbs). Varus deformity did not occur in any of the limbs.

Discussion: Incongruency, both radio-ulnar and humero-ulnar, results from asynchronous growth. These incongruencies, musculotendinous mismatch, and rotational instability have all been proposed as potential causes of medial compartment disease of the elbow. The bioblique nature of this osteotomy appears to provide transverse plane stability and has improved clinical function of the elbow by facilitating restoration of joint congruency. Postoperative complications have been minimized by decreasing instability and preventing varus formation. Delayed union was only evident in a single case where the procedure was performed as a bilateral simultaneous procedure in a young, very active dog. The rationale for our directionally controlled osteotomy is to enable dynamic proximal ulnar motion whilst avoiding proximal segment transverse deviation.

2. BICEPS ULNAR RELEASE PROCEDURE FOR TREATMENT OF MEDIAL CORONOID DISEASE IN 49 ELBOWS

Introduction: Disease of the medial aspect of the coronoid process (MCD) and the opposing surface of the humeral condyle is a commonly recognized cause of thoracic limb lameness in dogs. Humero-ulnar conflict (HUC) may be implicated in the initiation of diffuse subchondral pathology and progressive frictional abrasion of the cartilage and subchondral bone of the medial compartment. Mismatch in synchronized development of the osseous and/or musculo-tendinous components of the elbow joint may contribute to supra-physiologic overload of the medial coronoid process. The biceps brachii/brachialis muscle complex has a large fan-shaped insertion on the medial coronoid process and a smaller insertion on the proximal radius. The moment arm exerted by this musculo-tendinous unit is significant. The objective of this pilot clinical study was to establish technique, assess feasibility and evaluate outcome of performing biceps ulnar release procedure (BURP) in dogs affected by radiographically and arthroscopically confirmed MCD. Our hypothesis was that BURP would ameliorate lameness
and pain and would not result in adverse sequelae.

**Materials and Methods:** BURP was performed as a solitary procedure where thoracic limb lameness was present, pain was localized to the medial aspect of the elbow, subtrochlear sclerosis was radiographically evident and synovitis plus cartilage disease of the medial coronoid process (modified Outerbridge score 1-3) was arthroscopically determined with or without fissuring of the radial incisure but with minimal disease (grade 1-2) of the opposing humeral condyle. BURP was performed as an ancillary procedure with subtotal coronoid ostectomy (SCO) where overt fragmentation of the medial coronoid process was associated with pathology of the opposing aspect of the humeral condyle exceeding grade 2. BURP was performed via mini-medial arthrotomy whereby the ulnar component of the tendon of insertion of the biceps brachii/brachialis was cut parallel to the caudal border of the medial collateral ligament. Owner visual analogue scale (VAS) questionnaires were completed pre-operatively and at 5-17 (mean 8.3) weeks post-operatively, including interrogation of a range of patient functions and perceptions of overall surgical outcome. A numerical score was attributed to each function parameter with a value of 0 for poor and 100 for excellent outcomes. Simultaneous veterinary subjective assessment of lameness and pain was also performed. Force plate data was collected 5-17 (mean 8.3) weeks for 25 dogs using a biomechanical platform (type 9281CA, Kistler Instrumentation, UK). Five valid trials were obtained for bilateral thoracic limbs of each dog at the walk (velocity 0.8-1.3 m/s). Ground Reaction Forces (GRFs) were obtained and analyzed, featuring specifically Peak Vertical Force (PVF), falling slope and Vertical Impulse (VI). Responses to owner questionnaires and force-plate results were analyzed using Minitab® 14.20 Statistical Software (Minitab Ltd., Coventry, UK) and compared by paired t-test with confidence interval set at 95%.

**Results:** BURP was performed on 39 dogs (49 elbows), 25 of which received BURP in association with another procedure (3 dogs, 4 elbows had same joint SCO and BURP; 22 dogs SCO unilateral and BURP contralateral). 7 dogs received bilateral BURP and 7 dogs unilateral BURP. Mean age was 26 months (range 3-111 months); mean body weight was 27.5 kg (range 9.4-46.1 kg). Owner assessment questionnaires were available for 18/39 (46.15%) dogs with a mean follow-up time of 8.3 weeks. Responses to 12/13 function-related owner-assessed questions showed statistically significant improvements (p<0.05) post-operatively compared with pre-operative assessments by paired t-test. Pre-operative function assessments ranged 25.2-55.8, while post-operative scores ranged 66.2-83.1. Owner-assessments of success were positive with mean score of 80.4 (±21.88). Owner responses to the question “Would you have this operation done again?” were positive with mean of 94.31 (±7.12). Force-plate data of four dogs operated unilaterally by BURP where the contralateral limb was considered clinically, radiographically and arthroscopically normal were considered for statistical analysis. Evaluation revealed no statistically significant difference between means of non-operated limbs and operated limbs analyzed by paired t-test. Mean Peak Vertical Force for non-operated limbs (NOL) was 9.96 ± 3.173 (N expressed as % body weight) compared with 9.57 ± 2.894 for operated limbs. Mean Falling slope for NOL was -1187 ± 621 (N expressed as % body weight/sec) compared with -1217 ± 532 for BURP limbs. Mean Vertical Impulse for NOL was 1.89 ± 0.571 (N expressed as % body weight) compared with 1.941 ± 0.365 for BURP limbs.

**Discussion:** This study has significant limitations, particularly with regard to absence of universal pre-operative force-plate data and paucity of long-term follow-up. However this pilot study intimates that the technique is feasible and early outcome measures are encouraging in dogs affected by radiographically and arthroscopically confirmed MCD. Definitive case-selection criteria have yet to be established and biomechanical data will be necessary to determine if BURP reduces joint contact pressure associated with HUC. Whether BURP can alter disease progression, preventing cartilage disease or fissures of the medial coronoid process becoming fragmented or reducing persistent frictional abrasion of the medial compartment following SCO remains to be determined. We did not observe adverse sequelae and BURP effectively addressed lameness and pain in the short term as assessed by veterinary, owner and limited force-plate outcome measures. Further investigation is therefore warranted.

**References:**


_Surgery Chapter_
3. SYNTHETIC OSTEO-CHONDRAL SUBSTITUTE (SOCS) FOR TREATMENT OF OSTEOCHONDritis DISSECANS OF THE CANINE ELBOW, STIFLE, AND SHOULDER WITH ARTHROSCOPIC AND MRI OUTCOME MEASURES

Introduction: Osteochondritis dissecans is an important cause of lameness in juvenile dogs. Progression of osteoarthritis is inevitable in spite of treatment modality and prognosis may be poor in some anatomical locations especially with increasing lesion size. Conventional treatments rely on removal of loose chondral flaps combined with stimulation of fibrocartilaginous ingrowth. Poor outcomes may be associated with the inferior mechanical properties of fibrocartilage. Osteochondral Autograft Transfer procedures have been reported in the canine stifle \(^{1,2}\) but concerns have been raised regarding donor site morbidity, particularly where donor core collection is performed from a distant joint. Allograft and xenograft transfer procedures are technically difficult. We hypothesized that resurfacing of OCD lesions in clinical canine patients using polyurethane synthetic osteochondral prostheses (Arthrex, Naples, FL) would be clinically feasible and biologically compatible and would achieve favorable short- to medium-term clinical outcomes whilst avoiding potential sources of morbidity.

Materials and Methods: Dogs presenting for lameness attributable to OCD of any joint March 2008 – March 2009 were prospectively selected. Lesions were assessed radiographically, by MRI and arthroscopically prior to intervention. MRI was performed using a 1.5T Siemens Magnetom Symphony with a combination of Proton Density Fat Saturated, T2 and T1 sequences. Slice thickness was 2.5–3 mm; fields of View were 180–260 mm. Osteochondral autograft transfer system (OATS™; Arthrex, Naples, FL) instrumentation was employed for recipient socket preparation. Recipient sockets were created of appropriate depth, diameter and number to cover defects and were filled with polyurethane synthetic osteochondral prostheses in press-fit fashion. 6, 8 and 10mm graft diameters were employed. Bi-oblique dynamic releasing proximal ulnar osteotomy was performed in 7 of 8 elbows with the objective of protecting the prosthesis surface from wear associated with humeral-ulnar conflict. Subjective evaluations of lameness and pain on joint manipulation were performed at 2, 6, 12-18 and 22-28 weeks. Radiography and MRI was repeated at 12, 28, and 52 weeks. MRI interrogation was graded as (1) Excellent where a fluid signal was not evident at the host-graft interface, there was evidence of in-growth between two concomitantly placed grafts, the host-graft surface(s) appeared perfectly aligned and joint effusion had resolved; (2) Good where there were patchy areas of fluid evident at the host-graft interface, no obvious fluid signal between multiple plugs, the graft surface was within 0.5 mm of the host cartilage surface and no or slight joint effusion; (3) Poor where fluid signal was evident surrounding the host-graft interface, the host-graft surface was 0.5 - 1 mm disparate or where there was residual joint effusion. Arthroscopic evaluation of all elbow grafts was performed at 12 weeks post-operatively to determine if further intervention were required due to persistent humero-ulnar conflict, based on a previous study indicating merit of second-look arthroscopy (SLA).\(^1\)

Results: 12 dogs, constituting 15 joints received synthetic osteochondral cores (SOC). Mean patient age was 10.9 months (range 5-26 months). Mean body weight was 38.8kg (range 22-63kg). Breeds represented were Golden retriever (2), Labrador retriever (3), Irish Wolfhound (2) and five others. Lesions treated included caudo-central humeral head (n=5 joints), medial humeral condyle (n=8 joints) and lateral femoral condyle (n=2 joints). 2 prostheses were used in 5/15 joints while a single prosthesis was used in 10/15 joints. Single session bilateral procedures were performed in 2 dogs (bilateral femoral condyle and bilateral humeral head respectively). Complications included septic arthritis in one shoulder, patellar luxation post-operatively and in one elbow osteotomy delayed union in one elbow. There was no complication associated with SLA of elbow grafts and one elbow required ulnar osteotomy due to frictional abrasion attributable to humero-ulnar conflict. Lameness resolved in 11 dogs by 12 weeks post-operatively and in all dogs by 16 weeks postoperatively. Pain on joint manipulation resolved in 10/12 dogs by 12 weeks post-operatively and all dogs by 16 weeks postoperatively. All dogs (15 joints) were interrogated radiographically and by MRI at 12 weeks post-operatively. This revealed 9 excellent, 5 good and 1 poor graft integration (the patient which had sustained septic arthritis also had core subsidence, but clinical signs resolved). All graft sites (15) with MRI follow-up at 22-27 weeks (14) and 50-62 weeks (7) retained the level of host-graft interface characteristics evident at the 12 week interrogation time-point. Sentinels of osteoarthritis including synovitis and osteophytosis were present throughout but particulate synovitis was not detected at any time point. Presence of a peri-implant fluid signal was the most frequently observed cause for a diminished MRI score. Cartilage wear was not detected on joint surfaces articulating with synthetic osteochondral cores by either MRI or arthroscopic imaging at 12 weeks postoperatively but one elbow graft had sustained wear associated with persistent humero-ulnar conflict and this indicated further intervention by proximal ulnar osteotomy.

Discussion: Technical application was straightforward and was considered simpler than established OAT procedures due to lack of requirement for donor harvesting and manipulation. Low morbidity of affected joints was recorded and positive early
clinical outcomes were documented based on clinician and owner assessments. Only one complication (core subsidence) was related to application technique. There was no requirement for ongoing analgesia. Post-operative imaging supports biocompatibility of the prostheses (consistent with existing biological applications for polyurethane including articular implants) and feasibility of application across a range of anatomic locations. The degree to which the SOCs incorporated in to the subchondral bone did not change between 12 and 52 weeks post-operatively. Synovitis was present pre and post-operatively as would be expected but particulate synovitis was not observed on follow-up imaging. Morphological changes to synovitis identified on elbow SLA included marked decrease in vascularity indicative of quiescence. Durability of the implant remains unknown pending longer term outcomes, but application may reduce reported unpredictability of long-term donor core outcome associated with variation in cartilage thickness or articular surface contour between donor and recipient sites\textsuperscript{2,3} and micro-anatomical features such as split-line pattern orientation\textsuperscript{4}. Early results support our hypothesis and indicate favourable results to one year post-operatively, but further investigation is required to determine longer term outcomes. Synthetic osteochondral core transplant is a potentially viable treatment option for OCD in clinical canine patients and warrants ongoing study.

References:
Introduction: Osteoarthritis (OA) is one of the most common diseases of dogs. Estimates suggest that 20% of the canine population are affected by OA and therefore the impact of the disease is very large. This is further reflected in the large market for drugs used to treat the disease. Osteoarthritis is a disease of the whole joint – the articular cartilage, bone and synovium. The relationship between the pathology in each of these tissues is poorly understood but is the articular cartilage that has received most attention in terms of research. Although joint biomechanics undoubtedly have an important role in disease initiation and progression, biochemical changes occur in all joint tissues and contribute to joint failure. OA is a heterogeneous disease and assessment of the disorder is difficult. The poor correlation between radiographic and clinical data highlights this difficulty. Expression of different facets of the disease seems to vary between individuals and even between different joints in the same individual. In small animal medicine this is exemplified by differences in osteophyte expression which clearly do not tally with the clinical picture. One current model of OA attempts to incorporate the heterogeneic nature of OA and how various contributing factors may interact. It is thus helpful to think of OA as a disease process rather than a disease entity.

Management of OA: Because OA is such a common disease process and also because there is no cure, there are a plethora of candidate treatments for the condition. Given this situation it is imperative for veterinarians to provide good quality evidence-based advice to clients. It was on this basis that we set out to conduct a systematic review of all reported modalities for management of canine OA.

The aim of the study (Sanderson et al 2009) was to identify and systematically review the evidence base on the reported candidate therapies used in the management of canine osteoarthritis (OA), inclusive of alternative therapies, functional foods, intra-articular agents, nutraceuticals, pharmacotherapies, physical therapies, surgery and weight control. Online databases were searched at the end of July 2007 for terms inclusive of disease process and species, with papers selected based on their relevance to management of canine OA. Therapies aimed at both symptom and structure modification were reviewed. All those identified were in English language peer-reviewed journals. Literature was reviewed as per the set evaluation criteria. Grading of papers was strict, taking into consideration whether the study identified a primary outcome variable, whether a placebo or positive control was used, and whether assessment of the primary outcome variable was objective, semi-objective or subjective in nature. Seventy-four papers were identified and evaluated. These addressed four alternative therapies, two uses of functional food, three intra-articular agents, seven nutraceutical agents, 21 pharmacological agents, two physical therapies, three surgical techniques and two combinations of weight control. Evaluation of symptom-modifying therapies showed that a high level comfort exists for the use of carprofen, firocoxib or meloxicam. A moderate level of comfort supports the use of etodolac. Of the candidate structure-modifying candidate therapies, GAGPS, licofelone, elk velvet antler and a functional food containing green lipped mussel were deemed to have a moderate level of comfort. The use of doxycycline, electrostimulated acupuncture, extracorporeal shockwave therapy, gold wire acupuncture, hyaluronan, pentosan polysulphate, P54FP, tiaprofenic acid and tibial plateau levelling osteotomy is not supported by the literature reviewed.

Further to this study, given that the highest level of comfort exists for the use of NSAIDs for canine OA, we wished to systematically review the long-term use of NSAIDs for canine OA (Innes et al 2010). The published, peer-reviewed literature was systematically searched for information on the safety and efficacy of long-term (defined as 28 days or more of continuous therapy) NSAID use in the treatment of canine osteoarthritis. Online databases were reviewed in June 2008 and papers were selected based on their relevance. Fifteen papers were identified and evaluated. Six of seven papers indicated a benefit of long-term treatment over short-term treatment in terms of the reduction of clinical signs or lameness; one study showed no benefit. Fourteen papers evaluated safety with calculated experimental (adverse) event rates (EER) between 0 and 0.31, but there was no correlation between study length and EER (rs=–0.109, P=0.793). The balance of evidence for the efficacy of NSAIDs supports longer-term use of these agents for increased clinical effect. There is no indication in the literature that such an approach is associated with a reduction in safety, although robust data on the safety of long-term NSAID use are lacking in large numbers of dogs.

References
Synovial fluid provides lubrication and cushioning to the joint. It also crucially provides nutritional support to the joint as articular cartilage lacks blood and lymphatic vessels and nerves. It is derived from and has many biochemical similarities to plasma although it is typically low in protein. Normal synovial fluid is largely lacking in fibrinogen and other coagulation factors and therefore normal fluid does not clot. The viscosity and lubricant properties are due to the presence of a glycosaminoglycan called hyaluronic acid that is produced by type B cells of the synovial membrane. Normal synovium is sterile and poorly cellular consisting predominantly of non-phagocytic large mononuclear cells.

Laboratory investigation of joint disease may be multifaceted including cytology, haematology, biochemistry, microbiology, serology and/or histopathology.

### Cytology

Synovial fluid may be submitted in EDTA (cytology), lithium heparin (mucin clot test) and plain tubes (microbiology). Depending on volumes and sample types, cytological evaluation may include assessment of colour, turbidity, volume, mucin quality, total cell counts and total protein. Samples may clot if there is blood sample contamination, inflammation or haemarthrosis. Although normal samples do not clot, if left to sit undisturbed for several hours, samples may gel (thixotropism). This is distinguishable from a clot as it is easily reversed by gently shaking the sample. Viscosity is an indirect measure of hyaluronic acid concentration and is often measured subjectively (strand test) on samples after addition of an anticoagulant. Alternatively, hyaluronic acid quality and quantity maybe evaluated on heparinized samples using a mucin clot test. This is achieved by the addition of glacial acetic acid to samples and observation of the quality of clot thus formed. Total cell counts can be roughly estimated from synovial fluid smears but manual counts are far superior if sufficient EDTA sample is available (samples are typically too viscous to analyse with automated cell counters). Normal cell count ranges vary slightly between joints but generally are < 3 x10^9/L with most being large mononuclear cells (approx 60-97%). Neutrophils represent less than 12%, lymphocytes are variable but typically represent less than 40% and eosinophils are absent. Normal synovial fluid contains very few erythrocytes with sampling contamination most commonly accounting for increased numbers. Assessment of samples for xanthochromia, erythrophagia and haemosiderosis may help determine whether the blood may represent true haemarthrosis. Neutrophils are assessed for phagocytosed material and any evidence of intracellular microbes. Large mononuclear cells should be assessed for phagocytosed debris, excessive cytoplasmic vacuolation and microorganisms. Protein levels are typically low and of low priority.

In disease, there are only a relatively limited number of synovial fluid cytological responses and, generally, most fluids will be categorised as either normal, degenerative, inflammatory or hemorrhagic. Often further classification of the fluid is not possible.

The clinician can often differentiate between iatrogenic sampling haemorrhage (artefact) and true haemarthrosis at the time of sample collection.

- **Haemarthrosis** is characterised by reduced viscosity/mucin quality, haemorrhagic sample with evidence of erythrocyte degradation products and lacking platelets. The neutrophil count may be slightly increased but otherwise, the nucleated cell populations are most likely to reflect a non-inflammatory arthropathy.

- **Degenerative arthropathies** are associated with synovial fluids lacking turbidity, with normal to decreased viscosity and mildly increased nucleated cell counts with a predominance of large mononuclear cells. The latter may display activated morphologies such as increased vacuolation or phagocytic debris. Causes of degenerative synovial fluid include trauma, degenerative joint diseases, osteoarthritis, elbow dysplasia, osteochondritis dessicans, hip dysplasia, dislocations, joint instabilities (eg ligament ruptures) and neoplasia.

- **Inflammatory arthropathies** are numerous and primarily divided into infectious and non-infectious diseases. These are associated with fluids of low viscosity, increased turbidity and high cell counts with significant increases in neutrophils or (rarely) eosinophils. The presence of degenerate changes (pyknosis, karyorrhexis, karyolysis) in neutrophils and evidence of microorganisms are useful in supporting infectious aetiologies. In adult animals, single joints are most often affected but polyarthropathies can occur, particularly in juvenile animals. In horses and ruminants, infectious causes represent the vast majority of inflammatory arthropathies. In small animals, non-infectious inflammatory arthropathies are common and typically affect multiple joints with histories of shifting lameness. Microbiology of samples can help in excluding sepsis. Non-infectious inflammatory arthropathies may be immune-mediated or non-immune mediated but cytology is limited in differentiating the causes. Exceptions may include cases of canine lymphoplasmacytic synovitis, SLE and idiopathic eosinophilic polyarthritis.

Haematology and biochemistry is seldom specific but may add to the overall information database, particularly in the case of inflammatory arthropathies where systemic inflammatory responses or multisystemic diseases are evident (eg SLE).
Serology
Antinuclear antibody (ANA) and rheumatoid factor (RF) serology may be used to assess inflammatory arthropathies and tend to be positive in systemic lupus erythematosus and rheumatoid arthritis, respectively. However, sensitivity and specificity of these tests is poor and interpretation of test results is poorly defined in animals having been largely extrapolated from human testing. Negative serology results do not exclude these diseases as differentials.

Histopathology
Articular and periarticular joint neoplasia may arise from synovial mesenchyme or supporting structures. They are poorly defined in the literature, uncommon, often appear frustratingly similar histologically. This is often compounded by lack of experience/expertise amongst pathologist in diagnosing these tumours. Therefore, any ancillary clinical information that is provided to the pathologist by the clinician is crucial including, species, signalment, anatomic location, gross appearance and thorough radiologic surveys. As synovial tumours may mimic other soft tissue tumours, accurate description of anatomic site may be critical in a definitive diagnosis. As in other sites, tumour lesions may be neoplastic or non-neoplastic. The latter may include resolving haematomas, osteochondromatosis, tumoural calcinosis, a variety of idiopathic proliferative synovial lesions (eg villonodular synovitis, nodular tenosynovitis etc), benign synoviomas, fibromas, haemangiomas, hamartomas, myxomas, chondromas, reactive bone formations, synovial cysts etc. Malignant tumours are generally better described than the benign tumours but remain a poorly defined group of neoplastic lesions and literature is often confusion and misleading with much extrapolation from human literature. Malignant tumours include synovial sarcoma, malignant fibrous histiocytoma, malignant giant cell tumour of soft parts, histiocytic sarcoma and malignant mesenchymomas (dogs). Other neoplastic differentials for tumours adjacent to or involving joints include chondrosarcomas, fibrosarcomas, osteosarcomas and lymphoma.

Microbiology
Infectious causes of inflammatory joint diseases are varied but most commonly involved bacteria. Bacteria are seldom readily evident in cytological preparations and bacterial culturing is typically required to investigate the possibility of sepsis. Even when infections are present, microbial numbers may be low and cultures may require sample concentration or growth promotants. Preferred samples include synovial fluid in plain tubes or blood culture bottles or fresh synovial membrane biopsies. EDTA samples are not acceptable for microbiology. Less commonly, mycoplasma (particularly large animals), fungi, protozoa and virus may be implicated in infectious joint disease.

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NEW THOUGHTS ON REPAIR AND SALVAGE OF THE CARPUS AND METACARPUS, INCLUDING ACUTRAK, DCOI, AND PAWS
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Traumatic injuries of the carpus are relatively common in dogs and constitute fractures, dislocations, subluxations, shearing injuries and strains/sprains. Early diagnosis and intervention is of paramount importance since degenerative joint disease is the inexcusable and inevitable consequence of misdiagnosis or neglect. Misdiagnoses are generally the result of under-estimation of the extent of ligamentous trauma in hyperextension injuries, which can only be evident on thorough clinical examination and stressed radiographic projections. Radiographic exposure factors, film/screen combinations or appropriate use of digital radiography are all fundamental to detection of subtle osseous fissures or lesions. Specific radiographic positioning and comparison with radiographs of the contralateral limb also minimises propensity for missed diagnoses. CT may be very useful in this regard. In cases of strong clinical suspicion and difficulty localizing a potential injury, sequential radiography following subsidence of swelling or following provision of NSAID medication may help. Other misdiagnoses involve inaccurate localisation of the focus of pain and osseous or musculo-ligamentous disruption elsewhere - for example disease of the medial coronoid process and shoulder injuries such as medial gleno-humeral ligament disruption and bicep tears can produce partially-weight-bearing lameness which can mimic the clinical appearance of carpal lesions.

Fractures of the distal radius may or may not involve the joint surface. Anatomic stable reconstruction is indicated for fractures propagating into the articular surface or for juxta-articular fractures in small-breed dogs (Italian greyhound, Yorkshire terrier) which have an intrinsic propensity for non-union. Mini-screw-plate reconstruction is indicated for small juxta-articular segments and the author has found augmentation of healing using xenogenic bone matrix extract in a resorbable collagen lyophilisate (Colloss™) has expedited osseous union in this notably recalcitrant region. The author has found this technique with a cranially or medially applied plate more reliable and expedient than application of external skeletal fixation, even with wire-frame constructs. Post-operative cast application has not been deemed necessary excepting bandage for mitigation of swelling in the immediate post-operative period. Whilst cast/splint apposition of fracture segments may be successful, the author has seen several examples of non-unions associated with ill-conceived cast/splint application. Early surgical intervention is indicated to avoid mal-alignment or non-union and discomfort associated with carpal motion thereafter. Application of cross-pins with ancillary cast support and healing by adaptation osteosynthesis has not been reproducibly successful in the author’s experience. The author has also successfully employed intramedullary pins recessed and countersunk from the distal radial articulation with type one external skeletal fixation in small thin-boned dogs and cats.

The antebrachiocarpal joint contributes 70% of carpal motion, the middle carpal joint between the proximal and distal row of carpals contribute 5% and the carpometacarpal joint between the distal row of carpal bones and the bases of the metacarpal bones contributes only 5% of total motion The carpal joint allows movements of extension, flexion, internal rotation, external rotation, valgus, varus and a few millimeters of translation in palmaro-dorsal direction. Dorsal ligaments are quite thin joining individually the adjacent bones, whilst palmar ligaments are thicker and are in part embedded in thick palmar fibro-cartilage that attaches to the palmar aspect of the carpal bones and bases of the metacarpal bones. This structure provides a strong support to the plantar aspect of the joint that is constantly under tension. The collateral ligaments are strong, especially medially where the ligaments are constantly under tension due to normal five degrees of valgus. Unlike the tarsus, the collateral ligaments span only one joint level. The joint capsule separates the antebrachiocarpal joint from the middle carpal and carpometacarpal joints creating two separate compartments.
Fractures of the collateral support of the antebrachio-carpal joint involving the radial or ulnar styloid processes with associated medial or lateral collateral instability respectively are uncommon but readily reconstructed using pin/tension band techniques or in cases of larger fragments, lag screw. In cases of significant comminuted fragmentation of the medial styloid process of the radius or severe collateral ligament disruption, sometimes the articular surface is severely disrupted and pancarpal arthrodesis may be indicated. Occasionally small articular fragments can be re-apposed using bio-absorbable polylactide darts or nails (Smart Nail™; Chondral Dart™).

Antebrachiocarpal luxations typically involve palmar radiocarpal (ulnocarpal) ligament tears or avulsions or short collateral ligament tears. Styloid fractures can also be involved. Sometimes, but rarely in the author’s experience, the palmar component of the injuries can be managed by coaptation. To assess the extent of short radial collateral ligamentous injury, it is critical that the medial aspect of the joint be stressed during both extension and flexion in order to evaluate the oblique component of the short radial collateral ligament, as well as to assess the straight component of the short collateral ligament, which is stressed during extension. Because of the size of these ligaments, suture reconstruction is difficult at best. Autogenous reconstruction of the short radial collateral ligament may be attempted by using a portion of the flexor carpi radialis tendon, whilst reconstruction of the short ulnar collateral ligament may be attempted by using a portion of the ulnaris lateralis tendon. Occasionally the flexor carpi radialis muscle may be torn and must be repaired by sutureing. After these various components have been managed by some form of reduction and repair, the carpus is cast in approximately 20 degrees of palmar flexion for approximately 4 weeks and then splinted in decreasing amounts of flexion. This is followed by a soft roll dressing and gradual rehabilitation.

Carpal fractures are almost invariably avulsion fractures of ligaments and tendons or the result of a combination of shearing and compressive forces acting on the bones during hyperextension. All fractures are articular with the exception of two types of accessory carpal bone lesions. Clinical examination consists of accurate palpation to localize pain, soft tissue swelling, instability and crepitus. The range of motion of the joint should be tested in flexion, extension, rotation in extension and 90 degrees of flexion in addition to cranial translation with the carpus flexed at 90 degrees.

The canine radial carpal bone has 3 centres of ossification. Radial carpal fracture has been documented through the fusion planes. Documentation of incomplete radial carpal fracture is consistent with aetiopathogenesis of incomplete ossification in some breeds, most notably the Boxer. Pro-dromal lameness may precede overt debilitation. Decreased range of motion and pain on flexion may be evident at clinical examination. Traumatic fractures may also occur caused by compressive forces during hyperextension. Lameness in such cases is commonly non-weight-bearing and there is often significant carpal swelling. Racing greyhounds can sustain incomplete mid-body radial fractures, possibly associated with chronic stress fatigue and most commonly affecting the right thoracic limb due to the anti-clockwise shape of the racing track. Chip fractures of the radial carpal bone are also infrequently seen and commonly in conjunction with hyper-extension or hyper-flexion injuries. As such, removal of small fragments, or reattachment using bio-absorbable polylactide nails, may not ensure resolution of lameness since disruption of periarticular structures may be pertinent influences on prognostication. Avulsions of the palmar prominence of the radial carpal bone are caused by the distraction of the origin of the palmar radial carpal-metacarpal ligament or distraction of the insertion of the oblique component of the short radial collateral ligament on the palmar prominence of the radial carpal bone, or both. This avulsion may be stabilized by either lag screw or pin and wire fixation. Positional radiography with superlative clarity is mandatory for diagnosis and CT is very helpful where injuries are complex. Pulpation of associated instabilities may be contingent on associated soft tissue swelling. Application of cold-packs, massage and NSAID therapy may be indicated prior to definitive elucidation of laxity and formulation of appropriate treatment. Post-operative splint bandaging in partial flexion with gradual rehabilitation is indicated for repair of all avulsion injuries.

A cannulated, headless, titanium, variable-pitched, tapered, self-compressing screw (Acutrak™) is employed by the author to repair sagittal or bi-planar fractures of the radial carpal bone. The screw may be accurately inserted along a guide-wire and may be countersunk beneath the articular surface of the radial carpal bone to compress the fusion plane. Headless design reduces the risk of splitting small fragments and core screw size is small compared to conventional alternatives of similar strength. Osseous union is achieved with restoration of normal integrity and stability and without residual pain, restriction of motion or lameness. Casting is not required. By contrast, cast immobilisation alone has been linked with a high incidence of pseudoarthrosis, whilst lag screws may result in reduced range of motion and fragment removal may decrease carpal stability. In the case of comminuted radial carpal fractures, pancarpal arthrodesis may be required to salvage limb use.
Luxation of the radial carpal bone is an uncommon injury in dogs. It has been described in Border Collie, Rough Collie, Poodle and Kerry Blue breeds and is usually associated with significant trauma, commonly a fall. The bone is always described as being displaced in a palmaro-medial direction having rotated through 90 degrees to lie on the palmar aspect of the radius. The radial collateral ligament is invariably ruptured. Correction requires surgery to first rotate and then relocate the radial carpal bone. Once back in articulation the radial carpal bone can be held in position by passing a single pin through it into the ulnar carpal bone. The radial collateral ligament can be repaired and protected with a figure-of-eight wire if necessary. The joint is then bandaged for 4-6 weeks post surgery. Dogs may comfortably maintain joint motion if the condition is addressed promptly, but pancarpal arthrodesis should be considered if a delayed presentation is encountered.

Ulnar carpal bone fractures are extremely rare and are fixed using the same techniques or a lag screw. These fractures are generally difficult to diagnose with certainty on conventional radiography. Contrast enhancement on digital radiography may help, as will CT scan. Small chip fractures of the distal carpal bones are usually excised. Medial slab fractures or luxations of the second carpal bone should be treated by open reduction and then maintained by a lag or positional screw placed medial to lateral. Dorsal slab fractures of the third carpal bone may be exposed by longitudinally splitting the extensor carpi radialis tendon. Repair is by lag screw fixation. Post operative support of the joint using a dressing for two to three weeks and rest for four weeks after surgery is indicated.

Fractures of the accessory carpal bone predominately occur in the elite athlete and whether they are of a ligamentous or a tendinous nature, they are primarily hyperextension injuries. Acute lameness with carpal swelling is often initially evident and then lameness may resolve until exercise is re-introduced. When possible these are managed by rigid internal fixation followed by decreasing amounts of flexion casting. As revealed by physical examination of the carpus, ligamentous avulsion fractures of the accessory carpal bone are characterized by a decreased range of motion, with pain on flexion. Tendinous avulsion fractures of the accessory carpal bone have a normal range of motion and increased soft tissue swelling; any pain is present on extension. Lateral radiographs in the extended position tend to distract the fracture fragments and enhance visibility on radiographic projections.

Ventral avulsion fractures of the accessory carpal bone are Type III sprain injuries that result in an intra-articular fragment, which is produced by the avulsion of the accessory carpal ulnar ligament from the base of the accessory carpal bone. This intra-articular fracture leads to degenerative joint disease. Small fragments are excised whilst larger fragments may be reaposed by means of a small positional or lag screw. The surgical approach is from the palmar aspect of the carpus between the paired accessory carpal-metacarpal ligaments. Dorsal avulsion fractures of the accessory carpal bone may be either sprain or strain-type injuries. Tendinous, strain injuries involve avulsions of the flexor carpi ulnaris tendon from the dorsal apical aspect of the accessory carpal bone. These are repaired by small fragment excision and tendinous reconstruction via a proximo-distal transosseous tunnel in the accessory carpal bone. Dorsal avulsion sprains involve the dorsolateral basilar aspect of the accessory carpal bone. Avulsions of the small ligament located there are excised. As for primary repairs of luxation, for all such injuries, he carpus is cast in approximately 20 degrees of palmar flexion for approximately 4 weeks, then splinted in decreasing amounts of flexion over 4 further weeks. This is followed by a soft dressing and gradual rehabilitation. Severely comminuted fractures of the accessory carpal bone are uncommon injuries that are best managed by casting the carpus in a moderate degree of palmar flexion, with a gradual return to normal position. The prognosis is guarded and pancarpal arthrodesis may be indicated.

Dislocation of the accessory carpal bone can occur if the ligaments (palmar accessory carpo-metacarpal ligaments) extending from the caudal surface of the accessory carpal bone to the proximal metacarpal bones are disrupted. Additional disruption of the small ligaments attaching the base of the bone to the ulnar carpal bone allows upward displacement of the accessory carpal bone. This event is reported to occur in association with concurrent luxation of the antebrachio-carpal joint. Repair involves suturing the palmar carpal fibrocartilage and wiring the accessory carpal to the base of metacarpal V. Subsequent splint support is mandatory.
Well planned and executed carpal bone repairs generally heal well with favourable clinical outcomes. Early controlled mobilisation with protection of the repair is of paramount importance with application of both passive and active physical therapy modalities particularly relevant. Whilst return to previous athletic performance cannot be guaranteed, this is possible, or at least pain-free normal activity levels are generally achievable. In cases where severe osseous or multiple ligamentous disruption is present, identification of poor prognosis should be expedient and carpal arthrodesis should be an early consideration to avoid prolonged suboptimal recovery or chronic pain. Injury configurations where partial carpal arthrodesis or carpo-metacarpal arthrodesis in isolation is indicated is rare; generally pancarpal arthrodesis is indicated. Pancarpal arthrodesis is always indicated where hyperextension injuries have significantly disrupted the antebrachio-carpal joint and palmar fibro-cartilage. This injury usually occurs subsequent to a fall from a height with the animal landing on the forelegs. Usually the limb is initially non-weight-bearing and if weight-bearing occurs, it is usually with a palmograde posture. This can sometimes be bilateral. Certain breeds seem predisposed to hyperextension, particularly the Rough Collie in which hyperextension has been reported without any visible significant trauma. Such injuries are frequently underestimated on radiographic evaluation. It is worth noting that fracture of the bases of Metacarpal Bones 2 and 5 may accompany hyperextension injuries of the carpo-metacarpal joints. Stress-radiography is indicated, as is comparative radiography of the contralateral limb. Appropriate physical examination is facilitated by cryo-therapy and bandaging until peri-traumatic swelling subsides.

For pancarpal arthrodesis, cartilage interfaces at all three joint levels must be thoroughly debrided with a high-speed burr and packed with cancellous bone harvested from either the ilii or proximal humeri. Cranio-medial skin incision is generally preferred by the author. Particular care to preserve neuro-vascular supply to the foot must be a paramount concern. Pancarpal arthrodesis is generally achieved by application of a dorsal plate from distal radius to metacarpal bone three or four depending on ease of anatomical alignment. Hybrid tapered 3.5/3.5, 3.5/2.7 or 2.7/2.0 plates are generally applied and the author prefers to contour these plates in the bridge portion to 10-15 degrees to minimise the propensity for nail-scuffing and promote normalised limb use. The author generally packs bone-graft first and then places the proximal extent of the plate along the distal radius under the extensor carpi radialis muscle. The central plate hole is aligned over the radial carpal bone and the first screw is placed in the most proximal extent of the third or fourth metacarpal bone, since alignment with the metacarpal bone is paramount. Next the most distal metacarpal screw is placed to ensure optimal purchase in the area of most limited bone stock. Then the most proximal radial screw is placed such that alignment of the distal antebrachium and metacarpus is optimised and then the radial carpal screw can be placed at any appropriate trajectory, with the bone drawn toward the plate by this screw. Remaining screws are then placed. The author agrees with previous data suggesting that more than 60% length cover of the metacarpal bone is desirable with tapering screw length to minimise stress-riser concentration and fracture, but disagrees with previous suggestions that external coaptation is necessary. The author employs support dressing in the immediate post-operative period only to ameliorate swelling, but no cast or splint is employed thereafter. The author has performed in excess of fifty such procedures with no complications associated with absence of ancillary external support. More recently, application of minimally invasive approaches to debridement of articular surfaces and mini-incisions for application of implants has served to reduce post-operative swelling and promote early mobilisation. For this technique all metacarpal screws are placed first, then distal radial screws for alignment and lastly a screw in the radial carpal bone. The author has not perceived salient clinical advantage from applying a customised stepped plate to maintain caudal position of the radial carpal bone if the plate is mildly contoured and if fixation is robust.

It has been suggested that a broad plate employing divergent holes distally to facilitate screw purchase in metacarpal three and four is desirable to avoid requirement for external support, but the author does not feel that this claim is justified by clinical data. Furthermore, enforced immobilisation of two contiguous metacarpal bones has given rise to discomfort only alleviated by plate removal in the author’s experience. Appropriate capture of the metacarpal bones by the divergent holes at the most distal extent of the plate is not possible in patients with particularly divergent metacarpal bones and the author has observed iatrogenic fracture of the axial cortex of the metacarpal bones in such patients. Some authors have also employed two dorsal plate or a dorsal and a medial plate. The author has only rarely perceived requirement for these applications.

Skin breakdown can occur when bulky internal implants are applied to the carpo-metacarpal region where skin-cover is particularly tightly opposed, especially in greyhound breeds. Respectful soft-tissue handling, preservation of blood supply and avoiding placing the major incision directly over the plate helps avoid problems, as does frequent post-operative bandage changes, avoidance of over-tight splinting and minimisation of time of splint application. Minimally invasive plate osteosynthesis (MIPO) has also significantly decreased vascular compromise. Occasionally releasing incisions may be employed, subsequently addressed using topical hydrogel (Intrasite™) and/or collagen (Collamend™) dressings. The author cautions against improper support dressing application which can result in significant compromise to neuro-vascular structures.

Surgery Chapter
Carpal shearing injuries are not uncommon and repair may be frustrated by loss of vital structures, open contamination and profound joint instability. Profound neuro-vascular impairment may prompt amputation. Otherwise, debridement and protective dressings to promote granulation is indicated until reconstructive surgery can be contemplated. Culture-targeted antibiotics is also indicated. Stability may easily be imbued using simple external skeletal fixation constructs, which can serve as temporary or definitive fixation for pancarpal arthrodesis. The author advocates aggressive surgical debridement of necrotic tissue, removal of joint surfaces with a high-speed burr and application of definitive fixation which allows appropriate application of ongoing dressing. External fixation systems are employed when skin closure is impossible and internal plate-screw fixation where skin closure and thorough debridement is possible.

Addressing degloving injuries of the carpus and metacarpus can be challenging depending on area and depth of tissue loss. Wet-to-dry dressings can be employed, as can hydrogel dressings and these can be protected with creative use of curved bars on external skeletal fixators forming a “tent” to optimise oxygenation and minimise occlusal-injury. Collagen matrices (Collamend™) and lyophilized porcine urinary bladder extracellular matrix (ACell Vet™) have been employed by the author with considerable success. Free-skin grafts can be employed once a healthy granulation bed has been re-established whilst skin flaps and myocutaneous grafting techniques can be employed for profound defects. Skin stretching on suture stents driven by external skeletal fixator motors and skin mobilising devices can be practical in certain instances.

Conventional management of metacarpal fractures employs intramedullary pins, bone plates, external fixators, screws, cerclage wire and external coaptation. Complications are common. Pins are difficult to place, even via bone slots or by a dowel technique, particularly in short distal juxta-articular segments; screws are also difficult to place in contiguous bones anatomically oriented as a dorso-palmar arc and stress-riser fractures can occur; plates may be bulky and it may be difficult to achieve closure of the soft-tissue envelope; cerclage wire may compromise blood supply. Veterinary cuttable plates are best used due to their low profile and underside concavity. Fractures are sometimes open and infection can be a consideration as can treatment of disruption of the soft-tissue envelope. External skeletal fixation with conventional transverse transfixion pins has been described as efficacious but in the author’s opinion is more potentially hazardous than longitudinal intramedullary pin/wire placement due to the natural arc of the metatarsal bones precluding transfixation across all four bones except at the base. Additionally, there is a risk of iatrogenic fracture as trajectory of implant relative to bone diameter may not allow centralisation of the pin relative to the bone, malalignment of metacarpal bones is common when “skewered” transversely and synostosis can ensue and can produce residual complications, especially in very young animals.

The author has applied a novel form of external skeletal fixation with consistent success in a large case series of metacarpal fractures, including fractures of all metacarpal bones simultaneously, distal juxta-articular fractures and severely comminuted fractures. K-wires are directed distally from the fracture sites to exit the metacarpal bones at the dorsal aspects of the metacarpophalangeal joints. The fractures are reduced and the k-wires reverse-driven into the proximal segments. One or two k-wires are placed transversely through the distal row of carpal bones, exiting medially and laterally. All k-wire ends are bent dorsally and embedded in a bolus of epoxy, held in alignment until set hard. For younger animals the wires are bent dorsally at a distance from the MC–P joints to facilitate continued growth. Long-term lameness was not reported for any case (mean 2 years) and radiographic follow-up (mean 1.4 years) did not reveal arthrosis of the MC– P joints. The frame construct has been attributed the nomenclature “secured-pin-intramedullary-dorsal-epoxy-resin” (SPIDER). The technique has also been successfully employed for carpo-metacarpal luxations, avoiding pancarpal arthrodesis and avoiding residual implants which could cause impingement challenges after partial carpal arthrodesis. Advantages of SPIDER compared with conventional methodologies include minimal biologic approach, application speed, absence of problems with soft-tissue cover of metallic implants, avoidance of bandaging inconvenience and complications, minimal swelling, reliable healing, early return to function, inexpensive equipment and no residual implants.

In cases of profound loss of osseous and of myo-cutaneous tissues, once a soft-tissue envelope has been re-established in the carpo-metacarpal region in the manner described above, the author has had considerable success employing cortico-cancellous bone blocks harvested from either the ilial wings or caudal vertebrae to restore distal carpal and metacarpal bone-stock adequate for resumption of normal ambulatory capability. The shaped bone blocks or tail vertebrae are threaded on “skewer” wires and a customised hybrid arch-wire external skeletal fixation system is employed with anchorage proximal and distal to the region of bone deficit to transfer weight-bearing from the distal antebrachium to the digits. The construct is mounted on motors which allow three weeks of oscillatory motion in the sagittal plane which may promote cortico-cancellous integration and prevent sequestrum formation. This osseous gymnastics has been termed “distraction-compression-osteointegration (DCOI)” and reconstruction of osseous defects involving all four metacarpal bones has been achieved successfully.
In the case of metacarpo-phalangeal luxation or infectious arthritis, skewer wires can be used to facilitate stability or arthrodesis and if protection from weight-bearing is required for healing, a customised wire-arch hybrid frame can be constructed which allows ambulation on metal arches whilst providing a “tent” for healing, dressing of pad or palmar lesions or abscess-drainage. The technique has been termed “Pedal Arch Wire Scaffold (PAWS)”

Where irreparable neuro-vascular trauma accompanies osseous compromise and amputation is required, recent advances in prostheses now prompt consideration of partial limb amputation and application of intraosseous transcutaneous amputation prostheses (ITAP™). These devices can result in a resilient bone-implant and skin-implant interface which is resistant to infection and dermal marsupialisation. The author has had success in application of these prostheses in distal thoracic and pelvic limbs and iterations of exoprosthesis are rapidly evolving for both human and canine limb-salvage.

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Tarsal and metatarsal injuries are common in dogs and include fractures, dislocations, subluxations, shearing injuries and strains/sprains. Early diagnosis and meticulous surgical technique is of paramount importance since degenerative joint disease is the inevitable consequence of misdiagnosis or suboptimal intervention. Injuries are typically characterized as closed, comminuted and due to indirect trauma. They are often associated with severe dorsiflexion when under load and with extensive swelling and associated soft tissue damage. Diagnosis is achieved by palpation, by evaluating the range of motion, and by carefully positioned orthogonal, oblique and stressed radiographs on high-detail film, digital radiography or using CT scan. Physical and radiographic interrogation of the contralateral limb will assist comparative evaluation.

Fractures of the distal tibia may or may not involve the joint surface. Anatomic stable reconstruction is indicated for fractures propagating into the articular surface or for juxta-articular fractures in cats and small-breed dogs which may have a propensity for non-union. Mini-screw-plate reconstruction is indicated and the author has found that augmentation of healing using xenogenic bone matrix extract in a resorbable collagen lyophilisate (Colloss™) has expedited osseous union. Application of two 2mm cuttable plates (cranially and medially) has simplified repair and provided a rigid construct with reproducible healing efficacy which may be applied by minimally invasive plate osteosynthesis (MIPO) methology. Due to the small size of juxta-articular segments, hybrid external fixation frames may be useful where wires in circular frame components or small diameter pins on arch components may be employed for anchorage of the bone segments. The author has found application of double-arch pin frames with multidirectional hinge connecting elements useful in this regard. Epiphyseal separation, Salter-Harris Type 1 or 2 is the most common form of distal tibial injury in immature animals (4-8 months). This is readily repaired by judicious placement of crossed-K-wires and padded support dressing is usually only required for a week post-operatively. In very young animals, closed traction may be employed for reduction and application of a transarticular external skeletal fixator may be adequate for healing, but must be removed after approximately 20 days. Disruption of tibial growth may ensue and may need to be addressed by distraction osteogenesis if such injuries occur in very young giant breeds. Eccentric physeal closure may need to be addressed with appropriate correctional osteotomies.

Fractures of the medial malleolus of the distal tibia or of the distal fibula/lateral malleolus are commonly encountered injuries which must be recognised and treated early, since disruption results in significant tarso-crural laxity due to attachment of the collateral ligaments to these structures. Non-weight bearing lameness is usually evident and stressed-radiographic positioning may be required for diagnosis. Accurate surgical reduction using a k-wire and tension-band is indicated since these constitute avulsion articular fractures, followed by 1-2 weeks of padded support dressing. Minimisation of k-wire dimension and maximisation of tension band dimension is recommended to counter distractive forces and minimise potential for fragment splitting. Early physical therapy is important to optimise restoration of joint function. Occasionally disruption is so profound that ensuing instability requires pantarsal arthrodesis for salvage. This is particularly the case where concomitant medial and lateral disruption has occurred or where profound shearing injuries have been sustained. The author has employed autogenous ligament transplant and augmentation with fascial allograft in selected cases of shearing injuries, but if the articular surface of the talo-crural joint is significantly disrupted by shearing then pantarsal arthrodesis is generally inevitable in the author’s experience, until hemi-prostheses and total hock prostheses become viable reality.

Chip fracture of the caudo-distal tibial prominence which articulates with the talar sulcus has been observed infrequently. Reconstruction may be possible if the fragment is large enough to be secured with a metallic or polylactide implant (SmartNail™), but excision is often indicated as the fragment is frequently small. Diagnosis may require oblique radiographic projections and can often accompany concurrent malleolar fractures. Support dressing is indicated for 3-4 weeks and prognosis is guarded because of articular disruption.
The medial and lateral collateral ligaments of the tarso-crural joint are paired structures consisting of long and short components. The short collateral ligaments are important since they have a role in stabilising the joint in both flexion and extension. The short collaterals are often overlooked in repair procedures, due to their size and location, which seriously reduces the immediate stability of the joint. A technique for replacing both ligaments on the lateral and medial sides has been described using three small screws (and washers) with one screw placed at the communal origin of the collaterals on the distal tibia or fibula and the other two at the insertion points of the short and long collaterals. Bone suture anchors can also be used. Bilateral injuries must be stabilised on both sides. For this purpose the author generally employs the non-absorbable suture material Fibrewire™. Rupture of the short collateral ligaments can occur in isolation. Diagnosis in these cases can be difficult and often requires manipulation under anaesthesia and stress radiography. Surgical repair can be carried out with good results. These injuries may involve an avulsed fragment from the talar ridge. External supplementary support (bandage or external skeletal fixation) is essential for 4-6 weeks after surgery until the collateral structures begin to heal or are replaced with fibrous tissue. Prognosis for the function of the joint is guarded and pantarsal arthrodesis may be required.

Fractures of the calcaneus can be seen as solitary injuries or can be associated with other tarsal injuries, most often fractures of the central tarsal bone. Fractures through the shaft of the calcaneus or avulsion fractures of the insertion of the common calcaneal tendon can be stabilised using tension band wiring. Comminuted fractures present much more of a challenge and may require application of lag screws and possibly a neutralisation plate. Fashioning the end of the plate into a “crook” by opening a plate hole and bending it over gives an ancilliary point of attachment for fixation of proximal calcaneal fractures. The author cautions against suboptimal approximation of fragments or suboptimal fixation, since calcaneal non-union has frequently been observed, even following application of autogenous cancellous bone graft and this may be related to limitations of ability for secondary bone healing with intrinsic dependence on primary healing mechanisms (i.e. accurate anatomic reconstruction). Pantarsal arthrodesis may be indicated in cases of calcaneal fracture non-union or extreme comminution. The author has also observed occasional spontaneous fracture of the calcaneus in cats which can be difficult to manage since healing is rarely complete.

Repair of calcaneal fractures may be facilitated by lateral or by sternal patient positioning. The latter has advantages in that it assists with neutralisation of tensile forces on the Achilles mechanism. It may be necessary to incise the lateral retinaculum of the superficial digital flexor tendon to reflect this structure medially. It is desirable to pre-drill pin-paths since the Calcaneal bone is very dense. In this regard a drill bit that is approximately one size smaller than the pin that is to be utilized for stabilization is employed. Additionally, care must be taken to follow the medullary canal with the drill bit or pin, since cortical penetration is a distinct hazard. Application of appropriate forceps between the tuber calcanei and the base of the calcaneus may facilitate reduction whilst k-wires, pins or cerclage wire is placed. Generally wire is looped in a figure-of-eight fashion on the plantar aspect of the calcaneus between the pin end proximally and a transverse bone-tunnel distally. If pin irritation to the superficial digital flexor tendon is a concern, a proximally placed lateral to medial transosseous bone tunnel (cranial to the intramedullary implant) may be employed as a proximal anchor for the figure-of-eight tension band wire and the pin can be countersunk. Custom-eyelet pins (Acutrak Tension band™) may facilitate anchorage of the proximal pin end with cerclage wire without tendinous impingement by pin-ends.

Fracture avulsion of a small lateral or medial portion of the tuber calcis at the insertion of the retinaculum of the superficial digital flexor tendon can also occur and treatment involves removal of small fragments with repair of the retinaculum or in case of large fragments reconstruction and reattachment with k-wires or small screws is indicated. Lateral sagittal fragment reconstruction may be facilitated by application of small fragment forceps prior to fixation with countersunk cortical screws applied in lag fashion. Large oblique dorsoplantar fractures of the base of the calcaneus are managed by a pin and figure-of-eight wire seated into the body of the fourth tarsal bone. dorsomedial slab fractures of the base of the calcaneus rarely, if ever, progress to non-union and therefore can be managed by lag screw fixation or coaptation. Large oblique plantarodistal chip fractures of the base of the calcaneus are repaired by pin and figure-of-eight tension band wire. Small oblique plantarodistal chip fractures of the base of the calcaneus may be managed as a plantar proximal intertarsal subluxation (PPIS), with calcaneoquartal arthrodesis supported by a pin and figure-of-eight tension band wire into the fourth tarsal bone, or a small plate/screw construct.
Fractures of the talus are less common than those of the calcaneus but can involve the head, neck or body of the bone. Prognosis is generally guarded due to difficulty reconstructing small fragments and progressive arthrosis. Fractures of the articular surface can occur affecting either the lateral or medial trochlear ridges and reattachment can be accomplished with fine K-wires, small countersunk screws or biodegradable rods. The author has had success in this regard using small variably-pitched cannulated self-compressing screws which can be accurately guided down a k-wire guide and their headless configuration is ideal for application across articular surfaces (Acutrak™). A good exposure is necessary to allow accurate replacement of the fragment and whilst a caudal approach may be adequate for some fragments, medial malleolar ostectomy may be required for fractures of the medial ridge or ostectomy of the fibula to give access to the lateral ridge. The author recommends placement of guide holes for pin or screw placement before ostectomy to ensure accurate reconstruction and narrow blades should be employed. Neck fractures are the most common talar fractures in the author’s experience and surgical stabilisation can be challenging due to the shape of the bone and anatomic constraints. Closed traction and application of external skeletal fixation has been advocated in cats, but the author advocates internal fixation in dogs involving accurate anatomic apposition and implants must be placed internal to the bone structure or they will interfere with tarso-crural motion. In this regard small threaded pins such as Imex Interface™ pins are useful. In cats the author also prefers internal fixation and this may be readily achieved using two parallel k-wires driven retrograde through the talar head and then normograde and positioned immediately distal to the articular surface.

Fracture of the central tarsal bone is relatively common and is seen almost exclusively in the racing greyhound affecting the right hock. During anti-clockwise racing, the right central tarsal bone is acting as a buttress for the medial aspect of the tarsus where greatest compressive forces are applied. Adaptive remodelling due to cycling loading can produce changes of the bone mineral density with microcracks, predisposing to catastrophic fracture. In other breeds either pelvic limb can be affected. Loss of the stabilising effect of the central tarsal bone allows collapse and hyperextension of the joint and may lead to or occur concomitant with other injuries. As a first aid measure the hock should be supported in an extension splint to prevent further injury. Sometimes the fragment can be reduced manually prior to application of the dressing. Central tarsal bone fractures are graded I – V based upon the type of fracture and the amount of displacement. This is a radiographic and surgical classification based upon the number and type of displaced fragments rather than the total number of fragments present. Surgical stabilisation using 1-2 lag screws depending on fracture configuration is indicated. The author has also found variably pitched self-compressing screws (Acutrak™) useful for repair of central tarsal slab fractures. Post-operative splinting is indicated for 4 weeks and early rehabilitation is indicated. Prognosis is favourable if reconstruction is accurate and durable but severely comminuted fractures may not be reconstructable and partial tarsal arthrodesis may be required.

The vast majority of fourth tarsal bone fractures are seen in conjunction with fractures of the central tarsal bone (with or without calcaneal fracture). Repair is indirectly achieved by repairing the central tarsal bone fracture. Occasionally it is necessary to place a second screw from the second to the fourth tarsal bone to help shore up a severely comminuted fracture of the fourth tarsal bone. Third tarsal bone fractures present as a solitary lesion, although on occasion there is an associated second tarsal bone subluxation present. Fractures of the fifth tarsal bone also frequently occur concomitant with central tarsal bone fractures. Fractures of the second tarsal bone are rare; subluxations are somewhat more common. The most predictable results for all reconstructable tarsal bone fractures are obtained by using countersunk cortical bone screws in lag fashion. Screws may be placed into contiguous tarsal bones (e.g. T3 into T4). Well planned and executed repairs of the tarsal bones generally heal well with favourable clinical outcomes. Early controlled mobilisation with protection of the repair using appropriate bandaging techniques is of paramount importance with application of both passive and active physical therapy modalities particularly relevant. Whilst return to previous athletic performance cannot be guaranteed, this is possible, or at least pain-free normal activity levels are generally achievable. The author cautions against inappropriate selection of bandaging methodology or duration, having seen many examples of inappropriate application resulting in severe neuro-vascular disruption and even amputation.

Proximal intertarsal luxation or subluxation can arise as a result of rupture of the plantar ligament of the hock and is common in Shetland Sheepdogs where a degenerative aetiology is implicated (often bilaterally). There is often an insidious onset and the condition can go unnoticed for some time. There is usually little evidence of pain and the joint can be manipulated without distressing the animal. The angle between the proximal and distal rows of tarsal bones may be 90 degrees plantigrade. Traumatic disruption of the supportive structures of the talocalcaneocalcaneal joint as well as the calcaneoquartal joint can also occur, producing instability in a number of planes. Partial tarsal arthrodesis is often indicated but it may be adequate to simply fuse the calcaneoquartal joint by application of a longitudinal calcaneal lag screw or calcaneal pin and tension band between the calcaneus and the fourth tarsal bone.
In cases where severe osseous or multiple ligamentous disruption is present, identification of poor prognosis should be expedient and partial tarsal arthrodesis (PARTA) should be an early consideration to avoid prolonged suboptimal recovery or chronic pain. All relevant cartilage interfaces must be thoroughly debrided with a high-speed burr and packed with cancellous bone harvested from either the ilium or proximal humeri. Calcaneoquartal arthrodesis is readily achieved using pin and tension-band techniques whilst arthrodesis of proximal and distal intertarsal and tarsometatarsal joints requires more robust mechanical constructs. Historically, plate/screw fixation has been the most commonly employed technique to achieve partial tarsal arthrodesis, applied either medially or laterally. However it has been the author’s experience that skin breakdown is common when bulky internal implants are applied to this anatomic region where skin-cover is particularly tightly opposed. This can be circumvented by placing incisions away from plate application sites and leaving releasing incisions subsequently addressed using topical hydrogel (Intrasite™) and/or collagen (Collamend™) dressings. However, the author advocates avoidance of bandaging for tarsal and metatarsal injuries except to control perioperative swelling and believes that mechanical implant-constructs should be resilient enough to preclude requirement for external co-aptation. Improper support dressing application or compromise of the soft-tissue envelope by bulky internal implants can result in horrific compromise to neurovascular tissues to the point of necessitation of amputation.

Occasionally a countersunk double-pin technique can be employed without plate/screw support for calcaneoquartal and taloarticular arthrodeses, but generally either linear or circular external skeletal fixation is required if plate/screw constructs are not employed. The author has compared conventional plate-screw constructs for partial tarsal arthrodesis to use of external skeletal fixation and feels that the latter has several salient advantages. External skeletal fixation can be employed for any configuration of tarsal fractures/luxations, can be employed with a biologic mini-approach for debridement of articular surfaces, results in less swelling than attempts to close soft-tissues over internal implants and there are no residual implants. The author investigated comparison of linear and circular constructs for PARTA and feels that circular wire constructs are cumbersome, time consuming to apply and have no salient advantages by comparison with linear constructs. In a comparison of bilateral versus unilateral linear frames for partial tarsal arthrodesis, the author has shown adequate efficacy and increased speed of application for appropriately applied unilateral frames with “tie-in” for an intramedullary calcaneal pin and application of a half-pin on the plantar aspect of the calcaneus.

The common calcaneal tendon comprises three component parts - the paired tendons of the gastrocnemius m., the single tendon of gracilis m. semitendinosus m. and adductor m. and the superficial digital flexor tendon. Rupture of the common calcaneal tendon usually occurs as a result of a traumatic incident. The affected animals usually present with a sudden onset severe lameness. If weight bearing the hock will be seen to sink to a hyperflexed position with associated hyperextension of the stifles and the stance will be plantigrade. There may be little sign of visible pain. Inspection of the skin over the tendon may reveal an obvious wound. More commonly a small wound or a bruise may be all that is visible. Palpation of the tendon itself may reveal a defect but this can be obscured by the tendon sheath. Avulsion of the common calcaneal tendon can also occur as a chronic entity in large breed, active dogs especially the Doberman. The dogs may be presented with a history of lameness and a swelling may be palpable at the insertion of the tendon on the os calcis. Eventually hyperflexion of the tarsocural joint may be seen with the calcaneus forming a reduced angle with the ground during weight bearing. Knuckling of the digits may be seen accompanying this. This is not the flaccid knuckling seen in neurological deficits but a tense tight pull caused by stretching of the SDF tendon over the point of the hock as a result of hyperflexion. Alternatively the dog may present with a plantigrade stance. Acute trauma is rarely a feature of the history but there may be some report of indirect trauma through jumping etc. Radiography of the affected joint will show little change but tendon swelling may be visible and there may be enesthesiophytes or gross production of fibro-osseous tissue around the area of insertion of the tendon. The aetiology of this condition is obscure but it may result from repetitive trauma or an intrinsic collagen or vascular defect, which may be genetically-predisposed.

Surgical treatment is indicated for both tears and avulsions of the common calcaneal tendon. Occasionally, dogs which are hyperflexing but not plantigrade can be treated by placing a screw to hold the hock in extension without surgically interfering with the tendon. However, surgical reattachment is usually indicated using locking loop or similar sutures through the tendon and bone tunnels in the calcaneus. Support of the repair may be provided by a calcaneo-tibial screw and external coaptation but the author prefers external skeletal fixation for this purpose. The author has frequently seen failure of such repairs, particularly of chronic enthesiopathies where resection of a volume of necrotic fibrous tissue is necessary before re-attachment or in acute tears with significant damage to the tendon fibrils. Failure usually occurs upon resumption of normalised levels of activity and pantarsal arthrodesis is generally indicated.
Luxation of the tendon of the superficial digital flexor m. is seen infrequently and usually affects Shetland sheepdogs or collies with a variable presentation ranging from very mild to a severe lameness. Diagnosis can be made by feeling the tendon displace. This usually occurs laterally with disruption of the medial retaining structures. When the tendon is mobile a popping sensation may be appreciated. This can be best demonstrated by rotating the metatarsus medially while flexing the tarsal joint. In long standing problems with delayed presentation the tendon may be fixed laterally with little movement appreciable, the only sign being swelling at the point of the hock. Surgical management is indicated if the degree of lameness is severe or persistent. The tendon forms a fibrocartilagenous cap as it passes over the point of the hock and this pad is approached from the medial side if the displacement is lateral. The pad is mobilised and the tendon relocated in a central position on the groove on os calcis. It is of vital importance that once in position the tendon shows little tendency to dislocate again due to tension on the soft tissues. If this is a problem surgical release should be performed. The damaged medial retaining tissue is repaired using 8-10 well placed simple interrupted sutures of monofilament non absorbable material. The joint should then be immobilised for a minimum of 4 weeks to allow healing.

Until a viable total hock replacement system becomes available, pantarsal arthrodesis (PANTA) remains the mainstay of hock salvage procedures and is employed for treatment of end stage arthrosis in addition to unsalvageable traumatic lesions of the osseous or connective tissues. PANTA is generally performed in dorsal recumbence allowing accurate alignment of the stifte and metatarsus. All articular surfaces are debrided of cartilage with a high-speed burr and all joints are packed with cancellous or cortico-cancellous bone graft harvested from the proximal humeri or cranial ilii. Generally plate and screw fixation is employed and in this regard custom-designed medially applied plates have gained increasing popularity because placing dorsal plates from distal tibia to dorsal metatarsus involves implant application on the compression side of the joint which is theoretically suboptimal. In this regard plate-rod techniques have been designed to provide added structural resilience. The author has experienced problems associated with metatarsal fracture when plates are applied medially and additional problems with soft tissue envelope integrity and limb alignment. We have however, experienced considerable success with dorsal plating techniques provided that the calcaneus is locked with at least one screw to the distal tibia and provided that the distal extent of the plate extends more than 50% of the length of metatarsal bone 3. Hybrid tapered 3.5/3.5 or 3.5/2.7 or 2.7/2.0 plates have been employed. More recently the author has developed a pre-contoured tapered extended length plate with ovoid holes for proximal tarsal bone capture (FitzPANTA plate - canine). This implant facilitates a minimally invasive approach and appropriate tibio-tarso-metatarsal alignment and clinical outcomes have been satisfactory.

In cats 2.7mm and 2.0/2.7mm hybrid dorsal plate applications and medial plate applications have been plagued by significant issues with skin and soft tissue coverage of these bulky implants at this level, while dorsally-applied 2.0mm plates are insufficiently stiff to be used alone for this application. The author has harnessed the biomechanical benefits of plate-rod stabilization by application of the Acutrak Fusion screw as an intra-medullary calcaneo-talo-tibial rod in conjunction with dorsal 2.0mm plate and screw application with excellent results in a large number of cats while avoiding issues with soft tissue implant coverage. More recently the author has designed a new hybrid 2.4/2.0 dorsal hybrid tapered plate (FitzPANTA plate - feline) which is biomechanically resilient and has yielded very favourable results. Freeze dried allograft bone chips provide a useful augmentation to this surgery, though generally enough cortico-cancellous graft material can be harvested from the cranial ilial wings bilaterally (morsellised).

Splints or casts are deemed by the author to be unnecessary after PARTA except for immediate postoperative limitation of swelling. In a recent review of dorsal versus custom medial plates (also hybrid plates of similar dimensions to dorsal plates – three standard sizes) the author noted an increased rate of complications associated with implant loosening and poor limb use for medial plates, often attributable to trans-metatarsal bridging (even in configurations where screw length was tapered distally). In some cases where significant soft tissue loss is a salient factor, such as with shearing injuries, trans-articular external skeletal fixation may be employed efficaciously to support healing of pantarsal arthrodesis. Circular and linear frames can be employed. The author feels that there are no salient advantages for circular frames (which may take longer to apply) and generally applies pin-arch hybrid frames with or without a tied-in tibial/calcanean intramedullary transfixation pin.
Metatarsal injuries reportedly account for approximately 8% of fractures in dogs and are encountered relatively frequently in working dogs, especially agility dogs where negotiation of obstacles is intrinsic to performance. Non-surgical management techniques such as exercise restriction and external coaptation have been recommended for minimally displaced fractures and fractures of solitary minimally weight-bearing metatarsal bones. For other fractures, various management techniques have been described. Techniques utilizing intramedullary pinning either by normo-grade placement of suitably contoured K wires or retrograde insertion to avoid distal articular surfaces have been typically limited to mid-diaphyseal, simple metatarsal fractures due to the biomechanics of intramedullary pin repair. The implant diameter is limited to retain sufficient flexibility for placement while avoiding the joint surface. Excessive implant diameter may result in bone fissure propagation during insertion. Pins are difficult to place, even via bone slots or by a dowel technique, particularly in short distal juxta-articular segments and placement of intramedullary pins alone has not been successful at improving fracture alignment after surgery in some studies. External skeletal fixation with conventional transverse transfixation pins and primary repair of ligamentous injuries has been described as efficacious but in the author’s opinion is more potentially hazardous than longitudinal intramedullary pin/wire placement due to the natural arc of the metatarsal bones precluding transfixation across all four bones except at the base. Additionally, there is a risk of iatrogenic fracture as trajectory of implant relative to bone diameter may not allow centralisation of the pin relative to the bone, malalignment of metatarsal bones is common when “skewed” transversely and synostosis can ensue and can produce residual complications, especially in very young animals.

Bone plates and screws can be employed to address metatarsal fractures and in this regard veterinary cuttable plates have advantages with respect to a curved under-surface and low profile, but they are intrinsically mechanically weak. Many fracture configurations do not lend themselves to cerclage wire or lag-screw fixation. Fractures are sometimes open and infection can be a consideration as can treatment of disruption of the soft-tissue envelope.

The author has applied a novel form of external skeletal fixation with consistent success in a large case series of metatarsal fractures, including simultaneous fractures of all metatarsal bones, distal juxta-articular fractures and severely comminuted fractures. K-wires are directed distally from the fracture sites to exit the metatarsal bones at the dorsal aspects of the metatarso-phalangeal joints. The fractures are reduced and the k-wires reverse-driven into the proximal segments. One or two k-wires are placed transversely through the distal row of tarsal bones or the distal calcaneus, exiting medially and laterally. All k-wire ends are bent dorsally and embedded in a bolus of epoxy, held in alignment until set hard. Long-term lameness was not reported for any case (mean 2 years) and radiographic follow-up (mean 1.4 years) did not reveal arthrosis of the MT–P joints. The frame construct has been termed “secured-pin-intramedullary-dorsal-epoxy-resin” (SPIDER). Advantages compared with conventional methodologies include minimal biologic approach, application speed, absence of problems with soft-tissue cover of metallic implants, avoidance of bandaging inconvenience and complications, minimal swelling, reliable healing, early return to function, inexpensive equipment and no residual implants. The technique can also be employed to address tarso-metatarsal luxations by debriding the articular surfaces and applying the pins from the bases of the metatarsal bones distally first and then driving proximally and embedding in the distal row of tarsal bones, whereupon the frame is then constructed as described.

Addressing degloving injuries of the tarsus and metatarsus can be challenging depending on area and depth of tissue loss. Wet-to-dry dressings can be employed, as can hydrogel (Intrasite™) dressings and these can be protected with creative use of curved bars on external skeletal fixators forming a “tent” to optimise oxygenation and minimise occlusal-injury. Collagen matrices (Collamend™) and lyophilized porcine urinary bladder extracellular matrix (ACell Vet™) have been employed by the author with considerable success. Free-skin grafts can be employed once a healthy granulation bed has been re-established whilst skin flaps and myocutaneous grafting techniques can be employed for profound defects. Skin stretching on suture stents driven by external skeletal fixator motors and skin mobilising devices can be practical in certain instances.

In cases of profound loss of osseous and of myo-cutaneous tissues (usually shearing or crush injuries), once a soft-tissue envelope has been re-established in the tarso-metatarsal region in the manner described, the author has had considerable success employing cortico-cancellous bone blocks harvested from either the ilial wings or caudal vertebrae to restore distal tarsal and metatarsal bone-stock adequate for resumption of normal ambulatory capability. The shaped bone blocks or tail vertebrae are threaded on “skewer” wires and a customised hybrid arch-wire external skeletal fixation system is employed with anchorage proximal and distal to the region of bone deficit to transfer weight-bearing from the talocrural joint to the digits. The construct is mounted on motors which allow three weeks of oscillatory motion in the sagittal plane which may promote cortico-cancellous integration and prevent sequestrum formation. This osseous gymnastics has been termed “distraction-compression-osteointegration (DCOI)” and reconstruction of loss of all four metatarsal bones has been achieved successfully.

In the case of metatarsal-phalangeal luxation or infectious arthritis, skewer wires can be used to facilitate stability or arthrodesis and if protection from weight-bearing is required for healing, a customised wire-arch hybrid frame can be constructed which allows ambulation on metal arches whilst providing a “tent” for healing. The technique can also be employed for treatment of profound soft-tissue loss such as loss of pads of the case of trophic (neurogenic) ulceration and for providing a non-weight-
bearing environment for drainage of pedal abscesses. The technique has been termed “Pedal Arch Wire Scaffold (PAWS)”

Where irreparable neuro-vascular trauma accompanies osseous compromise and amputation is required, recent advances in prostheses now prompt consideration of partial limb amputation and application of intraosseous transcutaneous amputation prostheses (ITAP™). These devices can result in a resilient bone-implant and skin-implant interface which is resistant to infection and dermal marsupialisation. The author has had success with application of these prostheses in distal thoracic and pelvic limbs and iterations of exoprosthesis are rapidly evolving for both human and animal limb-salvage.

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USE OF INTERARCADE AND INTERDENTAL ACRYLIC BONDING FOR MANDIBULAR FRACTURE REPAIR
IN CATS AND DOGS
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Mandibular fractures account for 11% to 23% of fractures reported in the cat, and 2.5% of fractures reported in the dog. In previously published large retrospective studies of canine and feline cases of mandibular fracture, the complication rate following mandibular fracture repair ranged from 24 percent to 34 percent, with complications including malocclusion, osteomyelitis and soft tissue infections.

There are several anatomic, biological and biomechanical considerations that contribute to the high incidence of complications associated with mandibular fracture repair. Anatomic considerations include the fact that there are few safe corridors for implant insertion in the mandibular body, the thin mandibular ramus is difficult to access and has poor implant security, and the need for restoration of perfect dental occlusion means that non-anatomic fracture reduction is poorly tolerated. Presence of multiple fractures, or concurrent fracture or loss of teeth at the fracture site, can further compromise fracture reduction.

Biologic considerations include the contaminated environment of the oral cavity, and the fact that blood supply from the mandibular artery is often compromised at the time of fracture. Biomechanically, the mandible is subjected to bending forces as it is closed. Because the teeth are present on the dorsal surface of the mandible, plates and wires are necessarily applied away from the dorsal tension surface, creating a biomechanically inferior repair.

The goals of surgical repair of mandibular fractures are to achieve rigid stabilisation at the fracture site, restore normal occlusion, preserve fracture biology, avoid iatrogenic damage and facilitate an early return to function. Many repair techniques have been reported in the veterinary literature, including bone plating with conventional plates and miniplates, intramedullary pinning, external skeletal fixation, application of tape muzzles and interfragmentary wiring. No single technique is universally effective, especially where multiple fractures or fracture comminution are present.

An alternative technique known as interdental acrylic bonding, or interarcade canine acrylic bonding, has been described for the repair of mandibular fractures in dogs and cats. Interdental acrylic bonding, as described in previously published reports, involves the application of dental acrylic to the mandibular and maxillary canine teeth on both sides of the mouth, so that the mandibular and maxillary canine teeth are bonded together in a position that leaves the mouth slightly open to allow the intake of water and liquefied food. Previously published reports state that for interdental acrylic bonding to be successful, the patient must have four intact canine teeth at the time of acrylic bond application.

In the only published retrospective clinical series evaluating the use of interdental acrylic bonding in dogs and cats, the technique was found to be fast, easy, inexpensive and 100 percent effective for the repair of mandibular fractures. The only reported complication in that series was premature breakage of the acrylic bond in one case, necessitating replacement of the bond.

The purpose of this presentation is to review the technique, outcomes and complications in ten cats and dogs undergoing interarcade and interdental acrylic bonding for the repair of mandibular fractures, and to compare the findings in this group of patients to previously published reports of interdental acrylic bonding. Variations in technique are described, which challenge the previously published assertion that the presence of four intact canine teeth is a prerequisite for acrylic bond application. Complications in this group of patients included fracture non-union, bond breakage, loss of the tooth-bond interface, oesophagostomy tube displacement, and vomiting while bonds were in place. Technical considerations include the safe provision of general anaesthesia while bonds are in place, and the optimum method and timing for evaluation of fracture healing. The findings of this review support the use of interdental and interarcade acrylic bonding for mandibular fracture repair in dogs and cats, however the complication rate in this group of patients was higher than that reported in a previously published study.

HEMIPELVECTOMY: A SURGICAL OPTION FOR HINDQUARTER NEOPLASIA
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Background: Hemipelvectomy has been documented to be useful in the treatment of malunion in pelvic fractures, pelvic canal narrowing and aggressive tumour resections. In humans, it is commonly utilized to treat pelvic tumours and uncontrollable infections post total hip arthroplasty. Hemipelvectomy can be total or subtotal. Total hemipelvectomy involve complete excision of a hemipelvis. Subtotal hemipelvectomy only one section of the pelvis and may not involve the amputation of the ipsilateral pelvic limb.

Study design: Case report for 4 oncological cases (3 dogs and 1 cat)

Results: Case 1 – A 14 year old male desexed domestic short haired cat presented for a 3.6 cm by 4.1cm mass over the right pelvis. Radiographically, there was lysis of bone in the underlying acetabulum. Biopsy results were consistent with hemangiosarcoma. A subtotal hemipelvectomy (acetabulectomy) was performed. There were no post operative complications and was discharged 3 days post operatively when he was ambulatory. Case 2 – A 11 year old male desexed Rottweiler cross presented for a large grade II soft tissue sarcoma circumferentiating the L thigh, invading into the pelvis. A subtotal left hemipelvectomy (acetabulectomy) was performed. The dog was discharged 2 days later after good post operative recovery. Case 3 – A 8 year old female desexed Border Collie cross that presented for Grade III soft tissue sarcoma involving the L pelvis and the proximal L femur. A total left hemipelvectomy was performed. The dog was able to stand and ambulate on day 3 and eligible for discharge. Case 4 – A 10 year old female desexed Old English Sheep dog X that presented for osteosarcoma involving the L proximal femur. A partial L hemipelvectomy (acetabulectomy) was performed. Dog was ambulatory the next day and was discharged 3 days later. All the cases were staged with thoracic radiographs and abdominal ultrasound with no evidence of metastatic neoplasia. Computed tomography was used in all 4 patients to define surgical margins. Analgesia intra and post operatively consisted of a constant rate infusion of Fentanyl, epidural with Morphine and Bupivicaine and appropriate sized transdermal Fentanyl patch. All other follow up data will be presented.

Conclusions: Postoperative recovery in all 4 cases was excellent and was consistent with that reported in literature. Hemipelvectomy should be considered when neither mid femoral amputation nor coxofemoral can provide clean wide surgical margins. Meticulous understanding of functional anatomy and surgical technique is required before the procedure should be undertaken.

References

MAGAGEMENT OF SEVERELY COMMINUTED FEMORAL DIAPHYSEAL FRACTURE IN A CAT: HOW WOULD YOU FIX IT?

Surgery Chapter
Management of severely comminuted diaphyseal fractures of long bones can be challenging. They may be treated with various internal and external fixation apparatus, such as plate-rod combination, intramedullary (IM) pin tie-in with external skeletal fixation (ESF), and interlocking nails (ILN). More recently, locking screw-plate systems have been introduced to the veterinary science, and they have gained their popularity due to their superior biomechanical property. All of these systems have been reported to stabilise severely comminuted fractures of long bones effectively.

Currently, there is no exact recommendation for optimal strength for an implant to control fragments movement during healing. Minimally invasive approach and biological osteosynthesis have been advocated to encourage fracture healing rather than anatomical reconstruction of fragments. A recent study showed a plate-rod configuration provided better stability than ILN. A biomechanical research revealed that uni-cortical engagement of locking screws was weaker than bi-cortical engagement of non-locking screws. ESF with IM pin tie-in configuration can be used to stabilise comminuted fractures, but it may increase morbidity due to multiple transfixation pin insertions into the heavy musculature of the lateral femur, that may prevent the stifle motion and irritate patients. We should know advantages and disadvantages of each implant system, and we must apply the best implant(s) to individual cases to avoid implant failure and patient morbidity, achieving early functional recovery.

A six months old intact male domestic short hair cat was presented to the hospital for severely comminuted diaphyseal closed fracture of the left femur (Type C3) following a motor vehicle accident. A cuttable plate/screws and ESF with an IM pin as tie-in configuration were used to stabilise the fracture. Because no transfixation pins were inserted into heavy musculature of the lateral femoral shaft, the cat was comfortable, and maintained good range of motion of the stifle joint. Pin tract irritation/inflammation was not noticed. Although all components were down sized, the fracture was effectively stabilised initially. Two staged destabilisation procedures were performed at 6 weeks and 8 weeks post operatively. The triple combination was effective to manage the comminuted femoral fracture. This method can be applied to any weight and particularly useful for femoral and humeral comminuted diaphyseal fracture management. Advantages and disadvantages of current orthopaedic systems will be discussed.

References
FULL-THICKNESS MESHEDED FREE SKIN GRAFTS FOR WOUND COVERAGE AFTER TUMOUR RESECTION IN THE ANTEBRACHIUM IN 5 DOGS
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Primary closure of large skin defects in the distal limb in small animals is often impossible due to the insufficient surrounding mobile skin. Various reconstructive techniques have been described for wounds in the distal limb. They include distant flaps, delayed tube flaps, axial pattern flaps, reverse saphenous conduit flaps, tissue expansion, microvascular free tissue transfer and free skin grafts.

The loss of a large area of skin in the distal limb may arise from trauma, burns or tumour resection. Trauma and burn wounds are routinely managed with open wound management until the appearance of healthy granulation tissue. The wound would then be left to heal by second intention, or closed by surgical reconstructions.

In this report, full-thickness meshed free skin grafts were used to cover large skin defects in the distal limb in 5 dogs immediately after tumour resection with wide lateral margins. Full-thickness meshed free skin grafts are most commonly used to cover large wound defects after successful open wound management where there is healthy granulation tissue. The recipient graft beds in these cases consisted of epimysium of muscles and tendons. Despite some areas of partial thickness necrosis in some of these grafts, they all healed uneventfully with excellent cosmetic result. There was no evidence of local tumour regrowth at time of follow up 4-42 months after surgery.

References
Background: Brachycephalic Airway Syndrome (BAS) or Brachycephalic Airway Obstructive Syndrome (BAOS) is a well described disorder of the upper respiratory tract of brachycephalic breeds and occasionally other breeds. The primary problems associated with the syndrome include an elongated soft palate, stenotic nares, and tracheal hypoplasia. Secondary problems can develop due to the airflow turbulence created by the primary problems. These include eversion of the laryngeal saccules, pharyngeal hyperplasia, laryngeal collapse and tonsillar enlargement. A 2006 study by Torrez and Hunt found that 53% of dogs in their study for BAS also had laryngeal collapse in conjunction with the clinical signs noted above.

Objective: To perform a retrospective analysis of all BAS surgical cases referred to Veterinary Specialist Services, Underwood Queensland Australia. The goals of the study are to analyse primary and secondary BAS problems; post-surgical complications; and breed differences.

Methods: Data from all dogs that were referred for BAS and had airway surgery between March 2001 and February 2010 at Veterinary Specialist Services, Underwood were collected. Dogs were excluded from the study if they did not have surgery for an elongated soft palate, stenotic nares, laryngeal saccule eversion, tonsillar enlargement or laryngeal tieback. Dogs were further excluded if neoplasia was involved in the upper airway disorder or if they had laryngeal paralysis but no primary problems associated with BAS. The surgery records of all cases that fit the inclusion criteria were reviewed.

Results: 155 dogs were found to meet the inclusion criteria. Of these 155 dogs, 152 (98%) had resection of an elongated soft palate; 47 (30.3%) had alarplasty for stenotic nares, and 6 (3.9%) were observed to have tracheal hypoplasia. Of the secondary problems recorded 63 (40.7%) had a laryngeal sacculectomy performed, 77 (49.7%) had a tonsillectomy, 17 (11%) were noted to have laryngeal collapse, and 15 (9.7%) had laryngeal paralysis. The most common breeds were the Cavalier King Charles Spaniel (CKCS) (29 dogs, 18.7%), the Pugs (24 dogs, 15.5%), British Bulldogs (15 dogs, 9.7%), Staffordshire Bull Terriers (12 purebreed dogs and two crossbreed dogs, 9%), Shih Tzu (six purebreed dogs and three crossbreed dogs, 5.8%), Chihuahua (seven purebreed dogs and two crossbreed dogs, 5.2%), and Silky terriers (five purebreed dogs and three crossbreed dogs, 5.2%). All CKCS had an elongated soft palate and accounted for 41% of the laryngeal collapse cases (seven). All the pugs had an elongated soft palate, 75% (18) had stenotic nares, 70.8% (17) had everted laryngeal saccules, 54% (13) had a tonsillectomy, and seven had laryngeal collapse accounting for 41% of all cases of laryngeal collapse. Pugs and CKCS being only 34.2% of the study population accounted for 93.3% of the laryngeal collapse cases. Of the 155 dogs included in the study, only 13 (8.4%) were recorded as having serious complications in the immediate post-surgery recovery period. Seven required a temporary tracheostomy and five required re-intubation and sedation. Four dogs were euthanased and two died during the recovery period, with the remaining seven going on to make a complete recovery. The mortality rate in the study was 3.9%. Importantly, of the dogs with complications, three had laryngeal collapse, three had tracheal collapse, and one had tracheal hypoplasia.

Conclusions: Preliminary results indicate that similar breeds are presented for BAS surgery in this study compared to the study performed by Torrez and Hunt. The occurrence of laryngeal collapse was far lower in this study than compared with the same study by Torrez and Hunt. Complications are low with 96% of dogs having successful surgical treatment and being discharged from hospital.

References:
Trauma in small animals is commonplace in most veterinary practices, however there is little published data reporting incidences. Motor vehicle accidents have been accounted in several studies as the leading cause of trauma in companion animals (Cook et al, 1997; Mongil et al, 1995; Selcer 1982; Umphlet & Johnson, 1988 and 1990). Other causes of trauma include fight wounds, falls from heights and penetrating/lacerating objects, all of which often result in multiple injuries (Beardsley & Schrader, 1995; Dewey et al, 1993; Gordon et al, 1993).

A five year-old, female Doberman, weighing 29kg, was presented to Animal Emergency Services following multiple trauma. She had undergone surgical insemination two days prior to presentation and had been kept crated overnight. When let out of the crate, she ran straight through a plate glass window and sustained penetrating injury to the left abdominal wall as well as a subsequent evisceration and a severe laceration to the left antebrachium. This resulted in lacerations over the caudal radius and ulna, left abdominal wall, bladder, left uterine artery and evisceration of the omentum and small intestine.

After stabilisation for hypovolaemic shock, the bitch was immediately transferred to the care of Veterinary Specialist Services for emergency surgery. An exploratory celiotomy was performed to repair the abdominal wall, lacerations to the bladder and uterine artery, to replace the small intestine and omentum, and to achieve appropriate haemostasis. Following abdominal replacement, surgical repair of the following structures were also carried out: median, ulna and deep antebrachial arteries, median and ulna nerves, flexor carpi radialis and ulnaris, and superficial digital flexor tendon.

To date, there is minimal report on the technique of repair and outcomes of uterine artery laceration and distal ulnar/radial tendon/artery/nerve injury in dogs, compared to that in humans (Chin et al, 1998; Hudson & de Jager, 1993; Noaman, 2007; Pucket & Meyer, 1985). This case report represents a novel study of the surgical technique used for repair as well as functional outcome.

The patient achieved full recovery and regained full function of the limb within six weeks and was discharged. She then underwent a normal gestation and delivered 14 healthy puppies four weeks later.

References:
INTERVERTEBRAL DISC DISEASE SURGERY: AN EVALUATION OF RECOVERY RATE AND TIME FROM SURGERY TO DISCHARGE

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Intervertebral disc disease is an important neurological disease in the canine. Predictors of the outcome following surgery have been shown to include the degree of neurological dysfunction and duration of onset of clinical signs. This study aimed to evaluate success of surgery as demonstrated by the number of days spent in hospital post operatively.

A retrospective study was undertaken on records from Veterinary Specialist Services, Underwood and Gold Coast, Australia. All dogs with a surgically confirmed diagnosis of intervertebral disc disease were eligible for inclusion in the study. The period of the study was from the beginning of 2001 until the end of 2008. The following information was extracted from the records - breed, gender, weight, age, duration of onset, previous treatment, grade, site of lesion, days between presentation and surgery, surgeon and surgical technique.

The current study showed that breed, age, weight and surgeons experience has no influence on the outcome of the stay in hospital after intervertebral disc disease surgery. In this study gender, duration of onset, previous treatment, grade, site of lesion, days between presentation and surgery, physiotherapy and surgery performed were shown to affect the outcome and number of days spent in hospital.
Indications for lung lobectomy in veterinary patients include pulmonary neoplasia, abscess, granulomatous disease and bullae resulting in spontaneous pneumothorax. Conventional open approaches to individual lung lobes are well documented with common approaches made via fourth, fifth or sixth intercostal thoracotomies or median sternotomy. These afford a wide regional exposure as a result of forceful tissue retraction. Visualisation of intrathoracic structures remote to the operative site remains limited. Increasingly minimally invasive approaches to thoracic surgery are being made in both the human and veterinary literature in an attempt to reduce post-operative morbidity. The reduction in morbidity associated with thoracoscopic procedures has been previously reported.\(^1,2\) Other reported benefits of thoracoscopic surgery include improved visualisation with illumination and magnification, reduced requirement for post-operative analgesia, improved cosmetic appearance and reduction in hospitalisation periods.\(^3,4\) Major disadvantages associated with thoracoscopic surgery are associated with developing the requisite skills and the requirement for costly disposable instrumentation. Thoracoscopic assisted surgery offers a bridging modality offering most of the advantages of minimally invasive surgical techniques with a reduction in the learning curve for surgeons and facilitating the use of less costly disposable items. The establishment of an assisted portal permits hand or instrument access to the operative site, allows tactile palpation of tissues and facilitates delivery of large tissue specimens from within the pleural space. Whilst thoracoscopic lung lobectomy is previously reported in the veterinary literature,\(^5\) the ideal port sites for thoracoscopic assisted lung lobectomy have not yet been established.

A cadaveric study was designed to assess the relative access to the major lung lobes for the purposes of thoracoscopic assisted lung lobectomy or partial lung lobectomy in the dog. We hypothesized that a thoracoscopic-guided mini-thoracotomy could be performed safely and that the creation of an assisted portal using the wound retraction device would permit dissection of the lobar hilus, facilitate manipulation of the pulmonary parenchyma and allow exteriorisation of pulmonary tissues for partial extra-corporeal lobectomy. In addition, we proposed that that assisted portal would provide access for a linear stapler to achieve complete or partial intracorporeal lobectomy.

A novel wound retraction device, the Alexis Wound Retractor (Applied Medical, Stafford City, QLD, Australia) was used in the establishment of the assisted portals. This device consists of a cylindrical membrane sheath manufactured from a proprietary polyurethane material. Deformable rings at either end of the cylinder retain the device in-situ and facilitate uniform radial traction on the soft tissues and ribs. Reported benefits of the Alexis wound retractor are increased moisture at the wound site which has implications for post-operative surgical site infection rates.\(^6\) An additional theoretical benefit is the establishment of an impermeable barrier to reduce neoplastic seeding of portal sites which is a reported complication of thoracoscopic resection of pulmonary neoplasia in both humans and dogs.\(^7,8\) In the author’s clinical experience, the radial tension generated by the retractor also aids haemostasis at the portal site.

Following the introduction of the thoracoscope in the dorsal third of the eighth intercostal space, the assisted portal was serially established in the middle and ventral thirds of the fourth, sixth and eight intercostal spaces. Exposure of and access to the hilar region of each lung lobe was subjectively assessed at each site.

Placement of the thoracoscope in this position resulted in adequate visualisation of the ipsilateral hemithorax. Other authors have recommended placing the thoracoscope in the sixth intercostal space.\(^5\) Following establishment of the assisted portal however, the thoracoscope, the surgeons hand and instruments could be inserted to allow additional visualisation, palpation and manipulation of the pulmonary lobes. The assisted portal also allowed the introduction of standard, non-endosurgical linear stapling devices for the purposes of lobectomy.

Recommended positions for the establishment of the assisted portals for lobectomy of each lobe are provided in the accompanying table.
When the Alexis wound retractor was positioned according to these recommendations complete or partial lung lobectomy could be achieved intra and extra-corporeally using sutured or stapled techniques. Delivery of the caudal lobes is greatly improved by thoracoscopic division of the pulmonary ligamentous attachments. The clinical application of the technique has been validated in two cases accepted for publication, and the author has subsequently performed two additional cases without complication. Subjectively these animals made a rapid recovery post-operatively with a reduced requirement for analgesics than typically used for a more conventional thoracotomy in our hospital.

References:
PREVALENCE OF MENISCAL PATHOLOGY FOLLOWING ARTHROSCOPIC ASSISTED TIBIAL PLATEAU LEVELING OSTEOTOMY

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Objective: To determine the prevalence of late onset medial meniscal tears (LMMT) in dogs with naturally occurring cranial cruciate ligament (CCL) disease following arthroscopy and tibial plateau leveling osteotomy (TPLO).

Study design: Retrospective clinical case series

Sample population: Stifles (n=357) of dogs that had an arthroscopic assessment and TPLO with naturally occurring CCL disease.

Methods: Medical records were reviewed for all dogs treated with a standardized stifle arthroscopy followed by TPLO assessment between 1/11/06 and 1/11/09 by a single experienced surgeon. Partial meniscectomy (PMM) was performed in all stifles with concurrent medial meniscal tear (MMT). No procedures were performed on grossly normal menisci. Follow up phone interviews were conducted on all cases involved in the study. The sample population excluded dogs that had had prior stifle surgery, or where the CCL was left in situ.

Results: Of the stifles included in the study, 61.3% had complete CCL tears and 32.2% had concurrent MMT. LMMT was diagnosed in 5.6% of overall cases, in 7.8% of those with a grossly normal medial meniscus and in 0.87% of cases that had a PMM. A two-tailed Fisher exact test demonstrated a statistically significant (P<0.05) lower rate of LMMT in the partial CCL tear with normal meniscus than in the complete CCL tear with normal meniscus groups. All patients with definitive LMMT returned to peak postoperative limb function following PMM.

Conclusions: The overall rate of LMMT following TPLO is similar to previous reports. The prevalence of MMT and LMMT were significantly higher in stifles with complete CCL tears than those with partial CCL tears. PMM was successful in preventing LMMT and in resolving lameness due to LMMT.

Clinical Relevance: The rate of LMMT in arthroscopic assessed partial CCL tears compares favourably to that reported for LMMT following arthroplasty and meniscal release.

References:

Objective: The purpose of this study was to retrospectively report on the clinical outcome of 31 consecutive TKRs in dogs with severe, end stage, degenerative joint disease as consequence of various etiologies. We hypothesize that the TKR will be an acceptable treatment for severe degenerative joint disease based on subjective limb function, patient comfort, complications, contraindications, and owner acceptance.

Study Design: Retrospective analysis of canine total knee arthroplasty in 28 consecutive cases (31 stifles).

Methods: The case records of dogs that underwent a TKR between April 2008 and January 2010 at either The Pet Emergency & Specialist Centre (22 stifles) or Parramatta Veterinary Surgical Specialists Pty Ltd (9 stifles) were reviewed. Criteria included indication for TKR, surgical method, surgical or postsurgical complications, function of the limb or limbs, comfort of the patient, implant stability, radiographic follow-up and telephone contact with each owner.

Results: Twenty eight dogs with 31 TKRs were identified for inclusion in the study. Patient signalment, suspected underlying cause for the severe degenerative joint disease, body weight at time of the procedure were obtained. The mean body weight at the time of TKR was 34kg (SD ± 8.4) and the mean age at the time of TKR was 6.8 years (SD ± 1.9). The suspected etiology of severe stifle osteoarthritis in most cases was cranial cruciate ligament disease (29). Other etiologies found in our study were osteochondrosis dessicans (1) and one case suffered multiple failed medial patellar luxation surgeries and septic arthritis. Minor complications were sustained in 5 dogs which consisted of superficial wound problems; seroma formations (2), superficial skin dehiscence (2), pyoderma and incisional infection (1). Major complications occurred in 6 dogs; joint instability (4), infection of implant (1), aseptic loosening (1). Results were excellent in 58% of stifles, good in 19%, fair in 6%, and poor in 16%.

Conclusion: TKR in canines can be utilized to obtain significant improvement in dogs with disabling, painful osteoarthritis, but complication rates are high. Judicious case selection, correct implant selection, and careful surgical technique are paramount for successful case outcomes.
A MINIMALLY INVASIVE TECHNIQUE FOR FLUOROSCOPIC-GUIDED REDUCTION AND STABILISATION OF SACRO-ILIAC SEPARATIONS AND SACRAL FRACTURES USING CONVENTIONAL, NON-CANNULATED, INSTRUMENTATION

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Sacroiliac fractures and separations are common traumatic injuries in the cat and dog. Concurrent orthopaedic and soft tissue injury is common. In one review, 93% of dogs with unilateral sacroiliac separation had at least one other pelvic fracture, and 85% had major orthopaedic injury to the contralateral limb. So, whilst conservative management is often considered, open reduction and surgical sacroiliac stabilisation is frequently indicated to hasten recovery of limb function, reduce morbidity and restore pelvic canal dimensions. Specific indications for surgical management include: moderate to marked displacement of one or both hemipelves or sacral segments, significant pelvic canal narrowing, severe or unremitting pain, neurologic dysfunction attributable to the sacral or sacroiliac injury and comorbid major orthopaedic injury.

Numerous techniques, through varied approaches, have been reported for the surgical reduction and stabilisation of sacroiliac fractures and separations. Lag screws, Kirschner wires, transiliosacral rods and tension band wires have been used through dorsolateral, ventrolateral, dorsal, ventral abdominal and minimally invasive fluoroscopic approaches. Difficulty in identifying anatomic landmarks through conventional dorsolateral or ventrolateral approaches obscures recognition of safe corridors for implant placement and complicates the reduction of sacral or sacroiliac, fractures or separations, respectively.

A minimally invasive technique for sacroiliac fracture/separation reduction and stabilisation, using cannulated instrumentation, has been reported. Using this technique reported sacroiliac reduction, sacral screw purchase and incidence of screw loosening was improved when compared with reports employing other methods. This report introduces a novel method of sacroiliac fracture/separation reduction and demonstrates its applicability to fluoroscopically guided percutaneous sacroiliac screw placement using conventional (non-cannulated) instrumentation.

When possible, axial traction was applied to the distal pelvic limbs and a fulcrum positioned beneath the pelvis. Sacral or sacroiliac reduction, with compression, was then achieved with large pointed reduction forceps and positional screws inserted. Although the present report includes only five sacroiliac separations and one axial sacral fracture, the authors’ early experience with the technique indicates that it greatly facilitates reduction and safe screw placement for the surgical management of sacral fractures and sacroiliac separations in small and medium sized dogs and cats.

Elbow incongruity has been proposed as one potential causative factor in canine developmental elbow disease. It has been suggested that an association may be present between disparate anteroposterior growth with resultant cubital joint malformation and the development of an ununited anconeal process, focal trochlear osteochondral wear and fragmentation of the medial coronoid process\textsuperscript{1,2}. It is proposed that elevation of the articular surface of the medial coronoid above the radial head due to disparate growth of the radius and ulna during joint development may cause focal increases in transarticular pressures on various areas of the joint surface. This joint incongruity may contribute to microfracture of subchondral bone, abnormal development of the joint surface and destruction of articular cartilage in some patients\textsuperscript{3}.

The examination of canine elbow morphology in both normal and dysplastic patients has focused on several areas. Necropsy examinations of a small numbers of dogs affected by elbow dysplasia subjectively revealed the distal end of the trochlear notch and the medial coronoid process were lying above the level of the adjoining radial articular surface in some patients. The presence of a distinct 2mm proximal step between the surface of the medial coronoid and radial head surface was classified as a radial-ulnar incongruity (RUI) in the examined cadaver patients\textsuperscript{4}. The presence of RUI has been further investigated in several imaging studies involving radiography and CT. The accuracy of radiography in detecting RUI in experimental models has varied between investigators from poor to excellent depending upon the size of the induced step, the radiographic position, presence of in-vitro weight-bearing and the radiologists involved\textsuperscript{5-7}. Computer tomography (CT) imaging of the dysplastic elbow has been used to document elbow joint incongruity\textsuperscript{8,9}. The accuracy of CT imaging in detecting induced RUI in experimental models\textsuperscript{7,10,11} has demonstrated reconstructed CT is capable of imaging the relationship between osseous joint surfaces with some variation in accuracy between investigators, reconstruction protocols and limb position\textsuperscript{12,13}. The implementation of one experimental CT imaging protocol in clinical patients with medial compartment disease established that there was not a consistent radial-ulnar incongruency able to be visualized at the time of diagnosis on elbows in a non-weight bearing position\textsuperscript{14,15}. Some individual patients within both case series were found to have an apparent RUI although the studies differed in the location of that incongruency from coronoid apex\textsuperscript{14} to coronoid base\textsuperscript{15}. Arthroscopic assessment of experimental RUI demonstrated an averaged sensitivity of 94\% and specificity of 82\% with an inter-investigator agreement among surgeons scoring the arthroscopic images of 88.6\%. The arthroscopic examination out-performed both radiography and CT in identifying experimental RUI\textsuperscript{7}. Although MRI has been investigated and verified as an appropriate imaging technique for pathology detection in elbow dysplasia\textsuperscript{16-18} there is no verification of its ability to examine elbow geometry and incongruity.

Research into joint contact patterns and transarticular force in the canine cadaver elbow has demonstrated that in the normal elbow there are two ulnar contact areas, the craniolateral anconeus and the medial coronoid process. This indicates that although there is an apparent physiologic incongruity present in the humeroulnar joint there is continuous contact between the medial coronoid and radial head contact areas with no evidence of surface incongruity\textsuperscript{19}. The transarticular force measurement demonstrated a relatively equal distribution of joint force between the medial coronoid and radial head\textsuperscript{20}. When radial shortening was performed in cadaver limbs to mimic the step defect reported in RUI the radial contact zone became smaller, anconeal contact disappeared and coronoid contact increased. Following proximal ulnar ostectomy with intramedullary pin stabilization and limb loading, normal radius and coronoid contact area size, location and continuity was restored in six of ten limbs. Proximal ostectomy without stabilization resulted in varus deformity of the elbow under load. A midshaft ulnar ostectomy without radioulnar ligament release had no effect on contact patterns\textsuperscript{21}. No data on the effect of ulnar ostectomy on force transmission through the joint is available. The limitations of the published data also include the lack of investigation of the role that degree of elbow flexion and pronation and supination of the foot have on elbow contact and joint force. Although it is comforting to simplify the anatomical and biomechanical abnormalities into the presence or absence of RUI in static, non-loaded imaging techniques this approach is fraught with inaccuracy and misunderstanding. In human cadaver elbow incongruity investigations the stress distribution in the joint, measured by contact area and joint space was influenced by induced force across the joint. As load was increased a significant improvement in joint congruity was seen\textsuperscript{22}. As joint angle was modified the contact areas also changed\textsuperscript{23}. Concurrent measurement of subchondral bone density by CT osteoabsorptiometry demonstrated joint geometry and loading conditions influence the distribution of subchondral density\textsuperscript{24} and the physiologic incongruity present at some joint surfaces resolves with increasing pressure due to the viscoelastic deformation of articular cartilage and subchondral bone\textsuperscript{25,26}. These investigations have not been performed in the canine.
Current surgical treatment of dysplastic patients has two potential components. Firstly the removal of coronoid fragments with debridement of the exposed subchondral bed with or without subtotal coronoidectomy. Results with these procedures alone have been variable and subjective with many dogs having an apparent improvement in their gait and degree of joint pain. There is no peer-reviewed, published evidence that supports that this procedure slows or stops the ongoing development of elbow osteoarthritis. The second surgical manipulation is an osteotomy or ostectomy of the ulna, radius or humerus to attempt an improvement in the elbow congruity and decrease the biomechanical loading of the medial joint compartment. There are no comprehensive prospective, standardized studies with control groups and force plate data that has looked at the effect of these procedures in clinically affected elbow dysplasia dogs. In vitro studies of mid-humeral wedge and sliding osteotomy in loaded cadaver limbs demonstrated an alteration in joint surface contact in both the radius and ulna with a mean decrease in proximal ulnar articular force of 28% when an 8mm sliding humeral osteotomy (SHO) was performed. Clinical investigation of the SHO is ongoing and preliminary results are encouraging. There are no published peer-reviewed reports on radial osteotomy and a paucity of reports on ulna ostectomy.

The decision to perform an ostectomy following arthroscopic debridement of the coronoid must be made with limited scientific data as support and with the knowledge that some procedures have an inherently high morbidity and potential complications are serious and if they develop may lead to the loss of functional use of the thoracic limb. These risks are balanced against the subjective opinion of experienced surgeons who feel strongly that without an attempt to improve joint congruity and biomechanical loading of the medial compartment the surgical results with coronoid debridement alone are sub-optimal. When attempting a procedure with potentially disastrous complications the individual surgeon must fully inform the client of the potential benefits and possible complications with the proposed procedure and must continue to honestly assess the individual results that they achieve with standardized outcome measures to justify the semi-experimental nature of the treatment.

Clinically, the assessment of the radio-ulnar relationship is made with pre-operative radiographic and/or CT images. A standardized examination and measurement protocol is essential. On CT images the examination of the radio-ulnar subchondral surfaces at the apex, mid-body and commissure of the medial coronoid process in the transverse plane and at the commissure in the reconstructed sagittal plane is recommended. Imaging protocols vary between centers but obtaining lateral radiographs with the elbow flexed at 90 degrees and antero-posterior radiographs with the elbow joint extended is recommended. On CT examination having the patient positioned in dorsal recumbency on the gantry with the elbows flexed at 90 degrees correlates to the CT research examinations performed by some investigators or at 135 degrees for others. The presence of an apparent RUI should be accurately measured and documented.

On arthroscopic exploration of the medial compartment of the elbow the relative position of the articular surfaces of the radial head in relation to the medial coronoid can be assessed and compared to pre-operative images. The effect of surgical positioning of the thoracic limb has been examined in relation to arthroscopic assessment and an extended or neutral elbow flexion angle and foot position is preferred. If significant RUI is judged to be present, the performance of an ulnar ostectomy may be considered. The age of the patient, use of ulnar ostectomy or ostotomy, the proximal-distal location of the ulna ostectomy, the alignment of the ostectomy cut, the use of stabilization implants, the release of the radioulnar ligament and the post-operative use of external coaptation are all technical issues that should be considered.

The published support for proximal ulna ostectomy is the in vitro demonstration of significant resolution of RUI in 60% of cadaver specimens. The disadvantages include the development of proximal ulnar segment instability and potential varus malformation of the elbow in cases that are not stabilized intra-operatively. This instability and potential malunion of the ostectomy segments is influenced by the tensile stress exerted by the triceps tendon inserting on the olecranon. The disadvantages of stabilization include increased operative time, potential for implant infection, migration and failure. There is also an apparent increased pain and morbidity with the proximal osteotomy that slows patient recovery following the procedure.

The distal ulna ostectomy (Duo) has been used extensively by some surgeons to address suspected RUI and potentially decrease the humero-ulnar conflict that is thought contributes to coronoid fragmentation and medial compartment arthrosis. The ostectomy is performed between the distal limit of the radio-ulnar ligament and the proximal aspect of the distal ulnar physis. The ostectomy is directed in a distal oblique plane cranio-medially from the caudo-lateral diaphyseal surface to minimize both caudal and lateral drift of the proximal ulnar segment. An issue that remains to be resolved is the concurrent release of the radio-ulnar ligament. In experimental models when a distal ostectomy was performed without ligament release in cadaver limbs harvested from mature dogs it was not possible to resolve induced RUI due to the tethering effect of the ligament. In juvenile dogs this ligament may still retain enough structural flexibility to plastically deform under load and allow sufficient independent movement of the radius and proximal ulnar segment but this has not been ascertained.

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definitively. Following the initial osteotomy cut a section of bone is removed with a second osteotomy cut in the same plane as the first to remove a 3-5mm wide segment of ulnar diaphysis (Figure 5). Post-operatively some surgeons will place a caudal "spoon" splint to support the antebrachium, inhibit post-operative swelling, limit self-trauma to the surgery sites by the patient and assist in pain control. The splint is maintained for 1-2 weeks post-operatively. Follow-up radiographs six weeks post-surgery to assess ulnar bone healing and joint congruity are helpful. These radiographs often reveal exuberant bone callus formation at the osteotomy site which classically resolves later in the recovery period. Although atrophic non-union is recorded no apparent clinical significance was attributed to their presence.

Without further investigations into pre-surgical assessment of elbow incongruity to verify its presence, nature and location, in vitro cadaver investigation on the structural and biomechanical effects of structural modification techniques and verified outcome measure assessment of clinical cases it is not possible to recommend a particular pre-operative approach or procedure in suspected elbow incongruity patients. The individual surgeon must continue to critically evaluate their own patients, avoid bias and prejudice based on incomplete understanding of the disease process and attempt to improve the quality of life of their patients while minimizing unnecessary interventions. Although progress has been made in the pre-operative assessment of elbow dysplasia patients to document specific structural pathologies, there remain many questions on the definitive documentation of elbow incongruity and the most appropriate interventional treatment when radio-ulnar incongruity is thought to be present.

References:
ADIPOSE DERIVED STEM CELL TREATMENT FOR OSTEOARTHRITIS IN DOGS

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AdiCell\textsuperscript{TM} is a commercially available patented treatment for canine osteoarthritis that utilises cellular extracts from autologous fat tissue including adult stem cells. The purpose of this presentation is to briefly summarise the science behind stem cell treatments, the techniques and preliminary clinical results in dogs including my limited personal experience and a perspective on where stem cell therapy may fit among the various treatment modalities available for management of osteoarthritis in dogs.

What are adult stem cells?
Stem cells are cells found in differentiated organs and tissues that retain the potential to both divide and under certain conditions transform into other more specialised cell types. The use of stem cells for tissue regeneration and repair is a rapidly developing area of scientific endeavour in both human and veterinary patients. Potential use not limited to arthritis management but may offer new treatments for a wide spectrum of disorders with potential benefits in bone and tendon healing, repair of renal, pancreatic, cardiac, hepatic, neurologic and urethra (Webster et al, accepted for publication AVJ). Stem cells can be broadly divided into mesenchymal stem cells that can differentiate into various connective tissues including chondrogenic, osteogenic, myogenic and neurogenic lines or haemopoietic stem cells that give rise to blood cells. Adult stem cells differ from embryonic stem cells that are derived from the pre-implantation blastocyst that can differentiate into any tissue lineage. The use of embryonic cells has clear ethical and practical limitations in people and animals and may be associated with some risks including malignant transformation.

Stem cells in fat
Adult mesenchymal stem cells can be found throughout the body but are in significant numbers in adipose tissue, connective tissue, cord blood and bone marrow. They are both abundant and easily recovered from adipose tissue (fat). Adipose tissue has a rich capillary blood supply and associated with the capillaries are large numbers of non adipocyte cells including mesenchymal and hemopoietic stem cells, T cells, B cells, granulocytes, monocytes pericytes and mast cells. There are many published studies that confirm that stem cells exist in higher numbers in fat than in bone marrow. These cell types have broad range of functions including regulation of angiogenesis and anti-inflammatory cytokine production. Since large numbers of stem cells are required for stem cell therapies the high numbers available in fat avoid the need for stem cell numbers to be amplified with cell cultures. This avoids any possible risks associated with in vitro cell culture related changes.

Safety
The AdiCell technique is novel and has been used safely without major reported complications for around 3 years. Longer term safety can also be inferred from safe long term use of other similar autogenous cell transfer techniques including bone marrow transplantation that have been used for decades in human patients. The stem cells in Adicell are transplanted after minimal processing and no cell culture or storage to optimise viability and avoid any potential reported risks or detrimental effects that have been associated with allogeneic transfer or changes such as malignant differentiation that can develop during cell cultures. Similar fat transfer procedures have been safely used in human cosmetic and reconstructive surgery over the long term.

The AdiCell procedure
Fat is collected in sterile fashion from an inguinal site via surgical incision. The tissue is digested enzymatically and processed aseptically using in-clinic laboratory to separate the cellular components from connective tissue. The cellular component includes a mixed cell population that includes large numbers of stem cells as well as fibroblasts, endothelial cells and blood cells. The preparation process takes under 120 mins and the resultant cellular extract is separated from lipid and then diluted for injection into joints affected with osteoarthritis. Treatment is therefore minimally invasive. As very high numbers of stem cells can be collected from fat multiple joints can be treated simultaneously.

Rapid preparation and treatment of samples optimises cell viability and quality control systems are in place to ensure adequate cell numbers and viability.

Correct joint injection in confirmed by aspiration of synovial fluid before injection. Most dogs can be discharged on the day of treatment or following day. There are mild acute effects evident generally limited to some mild peri-articular swelling, temporary worsening of lameness and discomfort and surgical site swelling or bruising. Significant complications of the procedure have not been identified to date.
Mechanisms for action
Numerous scientific studies have shown that stem cell treatment may improve healing in cartilage defects in experimental models. The exact mechanism for improvement after AdiCell treatment remains uncertain. Theoretically stem cells may have the capacity to differentiate into chondrocytes, however, there is not yet evidence for chondrogenic differentiation of cells or cartilage regeneration in AdiCell treated dogs. Histologic studies have not been performed. The rapid clinical improvement observed suggests that stem cell secretions may play a significant role. Stem cells have been shown previously to embed in tissues and secrete anti-inflammatory and immunosuppressive cytokines.

Clinical results in dogs
A clinical study of AdiCell treatment for osteoarthritis in 26 dogs identified rapid and sustained clinical improvement in most dogs treated (Webster et al 2010, in review). Outcomes were measured using serial examination pre and post treatment with veterinary numerical rating scores and owner determined clinical outcomes measures. The magnitude of the treatment response appeared of similar magnitude to effects previously reported using comparable evaluation schemes to assess other arthritis treatments including non-steroidal anti-inflammatories, pentosan polysulphate or glucosamine/chondroitin supplements. Controlled clinical trials in dogs have not been completed using AdiCell but double blinded trials in dogs using similar adipose derived stem cell protocols appear promising (Black et al 2007, 2008). There is also considerable anecdotal clinical experience with the use of regenerative techniques for management of osteoarthritis using Adicer and promising results have been obtained.

Which dogs are candidates for AdiCell
Few real contraindications to treatment have been identified apart from general risks of anaesthesia or surgery or joint injection. Septic arthritis is certainly an absolute contraindication. Relative contraindications may include presence of significant joint instability, serious illness or neurologic lesions mainly because existing concurrent morbidities may affect the chance of favourable treatment outcomes. There is some anecdotal evidence for treatment benefit with immune mediated arthritides in a human patient but not in dogs at this time.

Osteoarthrosis and its symptoms are very common problems among canine patients presented to primary accession and referral veterinary hospitals and a source of concern for their owners. AdiCell stem cell treatment should be added to the list of treatment alternatives available to owners and their dogs for managing this disease. Suitable candidates for treatment may include dogs where NSAIDs or alternative treatments are not adequate or are poorly tolerated or if client compliance with chronic medication is poor. The relative non-invasiveness and ability to treat multiple joints is appealing to owners of elderly animals or animals with many affected joints. Suitable candidates may include dogs that have already undergone appropriate corrective surgical treatments but have ongoing or progressive arthrosis symptoms (eg cruciate repair, management of elbow incongruity, joint instability or trauma) or where surgical options are not being considered.

The one off nature of the treatment and its apparent long duration may make it particularly appealing to owners of younger dogs. In addition some owners wish to have access for their pets to cutting edge, novel or treatments that are perceived to be not drug based. The main disadvantage of treatment at this stage is the limited availability in some locations, the expense associated with treatments and the limited published long term follow up.

References can be provided on request.
VARIABLE OSTEOTOMIES FOR THE TREATMENT OF ELBOW DYSPLASIA
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Elbow dysplasia is a major cause of front limb lameness in dogs -- in a great majority of cases it is initiated at and/or limited to the medial compartment. A number of different osteotomies have been proposed and practised to treat the condition, mostly based on observing incongruities within the joint. Looking at the overall loading of the limb offers another view and may point to the cause of the condition and thus to a more rational approach to treatments.

In the frontal plane the ground reaction vector, as a rule in straight gait, will pass medially to the elbow. A simple inspection demonstrates that dogs show a large variety in their front limb conformation and use of it in gait – some will walk/run hitting the ground with right and left paws near the centre line, while others will hit the ground at a considerable distance from the centre line. Considering the offset of the ground reaction with respect to the elbow, a straightforward conclusion follows that a larger offset will generate a larger moment in the frontal plane, which by and large will cause compression of the medial compartment and tension in the lateral co-lateral ligament. Muscle forces play a minor role in this balance once the ground is hit. Looking at local incongruency, typically described as short or long ulna vs. radius, may suggest a wrong intervention.

If the medial offset of the ground reaction is the cause of the problem, can one better plan for a corrective osteotomy and what are the choices? It turns out that a number of corrections are possible and most have actually been used, even if based on wrong arguments. A short, probably incomplete list:

1. Prolongation of the radius by an oblique sliding osteotomy, fixed by a plate – will tend to lateralize the paw and thus decrease the medial offset of the ground reaction and hence to unload the medial compartment (planning?);
2. Oblique proximal osteotomy of the ulna, without fixation – will also tend to lateralize the paw (planning? execution?) and thus unload the medial compartment;
3. Distal shortening of the ulna – as above, but with lesser impact being closer to the ground (planning? execution?);
4. Proximal osteotomy of the ulna (recently proposed by Pfeil) fixed by a plate, imposing a shift, an angulation and an incidental rotation on the ulna, adding to lateralization of the paw and thus to unloading of the medial compartment. Planning, currently based on the joint condition, is under evaluation;
5. Sliding osteotomy of the humerus (recently proposed by Schulz), originally based on shifting the action of the triceps, incidentally results in lateralization of the paw (planning?);
6. Rotational osteotomy of the humerus (recently proposed by Tepic) aims at shifting the paw laterally – in vitro demonstration has yet to be confirmed by surgery.

All of these osteotomies could benefit from better, rational, yet straightforward planning and guided execution. With so many choices available, it is hard to imagine a comparative study being done in the near future, if ever. But collective experience of many surgeons may in due time provide an indication of which of the treatments is more effective, yet less morbid.
Feline pelvic fractures are common after impact trauma with a reported incidence of 22–32% of all appendicular skeleton fractures. In one study of 103 cats with pelvic fractures, ilial fractures were seen in 48.5% of cases and in all cases were associated with concurrent fracture of the pubis, ischium or acetabulum, or with contralateral sacroiliac separation. Oblique ilial fractures are very common in cats presented following vehicular impact trauma at the author’s facility but comminuted ilial and acetabular fractures are surprisingly common findings. The acetabulum is involved in ~ 20% of cases and is frequently associated with concomitant fracture of the pubis, ischium and ilium, and with fracture-luxation of the sacroiliac (SI) joint. SI luxation occurred with an incidence of 59% in a previous study of cats with pelvic fractures, and 27% of 264 separate pelvic fractures reported in a series of 103 reported by the author. SI luxation is usually associated with concurrent fractures of the pubis, ischium, acetabulum or ischium, the most common combination of injuries being SI luxation in addition to contralateral ilial fracture and pubic and/or ischial fractures.

Conservative management may be a viable option for ambulatory, non-painful cats or dogs, however surgical stabilisation provides pain relief and shortens the hospitalisation period. It has been perceived that cage-rest only for many cats and small dogs with pelvic fractures results in “adequate” outcome, but this is poorly defined. Fractures of the ilium and acetabulum disrupt the weight bearing axis and thus surgical stabilisation is recommended to shorten the convalescence period and improve the long-term clinical outcome. It is the author’s experience that with exception of minimally displaced pelvic fractures, or isolated pubic and ischial fractures, surgical repair generally results in more rapid recovery and more predictable outcomes. Suggested indications for surgical intervention include the presence of pelvic canal collapse, neurological deficits, disruption of acetabular integrity, intractable pain despite administration of appropriate analgesics, or the presence of concurrent orthopaedic injuries. Pelvic canal collapse is often present, which may subsequently lead to recurrent constipation, obstipation and megacolon. A recent study suggested that pelvic canal narrowing of >45% may pose a high risk for cats developing recurrent constipation. Surgical repair of all displaced pelvic fractures causing pelvic canal narrowing is recommended.

Ilial fractures are generally stabilized by open reduction and application of appropriately contoured plates and screws. Various types of plates have been employed for including dynamic compression plates, plastic plates, cuttable plates, T plates, miniplates, reconstruction plates and double plates. Even with proper implant selection and application technique, complications, such as implant failure and post-surgical muscular atrophy, can occur following lateral plate and screw stabilization of ilial fractures. Dorsal plate fixation was associated with improved clinical outcomes with a lower incidence of pelvic canal narrowing attributable to the increased purchase of dorso-ventrally orientated screws.

Various methods have been reported for stabilisation of SI luxation with the most popular technique being placement of a lag screw through the ilial wing into the sacral body following reduction of the sacroiliac joint. When using this technique the author prefers to drill the ilium first with a lag-dimension hole and then the corresponding sacral site with a screw-core dimension hole, such that the ilial wing can be reduced onto the sacrum appropriately, using the screw itself rather than reducing the SI first and then drilling. Other reported methods include placement of a transiliosacral rod, sacroiliac pin and tension band suture, transilial locking plate and indirect stabilisation by means of transiliial pins. When lag screw fixation is used, accurate screw placement into the sacral body and adequate screw thread length are important to prevent screw loosening. Inaccurate screw placement not only increases the risk of early screw loosening but also risks injury to the neurological structures within the cauda equina if the screw is malpositioned dorsally. Recent studies have reported a difference in the anatomy of the sacroiliac joint between canine and feline patients and recommendations have been made with regard to screw placement in an attempt to decrease the incidence of screw malpositioning. In feline patients the margin of error during screw placement is small and thus there is a significant risk of incorrect placement of the screw. The author submits that this may be avoided by pre-drilling before reduction as described. Various approaches have been used for stabilisation of the sacroiliac joint. Dorsolateral, ventral, ventrolateral and fluoroscopic assisted closed approaches have been reported for implant placement. The ventral approaches are technically challenging, fluoroscopy is not routinely available and thus the dorsolateral approach remains the most commonly used technique.
For acetabular fractures, surgical stabilisation is usually required to achieve a satisfactory outcome, but conservative management may be a viable option for ambulatory, non-painful cats, with isolated, non-displaced fractures of the caudal acetabulum, albeit that such cases develop inevitable arthrosis in the author’s experience. Cadaver studies have shown that weight bearing forces are transmitted across the entire radius of the acetabulum in both feline and canine pelvis, and poor results have been reported following conservative management of caudal acetabular fractures in dogs. Likewise, long-term evaluation following conservative management in cats with acetabular fractures revealed chronic hip pain and muscle atrophy in many cases. Various techniques and implants have been reported for stabilisation of acetabular fractures in dogs including dynamic compression plates, acetabular plates, mini-plates, reconstruction plates, reconstruction plates with plate luting and composite fixation using screws, wires and polymethylmethacrylate. Langley- Hobbs recently reported the successful treatment of four kittens with acetabular physeal fractures using screws and tension band wire, but to the author’s knowledge no other specific reports of acetabular fracture repair in cats exist in the veterinary literature. Femoral head and neck excision has been recommended for irreparable acetabular fractures where reconstruction of the articular surface is not possible; however this should be reserved as a salvage procedure. Fixation of fractures which cannot be accurately reconstructed may be attempted followed by total hip replacement as an alternative but viable approach.

Several reports published in the 1940s-1970s described the successful use of Kirschner-Ehmer splints for the stabilization of pelvic fractures. The author employs both internal and external skeletal fixation methodologies in his practice for pelvic fractures in both dogs and cats but would argue that there is a valid rationale for application of ESF in pelvic fracture management for feline patients especially and in some types of pelvic fracture configuration in dogs. The author has used external skeletal fixation to stabilise pelvic fractures in more than 200 dogs and cats. In cats, the techniques are sometimes more readily applied than in dogs due to relatively superficial pelvic bone prominences, less bulky muscle mass, ease of cage confinement for 4-6 weeks, and frequent presence of multi-component or comminuted fractures which either require extensive soft tissue dissection or are unreconstructable with internal fixation. Many canine pelvic fracture configurations can also benefit from less soft tissue dissection and realignment of pelvic segments provided by eternal constructs rather than attempting accurate reconstruction, but patient size, muscle mass and body-fat may be more problematic than in cats. Feline patients have “slender” pelvic bones with narrow medullary canals and premature loosening of internal implants has been a widely reported challenge. The threaded pins in external skeletal fixation constructs purchase well in limited pelvic bone stock and may be placed at divergent angles to provide both reduction levers and robust connecting elements for resilient support during bone healing, and may optimise the biologic environment for healing of comminuted fractures in cats. Pelvic fractures may proceed to union with less rigid stabilization than long bone fractures and restoration of adequate pelvic canal diameter is more important than precise anatomic reduction. The abundant pelvic musculature offers intrinsic mechanical support and an environment which promotes fracture union.

ESF configurations have been employed by the author to treat all configurations of pelvic fractures, including SI luxation, simple and comminuted ilial and acetabular fractures and displaced ischial fractures in both dogs and cats. Factors considered which determine pin placement for ESF of pelvic fractures include the location and configuration of fractures, anatomical restrictions with the intention of minimizing musculotendinous trauma, available bone stock to maximize pin purchase and ease of application for fracture segment alignment. Fixation pins must be placed through both sacro-iliac joints and in at least one ischial segment to prevent axial migration of bone segments or implant loosening. Connecting rods are placed such that appropriate clearance of the dorsum by the articulating rods of the frame is ensured whilst optimising stability. Concerns which have been expressed regarding the application of external skeletal fixation for the management of pelvic fractures including impingement of musculo-tendinous and neurovascular structures, pin loosening or infection and problems with patient compliance have largely been overcome. While frame configurations and pin application parameters in previous reports describing the use of external fixators for stabilizing pelvic fractures were less well defined, application of pins in the anatomic locations and at the angles described by the author has been associated with minimal post-operative morbidity in dogs and cats with pelvic fractures. Negative profile partially-threaded pins are used because these pins are easier to place through small skin incisions with limited dissection and palpation without pre-drilling in clinical cases. Negative profile partially-threaded fixation pins are also easier to place than positive profile partially-threaded pins in the narrow ischiatic table. No adverse sequale have been associated with use of negative profile pins.
An in vitro study by the author has demonstrated that external skeletal fixation constructs have biomechanical advantages by comparison with plate and screw fixation for stabilisation of ilial fractures in canine cadaver pelves. The ventromedial surface of the ilium is the tension surface and supplemental ventral plate fixation increases the stiffness of fixation of ilial fractures and osteotomies approximately two-fold by comparison with lateral plating alone. External fixation offers an alternative to the double plating technique. Studies comparing external fixation to plate and screw fixation in long bone models indicate that fixator placement on the compressive surface has comparable biomechanical characteristics to plates applied to the tension surface of the bone. The superior mechanical characteristics manifested by external fixator constructs for application to pelvic fractures may be attributable to dissipation of load by the triangulated frame and mitigation of stress concentration at the fracture typical of failure in plate-screw constructs.

In a case series of 131 feline pelvic fractures repaired using external skeletal fixation, external fixator frames were constructed using small KE components (Veterinary Instrumentation, Sheffield, UK) and 1.6mm diameter negative profile partially threaded pins (Veterinary Instrumentation, Sheffield, UK). All SI disruptions/fractures and ilial fractures were approached via a single dorsal midline incision and incisions over the tuber ilii bilaterally facilitated ilial pin placement. Pins can be used to manipulate the displaced ilial wing caudally to reduce SI luxation. The pin is partially driven into the sacral body at a cranio-caudal angle and then used as a lever to manipulate the ilial wing caudally prior to seating it within the sacral body. With the smooth portion of the pin now acting as a reduction guide, reduction of the sacroiliac luxation is completed by sliding the ilial wing along the pin by axially applied digital pressure over the ilial wings (Pin Anchor Slide Technique, PAST). This technique may pose a significantly decreased risk of neurological injury compared to screw placement. Axial compression applied with large reduction forceps or digital pressure during frame assembly provides adequate stability to prevent loss of reduction or pelvic canal narrowing.

Generally speaking sequential realignment of fracture segments was achieved by placing 2-3 pins per major bone segment on separate connecting rods and attaching adjacent segments with link rods (Pin Anchor Realignment Technique, PART). Pin location was divided into three regions; ilio-sacral, ilial (including the cranial acetabulum) and ischial (including the caudal acetabulum). Generally the ilio-sacral pins were placed first, followed by the ischial pins and finally the ilial pins. There was gradual evolution in frame design, however frame configurations were variations of one of two main frame constructs in each case. A unilateral foundation frame was expanded to constitute a triangular frame or a quadrilateral frame. The unilateral foundation frame consisted of one or two ilio-sacral pins and one or two ischial pins on the side of the injury. This required contralateral stabilisation in all cases. The basic triangular frame consisted of two or three pins placed cranial to the fracture (one or two ilio-sacral pins and one or two ilial pins), one or two pins caudal to the fracture (one or two ischial pins) and one or two ilio-sacral pins contralaterally. The basic quadrilateral frame constituted a triangular frame with an added contralateral ischial attachment with one or two pins. Additional ilial or ischial pins were added to these basic frames as determined by fracture configuration. The quadrilateral frame was used whenever bilateral injury to the weight bearing axis was present.

Follow-up radiography was evaluated for evidence of healing, implant failure as well as any progression of pelvic canal narrowing or loss of sacroiliac reduction. Fracture reduction was classified as anatomic (no vertical step and <1mm horizontal gap defect), near anatomic (<1mm vertical step and/or ≥1mm <2mm horizontal gap defect) or non-anatomic (≥1mm vertical step defect and/or ≥2mm horizontal gap defect) as previously described by Boswell et al. The sacral index (SaI) was used to objectively measure the degree of pelvic canal narrowing, defined as the ratio of the width of the sacrum at the cranial border to the width of the pelvic canal the narrowest point, measured between the medial cortices of the acetabular bones.

Clinical and radiographic measures of outcome, both short and long-term, revealed very satisfactory reconstruction and functional pain-free outcomes. For ilial fractures, 24 cases (36%) had anatomical reconstruction, 17 (26%) were near anatomical (19%) were good, four (6%) were fair and two (3%) were poor. Of 39 simple fractures, 22 (56%) were classified as anatomical, (13) 33% as near anatomical, and the remaining four cases (11%) classified as good. Of 16 mildly comminuted fractures, two (13%) were classified as anatomical, four (25%) as near anatomical, eight (50%) as good and two (13%) as fair. Of 11 highly comminuted fractures, seven cases (64%) had good reduction, two (13%) were fair and two (13%) were poor. For ilial fractures overall, there was no difference between the median pelvic canal diameter post-operatively (100%, range 64-114%) and at follow-up (96%, range 57-114%), (P=0.29). There was no difference between cases of comminuted or simple fractures post-operatively (100 and 100% P=0.26) or at follow-up (96 and 96% P=0.45). Overall, the median change in pelvic canal width from post-operatively to six week follow-up was 0% (mean 2% range 0 – 21%).

**Surgery Chapter**
For SI luxation cases, the mean degree of narrowing noted on follow-up radiographs was 5%, which is far less than the >45% value which has been suggested to pose a high risk of complications related to constipation. Even for acetabular fractures, anatomical or near anatomical reduction was achieved in 76% of cases and only highly comminuted fractures yielded suboptimal but still functional reconstruction. In only a single case was reduction classified as non-anatomical for fracture configurations which were not highly comminuted. In the majority of cases, overt step defects between major fracture fragments were infrequently seen and the majority of non-anatomical reconstructions were classified as such due to areas of comminution secondary to collapse of the medial acetabular wall. It is our clinical impression that if rigid support can be provided to the dorsal rim of the acetabulum and so long as significant step defects are not present between major bony segments, a functional fibro-osseous joint can result with satisfactory clinical outcomes. This was possible due to the case with which the fixation pins could be used to manipulate the main fracture segments into reduction. The ability to subsequently fix the fracture in appropriate alignment by tightening of the clamps distant from the fracture itself, without the need for reduction forces across the fracture is another distinct advantage of this technique.

Median lameness scores at frame removal were zero to 0.5 for SI luxation, ilial fractures and acetabular fractures. The mean VAS activity score as reported by owners was 96% for all cases grouped and a mean mobility score of 89 to 96 was achieved for acetabular and ilial fracture groups respectively, with even comminuted acetabular fractures yielding favourable clinical outcomes.

The potential for trauma to the frame is the major disadvantage of the external fixation technique and clients must be counselled accordingly. A previous report on the use of external fixation for the stabilisation of spinal fractures in dogs stated that complications associated with spinal external fixation were minimal and included mild pin tract inflammation and radiographic pin loosening. In comparison, the smaller muscle mass in feline patients and the short time that the frame is required to remain in situ (mean 44 days), should further allay the concern with regard to pin tract morbidity when applying external fixation to the feline pelvis.

The ESF technique allows pin placement with almost limitless versatility to accommodate the configuration of the fracture(s) being stabilised. When using plate fixation, screw placement and angulation is dictated to a certain degree by the position and shape of the holes in the plate, which may result in suboptimal screw placement, due to the proximity of fracture lines. The ESF technique also adheres to the AO paradigm of minimally invasive biological osteosynthesis, using dissection windows to palpate or achieve direct visibility of fracture sites. Transfixion pins are placed percutaneously once direct visibility of the fracture has been achieved, or in the case of simple fractures, via palpation of the fracture. This maintains more of the intrinsic stability provided by surrounding muscles and may result in reduced morbidity and an early return to function.

Concurrent stabilisation of multiple pelvic fractures using traditional internal fixation techniques also requires multiple surgical exposures to facilitate positioning of internal implants. The significant additional dissection required, particularly in cases with severe bilateral injuries, causes further disruption to the soft tissue envelope, decreasing the inherent stability afforded by the surrounding musculature and further increasing morbidity. Patients may occasionally require multiple surgical procedures or may need to be re-draped to repair multiple injuries, prolonging anaesthesia and increasing costs. The longest procedure noted in the current series of pelvic ESF was that of a comminuted acetabular fracture with involvement of the caudal ilium, bilateral SI luxation and contralateral ilial fracture, for which the surgical time was 92 minutes, and total anaesthetic time was 161 minutes.

In the absence of significant neurological dysfunction, a return to normal function can be expected following application of ESF for stabilisation of pelvic fractures in cats. The author submits therefore that judicious application of this technique in feline patients has merit and warrants consideration.
NEW HORIZONS -- FELINE COXOFEMORAL, STIFLE AND ELBOW JOINTS

Including notes for the lectures:

1. THE FELINE HIP – FROM MEDICAL MANAGEMENT TO SURGICAL SALVAGE AND BEYOND
2. ELBOW AND STIFLE DISEASE IN THE CAT – FROM DISRUPTION TO SALVATION AND EVERYTHING IN BETWEEN.

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DEGENERATIVE JOINT DISEASE – HIP, STIFLE, ELBOW

CLINICAL PERSPECTIVE

There may be many reasons for poor appreciation of the clinical significance of degenerative joint disease, including osteoarthritis, in the cat. A possible explanation might be that it is not clinically significant in the majority of animals and pathological changes do not lead to pain and difficulties in joint mobilization as observed in other species. However, it is much more likely that the clinical manifestations of the problem in cats are more difficult to identify. Cats are not subject to the wide range of juvenile joint dysplasia conditions that result in a high occurrence of secondary osteoarthritis in young pure breed dogs, making this a very common finding in this species. Mobility disorders are much more readily identified in dogs where the owner is characteristically present while the animal is exercising and able to recognize lameness or changes in activity pattern. The radiographic appearance of an osteoarthritic joint in the cat is much more subtle than the dog with less obvious proliferative osteophyte formation. This may result in the problem being overlooked or dismissed as clinically insignificant. Additionally, in the author’s experience, other clinical syndromes such as lumbosacral disease are commonly mistaken for hip or stifle arthrosis and vice-versa and as cats may be difficult to examine clinically, elucidation of actual diagnosis may be difficult.

RADIOGRAPHIC EVIDENCE OF DEGENERATIVE JOINT DISEASE

There have been a number of recent studies attempting to identify the incidence of radiographic degenerative joint disease in the cat population. Heightened awareness is conditioned by the increased longevity of the feline population in general and the recognition of the importance of chronic disease such as osteoarthritis.

Hardie and others (2002) retrospectively evaluated the radiographs of 100 cats over 12yrs of age on admission to the referral hospital. These cats had been referred for a variety of reasons but had all been subject to a radiographic evaluation. The average age of the study group was 15.2 years. Only 10 cases evaluated were judged to have no evidence of degenerative joint disease meaning that the study showed a 90% prevalence in this study group (Table 1). 64/100 cats had evidence of DJD of the appendicular skeleton (66%). In Hardie’s study there was no attempt to differentiate between types of degenerative joint disease, notably osteoarthritis.

Clarke and others (2005), in a similar retrospective study of a hospital population of cats made a differentiation between degenerative joint disease and its component diseases including spondylosis deformans and osteoarthritis. In this study of 291 cases an overall incidence of 34% for degenerative joint disease was described of which 16.5% were classified as osteoarthritis of joints in the appendicular skeleton (Table 1). The average age of this study group was 10yrs compared to the 15.2yrs in the Hardie study. The more conservative incidence may be due a younger population.

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This is supported by a further study by Godfrey (2005) which again retrospectively examined a test group of 491 cats. In this study, only appendicular osteoarthritis was investigated with an incidence of 22% described in the group (Table 1). The average age of this group was 10.8yrs. In each of these studies osteoarthritis was diagnosed on visual appreciation of periarticular osteophytes and in some cases subchondral sclerosis in synovial joints.

Summarizing the three studies (Table 1), incidence levels for DJD of 90% and 34% and for osteoarthritis, 66%, 22% and 16.5% were described representing a significant occurrence of disease in each of the population groups investigated. The main weight-bearing joints of the appendicular skeleton were most frequently affected by osteoarthritis with the elbow being the most commonly affected in 2 studies and the second most commonly affected joint in the third study which described the hip as the most common location. Axial DJD was described as most commonly affecting the thoracic spine (Clarke and others, 2005).
SIGNIFICANCE OF RADIOLOGICAL FINDINGS

The high incidence of radiographic DJD was not accompanied by a similar high level of clinical problems. Lameness, traditionally one of the most common manifestations of DJD in the appendicular skeleton was rarely described, only accounting for 4%, 16.7% and 17.5% of cases respectively in the three studies. Although it is accepted that there is poor correlation between the appearance and severity of radiographic changes and clinical signs, the low incidence of clinical problems recorded raises questions about the significance of the disease. Another explanation could be that mobility disorder is much more difficult to identify in the cat and that either signs were overlooked in the retrospective populations or that overt lameness is not one of the main manifestations of the disease in cats.

Clarke and Bennett (2006) conducted a prospective study on 28 cats with both radiographic evidence of osteoarthritis and a clinical problem with mobility to try and better characterize the clinical signs associated with the disease. The average age of this group was 11 yrs (3.2-16yrs). The elbow joint was most commonly affected (45%) with the hip the second most commonly affected joint (38%). 78% (22/28) of cases had bilaterally symmetrical disease with 7 of these cases having multiple bilateral sites. Clinically 43% were lame and 32% showed stiffness, two of the cardinal signs of mobility disorder. Interestingly the most frequent presenting signs described in this cohort were an unwillingness to jump (71%) and an observed reduced height of jump (32%). All of the cats were treated for 4 wks with a NSAID (Meloxicam) and the effect on the clinical pattern recorded. 61% of owners reported that their pet had made a marked improvement during the period of medication with statistically significant improvements in the ability to jump (P<0.001) and the height of jump (P<0.001) in particular. There were also improvements in other clinical signs recorded. This study demonstrated the difficulty in identifying clinical signs associated with the disease and emphasized the need for a very careful clinical examination and questioning of the owner to properly record these details.

CAUSES OF DJD IN THE CAT

The exact cause of the pathology in the cat is also a subject of interest as the majority of cats described had no evidence of primary joint damage. This has raised the possibility of osteoarthritis being a primary disease in many cats (Godfrey 2005; Clarke and Bennett 2006). Godfrey (2005) reported a primary incidence in only 11% of affected cats while Clarke and Bennett 2006, suggested that 71% of their cases were primary idiopathic OA. Related findings, particularly those of increasing incidence of the disease with age and high levels of bilaterally symmetrical disease (78% Clarke and Bennett 2006; 73% Godfrey 2005) are quoted in support of this theory.

Other causes of degenerative joint disease include congenital or developmental conditions (eg. hip dysplasia, patellar luxation), those of traumatic origin (eg. articular fractures, luxations, ligamentous insufficiency), infective causes, and immune-based polyarthropathies (eg. Rheumatoid arthritis, proliferative periosteal polyarthropathy).

TREATMENT AND EVALUATION OF TREATMENT EFFICACY

Any underlying cause for osteoarthritis should be considered and appropriately treated. Where no underlying cause can be elucidated, or where specific treatment fails to control clinical signs of disease, symptomatic treatment may be initiated.

Lascelles et al (2007) conducted a prospective study on 13 cats to evaluate the use of client-specific outcome measures (CSOM) and a collar-mounted activity monitor to detect pain in cats with osteoarthritis, and to assess the efficacy of treatment with meloxicam versus placebo treatment administered in a blinded, randomised, cross-over manner. All cats were older than 10 years, lived indoors, and had pain on manipulation of at least one joint with supportive radiographic evidence of osteoarthritis. All owners considered their cats to have impaired mobility or to have slowed down. CSOM questionnaires were tailored to each owner based on an initial discussion where they were prompted to define a series of place and time specific functions which they felt were impaired before beginning the trial (eg. “ability to jump up onto the bed last thing at night”, NOT “ability to jump”). Meloxicam and placebo medication were each administered for 3 weeks, with CSOM assessments and data download from activity monitors performed at 0, 1, 2 and 3 weeks for each. The cats had a median of 4 arthritic appendicular joints. Activity counts for the week when cats were administered meloxicam were significantly higher than at baseline (P = .02) but not after placebo (P = .06). Baseline activity counts were not significantly different from placebo (P = .6). The CSOM data showed that owners considered their cats to be more active on meloxicam compared with baseline (P = .001) and placebo (P < .004), and more active on placebo than at baseline (P < .01). Global quality of life questionnaire scores improved significantly with meloxicam (P < .042).
A previous study by Lascelles et al on 69 cats using subjective locomotor function scores (eg. weightbearing, lameness, pain on palpation) and general clinical parameters (eg. demeanour, appetite, food intake) confirmed similar efficacy between meloxicam suspension and ketoprofen tablets for treatment of locomotor disease. Significant side-effects were not observed, although duration of the course of medication was only 5 days. The meloxicam preparation was considered to be more palatable than the ketoprofen.

Carprofen, flunixin, robenacoxib and tolfenamic acid have also been shown to have efficacy as feline analgesics. However, there is a current paucity of data to support the safe chronic use of any NSAID in cats. Similarly, corticosteroid and opioid medications have been reported for chronic use as analgesics in feline osteoarthritis (Hardie 1997), but reliable data regarding their efficacy are lacking, and the high incidence of major side effects may preclude their use in this setting for most patients.

Various nutraceuticals, particularly preparations containing glucosamine and chondroitin sulphate (which may have synergistic properties) have known efficacy for amelioration of pain and clinical signs associated with osteoarthritis in several species including dogs (McCarthy 2007). Although specific efficacy data for their use in cats for this purpose have not been published, a wealth of clinician experience supports their long-term use as a safe alternative to reported prescription medications such as NSAIDs. Infrequent side-effects may include vomiting or diarrhoea although these commonly resolve by administering preparations with food, or by reducing dosage.

Rarely, combined symptomatic medications, nutraceuticals and adjuctive management techniques (body weight control, exercise limitation, physical therapies) may fail to provide adequate control of clinical signs of immobility or discomfort. Surgical salvage procedures may be considered in this circumstance. Examples include femoral head and neck excision, arthrodesis, and potentially total joint replacement.

References


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<table>
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OVERVIEW CONSIDERATIONS FOR REPAIR OF HIP, STIFLE AND ELBOW IN CATS

Failure of bone healing in feline patients has been poorly quantified, but is likely to be attributable to a combination of factors:

1. Small patent size means than blood vessels are small and relatively fragile, rendering them highly susceptible to traumatic injury and occlusion. Furthermore, collateral blood supply may be limited and close proximity of vessels may result in simultaneous injury.

2. Small bone size is associated with relatively thick cortical bone and a narrow medullary cavity. Osteogenic precursor cells from cancellous bone may therefore be limited at fracture sites with poor quality and size of fracture haematoma for initiation of secondary bone healing.

3. Despite small body weight, patient compliance with activity restriction guidelines poses a significant challenge, even with strict cage confinement. (Toileting habits of normally “outdoor” cats may also be challenging to manage during the confinement period, potentially resulting in urinary cystitis and/or constipation problems.)

4. Appropriate implant selection may be challenging, with a limited range of available implant sizes commercially available. This particularly applies to plate and screw fixations. 1.5mm and 2.0mm plates and screws would be considered applicable for most feline appendicular applications based on recommendations from canine (and human) bone fixation, but due to their relatively small cross-sectional area, they are exponentially less stiff and more susceptible to fatigue failure than equivalent implants of larger size. 2.7mm plates and screws may be used in many feline applications but their large size carries an increased risk of bone fissuring during application and the spacing of screw holes in these larger patients means that fixation of small bone fragments may be particularly challenging. The recent advent of 2.4mm implants will potentially prove very useful. While external fixation techniques may appear more readily applicable in small patients, their relative bulk and weight may introduce further difficulties in certain circumstances. Furthermore, the narrow limits of stress/strain tolerances of healing bone may be challenging to control where implant selection is dictated by bone / fragment dimensions rather than deliberate surgeon selection.

5. Soft tissue cover is limited, particularly over the distal limb in feline patients. Open fractures are common, and bulky internal implants are commonly associated with major soft tissue morbidity.

6. External coaptation may be highly challenging to maintain due to limb shape and conformation, high joint mobility, coat texture and patient compliance issues. Soft tissue morbidity remains a major issue with narrow tolerances for inappropriate pressure or friction, and potentially limited local vascularity in the region of injuries.
JOINT LUXATION -- HIP, STIFLE AND ELBOW IN CATS

Dislocations of the hip, stifle and elbow joints in cats are frequently surgical conditions. In a minority of cases, relocation of luxated elbow or hip joints and sling support plus cage rest may prove adequate for return to function, but surgery is often required and results in earlier functional recovery. Dislocations of the elbow may be addressed by primary ligamentous reconstruction with anchors and screws and synthetic suture or more recently Farrell proposed a technique using bone tunnels drilled in the distal humerus, proximal radius and proximal ulna and placement of nylon or other synthetic suture materials such as Fibretape™. Adjunctively or alternatively transarticular external skeletal fixation may be temporarily applied and subsequently removed.

For stifle luxation with multi-ligamentous disruption including the collateral ligaments, occasionally prosthetic sutures may be employed medially or laterally or both, between the fabellae and a bone tunnel in the tibial tuberosity or, more successfully in the author’s experience, between a condylar bone tunnel and a tibial tuberosity bone tunnel. However, balancing medial and lateral sutures without resulting in torsion or caudal tibial translation is a challenge. The author has successfully employed Fibretape™ TightRope™ suture material with metallic bone anchors. In cases where internal reconstruction is rendered ineffective due to multi-ligament disruption, temporary placement of a rigid transarticular external fixator may facilitate formation of robust periarticular fibrosis which may allow relatively normal ambulatory capability. The author has also used a transarticular pin anchored using a clamp system to a half pin in the proximal tibia. Hinged fixators are a useful adjunct when reintroduction of controlled motion is desirable.

When reconstruction attempts fail or when severe articular trauma has occurred, stifle arthrodesis has offered hope of limb salvage and in the author’s experience can provide very satisfactory outcome in terms of pain-free function, tough mechanical lameness remains. Both dorsal and medial plates have been employed by the author with the latter technique offering easier positioning of appropriate angulation and more optimal soft tissue cover. Total knee replacement is also now a reality for feline patients and has been developed by the author and co-workers. The device has been custom-designed from CT scans, but is potentially a universal “off-the-shelf” device. Early experiences are promising but much modeling work and clinical application modification is required before widespread application can be recommended.

Cranial cruciate ligament rupture occurs relatively commonly in cats. Conventionally cage rest was recommended and healing relied on formation of periarticular fibrosis, which often results in adequate ambulatory capability, though outcome is frequently sub-optimal in the author’s experience. Synthetic augmentation may be applicable using fabellotibial tuberosity nylon prostheses, synthetic suture and conventional bone anchors or more recent techniques such as bone tunnels and Fibretape™ Tightrope™ to try to attain isometry of ligament origin and insertion. Tibial tuberosity advancement and tibial plateau leveling osteotomy have also been performed by the author when treating cases recalcitrant to conventional repair techniques.

Coxofemoral luxations are common in cats. In the author’s experience closed reduction often fails. A simple peri-trochanteric purse-string suture may facilitate maintenance of reduction, but transarticular pin placement is more commonly adopted with satisfactory outcomes. However, this does require later pin removal and results temporarily in non-anatomic coxofemoral motion until pin removal is possible. The TightRope™ Fibrewire™ device can also be employed to stabilize hip luxations in cats and in the author’s experience results in rapid remobilization and resilient repair. When coxofemoral luxation accompanies pelvic fractures, the author has experienced success using a “toggle pin” technique whereby a swivel unit is subtended from a pelvic external skeletal fixation apparatus to maintain coxofemoral congruity.
FRACTURES -- HIP, STIFLE AND ELBOW IN CATS

Elbow fractures in cats are less commonly presented in the author’s facility than canine elbow fractures with published data suggesting that humeral fractures generally represent 4.4% of all fractures in cats. Most are in the mid-shaft region (87%), approximately 70% of which are comminuted. Where fractures are simple, they are typically oblique or spiral in configuration and follow the “musculo-spiral groove” toward the supracondylar region. A range of fixation techniques are reported and selection largely depends on precise fracture configuration and availability of bone stock for implant placement. Presence of the supracondylar foramen which contains the radial nerve makes repair more challenging, not least because in most cats it renders introduction of an intramedullary pin into the medial epicondyle impossible. Where possible in this region, pin diameter has been reported as being limited to 1.6mm maximum. If the pin tip is left in the proximal supracondylar region, it has been suggested that up to 2.4mm pin diameter can be applied. However, additional fixation is always required to provide rotational and often compressional stability which may be compromised by inclusion of a large intramedullary device. Intramedullary nails up to 5mm in diameter have been reported but require specialist skills and inventory and may be inappropriate for many fracture configurations. Cerclage wire is seldom appropriate for common fracture configurations and since the humerus tends to taper toward the supracondylar region (and has the closely constrained radial nerve), wire placement is challenging to maintain safely.

Plate and screw fixation is commonly applicable although contouring to match the three-dimensional shape of the humerus may be challenging except for the most cranio-lateral portion, while the proximity of neurovascular structures, close association with musculature and variable fracture configuration distally makes surgical approach challenging. External fixation with or without a tied-in intramedullary pin may be applicable to the majority of fractures and hybrid circular/arch systems may optimize limited distal bone stock by allowing placement of fine wires or half-pins in the region of the humeral condyle. A significant proportion of other fractures involve the humeral condyle with the lateral condyle most commonly affected. Simple lateral or medial condylar fractures may be stabilized by transcondylar screw and antirotational epicondylar implant placement. An alternative to standard compression screw placement is the titanium Acutrak screw. Benefits include cannulation which increases reliability of placement within the relatively narrow humeral condyle and its headless design which minimizes soft tissue irritation and eliminates the risk of splitting small bone fragments during countersinking. The variably-pitched, tapered design means that the screw is self-compressing, while allowing for purchase in new bone for each rotation during insertion.

Y, T and comminuted elbow fracture configurations may necessitate either complex screw and double plate application or advanced external fixation techniques with circular or hybrid components and olive/stopper wire fixation to achieve intercondylar compression.

Radius and ulna fractures are also common with wide variation in location and configuration although comminuted fractures appear overrepresented. It is rare for radial fractures to occur so far proximally as to compromise the elbow joint, but fractures of the ulnar notch and olecranon are more common. Anatomic reconstruction is essential and “drift” of the fracture interface during implant application can easily occur and careful attention is required in this regard. An intramedullary pin and tension band may be adequate or a compression plate with a hook fashioned from one of the plate holes over the olecranon may be applied for extra purchase in small olecranon segments. Plate and screw fixation (usually 2.0mm) is most commonly applied for more distal fractures of the radius and ulna. In many cases the feline ulna is sufficiently large to permit meaningful implant placement including plate and screw fixation proximally or intramedullary pin placement throughout. Although initial stabilization is seldom a major challenge, bone healing should not be assumed and there may be concerns regarding blood supply and soft tissue envelope.

Application of bone graft or biologic augmentation agents may be beneficial, particularly in more geriatric patients or where fracture configuration is anticipated to delay healing. The proximal humeri may provide small amounts of good quality graft, particularly in younger patients, but for more substantial quantities of autogenous graft material or in older patients, cortico-cancellous bone from the iliac crest may be harvested and morcellised. Freeze dried allograft feline bone chips (Veterinary Transplant Services®, Kent, WA) may be highly advantageous in this circumstance, and are worthy of consideration in all circumstances where graft is required, including arthrodesis in cats. Elbow arthrodesis is a consideration for unreconstructable articular trauma in cats but indications are rare and it is worth mentioning that salvage joint replacement is now a reality including trabecular metal mesh reattachment of ligament avulsion, but again indications are rare and experience limited at this point.
Fractures of the stifle in cats are not common and are usually the result of vehicular trauma and can be grossly comminuted. Small juxta-articular fragments may render reconstruction very challenging, but often achievable with small fragment plates and screws. Transarticular external skeletal fixation may assist healing by providing added temporary stabilization. Proximal tibial fractures are also challenging and may be comminuted. While external fixation, particularly circular hybrid fixation may be applicable for many fractures and does optimize implant purchase in limited bone stock, durability may be insufficient in some cases and bulky or heavy frame constructs in this location may hinder normal ambulation. Also, healing is prolonged necessitating long duration of frame application. The author has experienced most consistent results with a double-plate technique involving application of 2.0 mm cuttable plates both medially and cranially, allowing multiple screw placement even in very proximal bone segments and excellent multi-planar stability. Stifle arthrodesis and stifle replacement are salvage options as for profound fracture-dislocations.

Patellar fractures are rare and are usually associated with direct trauma. In some cats, bipartite patellae may be observed as an incidental finding and may be mistaken for fractures on initial radiographic examination. Transverse fractures of the patella are most common. Surgical stabilization is indicated either where the common tendon of the quadriceps apparatus (in which the patella is embedded) is disrupted, or where the patellar articular surface is disrupted. Fixation is generally achieved using a skewer wire and tension band technique, although in some circumstances, removal of a minor fragment may be adequate to provide acceptable joint function provided the quadriceps apparatus is undisrupted. Bone tunnels and synthetic suture placement may also be employed. Patellar fractures generally do not heal with radiographically evident bridging osseous union in cats and at best heal with a functional fibrous union. Many distract at the fracture site, but fibrous tissue maintains the pulley-effect of the patella and patellar tendon. Patellar fracture repair can be frustrating and may fail; it should always be supported and in this regard application of a transarticular static or hinged frame may be appropriate. Rupture of the straight patellar tendon can be repaired using bone tunnels and synthetic non-absorbable suture, potentially augmented with autograft or allograft and may also require transarticular support to facilitate healing. Quadriceps contracture which may occur for more chronic rupture cases can be addressed using distraction fixator arrangements before re-attaching the straight patellar tendon to the proximal tibia.

Acetabular fractures are common in cats and there is a paucity of reports regarding management in the veterinary literature. While conservative management may be a viable option for ambulatory, non-painful cats, with isolated, non displaced fractures of the caudal acetabulum, such cases are rare and surgical stabilization is inevitably required to achieve a satisfactory outcome.

Cadaver studies have shown that weight bearing forces are transmitted across the entire radius of the acetabulum in both feline and canine pelves, and poor results have been reported following conservative management of caudal acetabular fractures in dogs. Likewise, long-term evaluation following conservative management in cats with acetabular fractures revealed chronic hip pain and muscle atrophy in many cases.

Various techniques and implants have been reported for stabilization of acetabular fractures in dogs including dynamic compression plates, acetabular plates, mini-plates, reconstruction plates, reconstruction plates with plate luting and composite fixation using screws/wires/polyethylmethacrylate. Langley- Hobbs recently reported the successful treatment of four kittens with acetabular physeal fractures using screws and tension band wire, but to the author’s knowledge no other specific reports of acetabular fracture repair in cats exist in the veterinary literature. Locking plate technology, particularly the 2 mm string-of-pearls SOP™ plate which can be contoured in any direction and provides good bone anchorage even where paucity of bone stock is evident, may offer salient advantages for accurate reconstruction of feline pelvic fractures.

The author has successfully employed external skeletal fixation in a large case series of simple and comminuted acetabular fractures in cats. Using various pin and connecting rod configurations, anatomical or near anatomical reduction was achieved in 76% of cases and only highly comminuted fractures yielded suboptimal but still functional reconstruction. In only a single case was reduction classified as non-anatomical for fracture configurations which were not highly comminuted. In the majority of cases, overt step defects between major fracture fragments were infrequently seen and the majority of non-anatomical reconstructions were classified as such due to areas of comminution secondary to collapse of the medial acetabular wall. It is our clinical impression that if rigid support can be provided to the dorsal rim of the acetabulum and so long as significant step defects are not present between major bony segments, a functional fibro-osseous joint can result with satisfactory clinical outcomes. This was possible due to the ease with which the fixation pins could be used to manipulate the main fracture segments into reduction. The ability to subsequently fix the fracture in appropriate alignment by tightening of the clamps distant from the fracture itself, without the need for reduction forceps across the fracture is another distinct advantage of this technique.

Femoral head and neck excision has been recommended for irreparable acetabular fractures where reconstruction of the articular surface is not possible, however this should be reserved as a salvage procedure. Acetabular fracture malunion and end-stage OA can also be successfully treated with total hip replacement in cats. The author has had considerable success with
the technique and has evolved technique modifications to apply for commonly encountered challenges in this regard – including paucity of dorsal acetabular bone stock and revision of femoral head and neck excision to total hip arthroplasty where FHNE has garnered a suboptimal outcome in terms of persistence of pain and lameness. THR is now commonly performed on cats and small dogs in the author’s facility.
Metatarsal and metacarpal injuries account for 8.1% and 3.3% of fractures in dogs and cats respectively. Various management techniques are reported (including plates, screws, pins, wires, dowel pins, and external fixation devices) but selection guidelines, pre-operative planning and validated outcome measures are lacking. Restriction of physical exercise or external coaptation may be adequate for minimally displaced and solitary metacarpal or metatarsal injuries, particularly of digits 2 and 5, but in the majority of clinical circumstances, surgical intervention is indicated.

A novel, inexpensive ESF (Secured Pin Intradendular Dorsal Epoxy Resin, SPIDER) frame has been designed for stabilization of metacarpal and metatarsal fractures and subsequently adapted to allow for management of metacarpo- or metatarso-phalangeal luxations and for tarsometatarsal arthrodesis. Anatomical landmarks were established and techniques for pin placement to optimize biologic fixation principles elucidated. SPIDER technique has been developed sufficiently robust to avoid requirement for post-operative external coaptation, which has been a significant cause of morbidity. Lack of requirement for coaptation also facilitates management of concomitant soft tissue injuries which are common with fractures and luxations in this location. Implant removal is straightforward and can be performed under sedation without an additional sterile surgical procedure.

Surgical technique entails a single midline dorsal incision directly over the site of fracture or luxation. Where arthrodesis is required (e.g. of a tarso-metatarsal joint), articular cartilage should be removed and autogenous cancellous bone graft applied. K-wires (50%-75% medullary diameter) are directed retrograde through the fractures or luxations to exit the metatarsal or metacarpal bones at the dorsal aspects of the distal articular surfaces. Fractures or luxations are then manually reduced and the k-wires driven proximally into the proximal metacarpal or metatarsal bones (and through the tarso-metatarsal joints where arthrodesis at this level is indicated). One or two K-wires are then placed transversely across the bases of the metatarsal/metacarpal bones or distal row of tarsal bones nad calcaneal base where required for arthrodesis. All exposed pin ends are finally bent dorsally such that they converge over the dorsal aspect of the limb. The surgical site can be closed routinely prior to application of epoxy resin which is compressed over the ends of the K-wires (additional contouring of the k-wires at this site may improve stability of the epoxy resin bolus). Wooden spatulas (to a thickness of 4-10mm) are placed between the epoxy resin bolus and the patient skin surface to avoid thermal injury during resin curing, and to allow for postoperative swelling. Fluid lavage during resin curing reduces potential thermal conduction to the patient along the k-wires.

Cage confinement or equivalent is routinely enforced for 4-6 weeks depending on predicted rate of healing (based on injury and patient factors). Frame removal can be performed upon documentation of radiographic union. Clinical and radiographic records of 13 dogs and 20 cats treated in the author’s clinic by SPIDER application for distal limb injuries have recently been retrospectively reviewed including collation of clinical, surgical and radiographic data. Clinical and radiographic re-evaluation, and owner VAS function questionnaires were performed one year post-operatively (where available - 16/33 patients)

Our findings are reported below:

- Age ranged 2-140 months (mean 29.5 months dogs, 56.6 months cats)
- Weight ranged 2.0-6.4kg (cats), and 2.1-17.5kg (dogs).
- Injuries included
  - metatarsal fractures (3 dogs, 6 cats),
  - metacarpal fractures (7 dogs, 3 cats),
  - tarsometatarsal luxation (2 dogs, 10 cats) and
  - phalangeal luxation (1 dog, 3 cats).
- Based on injury configuration, intramedullary pins were placed in
  - 2 metatarsi/metacarpi in 1 dog, 5 cats
  - 3 metatarsi/metacarpi in 5 dogs, 1 cat
  - all 4 metatarsi/metacarpi in 7 dogs, 14 cats
- Functional limb use occurred by 5 days for all cases
- Frame removal occurred at mean 43.8 days (range 27-72) for cats, 34.1 days (range 13-59) for dogs
- Radiographic union was complete for all fractures.
Major complications included tarsal synostosis (1 puppy aged 3 months), valgus deformity (1 dog) and metatarsal deformity (2 cats).

- Pin tract discharge was graded as mild where present and in all cases resolved following implant removal.
- Radiography 12 months post-operatively (2 dogs, 8 cats) did not reveal osteophytosis or swelling of the metacarpophalangeal or metatarsophalangeal joints.
- Only 1/16 patients exhibited mild lameness one year post-operatively.
- Client perception of success was high for 16/16 patients.

Elevated time to frame removal within our case series was associated with type of injury (particularly multiple comminuted fractures and tarso-metatarsal luxation) and high patient age. Variation in body weight was not associated with complication incidence within this series. Twelve month post-operative evaluation in general did not reveal radiographic progression of osteoarthritis of metatarso/metacarpo-phalangeal joints or clinical discomfort.

In our hands, SPIDER has been shown to provide reliable and durable stabilization for all injury types described and has been quicker and simpler to perform than conventional techniques, particularly where multiple fractures or luxations are present and in extremely proximal or distal metacarpal or metatarsal fractures where bone stock is limited. External coaptation is unnecessary with proper application of the technique and carries significant benefits for patient, owner and surgeon. Technical adaptation to allow for tarso-metatarsal, metatarso-phalangeal and metacarpo-phalangeal arthrodesis was straightforward and was achieved without additional complication. Tarso-metatarsal arthrodesis was achieved by minimal surgical approach without additional talo-central or calcaneo-quartal arthrodesis as necessitated by internal fixation techniques, thus maximizing biologic potential. SPIDER was equally successfully applied in both juvenile and mature patients and surgical approach required has been minimal, consistent with biologic fixation principles. SPIDER technique is worthy of consideration across a range of distal limb injuries.
Arthroscopy is the preferred modality for investigation and treatment of the problematic elbow due to its minimally invasive nature, direct visualisation of the entire elbow joint, superior diagnostic ability and functional recovery from surgery (Meyer-Lindenberg et al VCOT 2003; Hoezler et al, Vet Surg 2004). It is arguably the gold standard in the assessment of elbow dysplasia.

The most common indication for elbow arthroscopy is in the management of elbow dysplasia, in particular medial compartment disease (fragmented coronoid process, humeral condylar lesions and staging / treatment of medial cartilage disease. Other indications include assessment and management of ununited anconeal process, incomplete ossification of the humeral condyle, assessment of incongruency (Wagner et al Vet Surg 2007; Werner et al VCOT 2009) and associated problems, fracture management, septic arthritis (Fearnside and Preston, AVJ 2002) , osteoarthritis (Vermote et al, VCOT 2010) and biopsies.

Although there are few comparative papers documenting superior outcomes with different treatment methods in the management of elbow disease, (Meyer-Lindenberg et al, VCOT 2003; Evans et al VCOT 2008), intuitively and from the human experience arthroscopic assisted surgery would seem to be the preferred method where possible compared with that of arthrotomy. It is my personal opinion that there is no indication for arthrotomy in the management of elbow dysplasia

Arthroscopy has a steep learning curve predominantly due to spatial orientation and triangulation between the arthroscope and instruments. The elbow is the easiest joint to master and is the preferred joint on which to learn the principles of arthroscopy.

Surgical approaches

The caudomedial approach is the preferred and most commonly used arthroscope portal (Van Ryssen AJVR 1993) although other approaches e.g. craniolateral (Bardet VCOT 1997, cranial (Bardet VCOT 1997) and caudal (Bardet VCOT 2000) have been described

The safety of the caudomedial approach has recently been evaluated in an anatomical cadaver study (Jardel et al VCOT 2010). Conclusions were minimal trauma to muscular, neurological and cartilage with egress, arthroscope and instrument portals. This is in contrast to arthrotomy where partial collateral ligament incision is often required to effect appropriate visualisation of the medial coronoid process.

Instrumentation

A 2.4 or 2.7mm arthroscope is generally recommended for the elbow. Selection of scope size is based on the diameter of the arthroscopy cannula since it too must enter the joint. For example, most arthroscope sheaths for a 2.7mm arthroscope have an arthroscope sheath that has a 3.8mm outer diameter. In smaller elbows a 2.4 mm scope is usually recommended (3.2mm cannula) to minimise cartilage damage on insertion. The advantages of the larger diameter arthroscope are the greater field of view and depth of view; the disadvantage is the greater likelihood of creating iatrogenic damage during insertion and during the procedure.

A 30 degree fore-oblique scope is recommended as the best compromise between ease of use and field of view. Zero and forty-five degree scopes are available but are not generally recommended. The working length of each scope varies but one with a shorter working length (8-15 cm) is easier to use and is less prone to scope damage.

Each arthroscope cannula can be fitted with a blunt or a sharp obturator with the blunt trocar generally preferred.

An assortment of arthroscopic hand instruments and a simple surgical kit are all that is necessary for elbow arthroscopy. Various hand instruments are available for intraarticular use that include probes, grasping forceps, biopsy forceps, and instruments for surface arthroplasty (hand held burrs, curettes, micropicks and a motorised shaver). Instruments can be inserted into the joint through an open instrument port, instrument cannulae, or a combination of the two. If one chooses to work through an instrument cannula, different size cannulae and ‘switching sticks’ are necessary. Intra-articular haemorrhage is not a major issue during elbow arthroscopy as with other joints e.g. stifle but various methods of intra-articular diathermy are...
Appropriate and controllable fluid flow is necessary in all arthroscopic procedures. Fluids can be given by gravity alone in large joints but preference is for a pressurised system (pressure bag or pump). Pressure is the key variable to be able to control in elbow arthroscopy (60-80mm Hg) with a relatively low flow (approximately 20%) to avoid sudden surges of fluid.

**Preparation and patient positioning**

The patient is clipped for a medial approach to the elbows, aseptically prepared and positioned in either lateral or dorsal recumbency, depending on surgeon preference. In general lateral recumbency for a single elbow and dorsal recumbency for bilateral procedures is recommended.

The limb is positioned such that the elbow joint can be centered over the edge of the table with a sandbag under the lateral aspect of the elbow to act as a fulcrum to open up the medial and caudomedial joint lines.

Self-retaining braces have been described but are not required for successful elbow arthroscopy (Schulz et al Vet Surg 2004)

The patient is draped routinely with the limb draped in or out of the surgical field, depending on preference and desired maneuverability. The monitor is positioned opposite the surgeon so a direct image can be visualized without having to constantly turn to look at the monitor.

**Anatomy**

**Portal sites and technique**

The number of portal sites established is two (egress, arthroscope) or three (egress, arthroscope, instrument) depending upon the purpose of arthroscopic intervention. If joint exploration is all that is required, an egress portal and an arthroscope portal are necessary. If tissue biopsy or if treatment of joint pathology are necessary then an additional instrument portal is required.

Accurate placement of the egress, arthroscope and instrument portals are essential. The egress portal is established first, followed by the arthroscope portal and lastly the instrument portal. The egress portal is established by inserting a 19 gauge 1 ½ inch needle between the medial epicondylar ridge and the most proximal ridge of the anconeal process. Once the needle is in place, joint fluid is aspirated to assure proper positioning of the needle within the joint. Lactated ringers solution (saline not recommended due to an increased risk of cartilage damage) is instilled through the needle to distend the joint. As the joint distends a small bulge at the caudomedial joint line can be appreciated in approximately the same line as the egress needle. A second needle is used to determine the correct position of the arthroscope portal through this bulge. This needle is inserted at approximately 30 degrees from perpendicular to the joint line. It is important to place this arthroscope portal as caudal as possible in the joint line (usually approximately 1cm distal and 0.5- 1cm caudal to the medial epicondyle) to provide the best angle from which to view the more cranial structures of the medial joint compartment. The more caudal approach eliminates the need for an assistant to place a valgus stress across the elbow for portal establishment.

Once the joint is entered, fluid will flow from the needle confirming proper placement in the joint. Use a number 11 Bard-Parker blade to make a small entry wound through the skin, superficial soft tissues and a small incision in the joint capsule. Although extravasation of some joint fluid can occur by penetrating the joint it rarely causes problems (cf. shoulder) as the volume is small and the arthroscope portal is immediately established. Remove the needle and insert the arthroscope cannula with the attached blunt obturator. The angle of entry is the same as with the guide needle, approximately 30 degrees from perpendicular proximally. Once in the joint, remove the obturator from the cannula. Fluid will flow freely from the cannula confirming correct placement. Attach the fluid ingress line to the arthroscope cannula and insert the arthroscope. Connect the light source and white balance where possible.

If treatment of joint pathology (FCP, OCD) or biopsy of intra-articular structures is required an instrument portal is established. To establish the instrument portal use a guide needle. Position the arthroscope facing towards and viewing the medial coronoid process. Insert a 19 gauge 1 ½ inch needle at the estimated position for the instrument portal. The needle is inserted at a slightly proximal to perpendicular angle such that it enters the joint at the 10 o’clock or 2 o’clock position for right and left elbows respectively. Do not attempt to further establish the instrument portal until you are confident with the needle position in the joint.

_Surgery Chapter_
The most common reason for not seeing the needle as it enters the joint is crossing the needle beneath the scope. This is caused by either inserting the needle to close to the arthroscope portal or attempting to ‘triangulate’ the needle toward the arthroscope. The needle is not angled (triangulated) toward the tip of the scope, but rather it is inserted at the correct location perpendicular or slightly off perpendicular to the skin surface.

Once the position of the instrument portal is confirmed by the tri-angulation needle, a 3mm incision is made through the skin and superficial soft tissues. If the surgeon wishes to work through an open instrument portal, the incision is lengthened (4-6mm) and carried into the joint. If the surgeon wishes to work through an instrument cannula, the appropriate cannula and obturator is inserted into the joint.

It is important to maintain joint access once established and although not so important in the elbow, loss of access to other joints, e.g. shoulder and hock can be problematic in reestablishing access once lost. The use of switching sticks is therefore essential in maintaining joint access.

Surgical anatomy

Maintaining spatial orientation is critical in successful arthroscopy. This is achieved by maintaining the scope in as close to as perpendicular a position to the joint and the maintaining the camera in a position such that the proximal aspect of the joint is always at the top of the screen. The light post is rotated around the arthroscope utilising the oblique angle of the arthroscope to maximise visualisation.

The joint is systematically inspected from a caudal to cranial location (anconeal process, trochlear ridge, lateral coronoid process and recess, radial head, medial coronoid and adjacent trochlear ridge, humeral condyle, annular ligament and medial collateral ligament.

References
Medial coronoid process disease (MCD) is a common expression of canine elbow dysplasia (CED) that is characterized by a combination of visible cartilage pathology and fragmentation of the underlying subchondral bone. Traditionally MCD was thought to involve discreet fragmentation of the axial and apical aspects of the medial coronoid process (MCP). Open arthrotomy and arthroscopic visualization of the medial coronoid process in clinically affected dogs has revealed a spectrum of pathology that includes cartilage fissures, fragmentation, chondromalacia-like lesions and ‘kissing’ lesions on the medial side of the humeral condyle\textsuperscript{1-3}. All of these lesions have been associated with varying degrees of synovitis and arthrosis. In a large MCD case series of 263 dogs (332 affected joints), 11% had concomitant OCD of the humeral trochlea\textsuperscript{2}. In another case series of 137 dogs (155 joints) with ununited anconeal process (UAP), 16% had concomitant medial coronoid fragmentation\textsuperscript{4}.

Arthroscopy allows improved visualization of all intra-articular pathology in CED patients, more accurate removal of osteochondral fragments and minimizes the potential for iatrogenic joint damage when compared to medial arthrotomy\textsuperscript{5}. Meta-analysis comparison of arthroscopic treatment to medial arthrotomy and medical management demonstrated arthroscopic superiority\textsuperscript{6}. The removal of axial and apical fragments of the promontory of the medial coronoid process has traditionally been the surgical standard of care for MCD\textsuperscript{7,8}. Clinical recovery following removal of coronoid fragments have been variable with many dogs having an apparent improvement in their gait and decreased degree of joint pain. Unfortunately, there is no evidence that supports that removal of displaced fragments in MCD patients slows or stops the ongoing development of elbow osteoarthritis\textsuperscript{2,8-10}.

Further investigation into the degree and extent of medial coronoid pathology has established that accumulation of subchondral fatigue microdamage in the trabecular bone of the medial coronoid process is important in the pathogenesis of MCD. The widespread fatigue microcracks and diffuse microdamage of the subchondral trabecular bone is not isolated to the radial incisure but often extends to the entire cranial portion of the coronoid process\textsuperscript{13}. That finding has stimulated the further development and clinical use of sub-total coronoidectomy via both open arthrotomy\textsuperscript{11,12} and arthroscopic-assisted procedures\textsuperscript{14}. Although early clinical results are promising\textsuperscript{12} long term studies documenting an advantage over medical therapy or coronoid fragment removal alone are still outstanding. Although arthroscopy is often touted as being a lower morbidity procedure compared with arthrotomy, research in normal dogs using a 2.7mm scope for arthroscopic elbow examination did not show any appreciable difference in post-operative kinetic gait assessment, subjective evaluation scores, and cubital joint range-of-motion between the two procedure types\textsuperscript{15}.

Arthroscopic evaluation and debridement of intra-articular elbow pathology is normally performed through a medial arthroscope portal established with the patient in dorsal recumbency and the surgical limb abducted and extended from the body. Techniques that have been employed to maintain the limb in an ideal position for the duration of the procedure include placing a custom padded block under the lateral aspect of the elbow as a fulcrum to allow maximum medial compartment laxity and use of a commercially available positioning arm\textsuperscript{16}. A 2.3 mm arthroscope (1.9 mm in small dogs) is recommended to minimize iatrogenic joint trauma. Arthroscopic subtotal coronoidectomy is performed with a caudo-medial scope portal and a cranio-medial instrument portal. Following joint examination, documentation and limited synovial debridement adjacent to the instrument portal, a custom 18cm, 2mm or 5mm osteotome (Gordon osteotome, Veterinary Instrumentation, UK & Jorgensen Laboratories, USA) is introduced into the joint and visualized. The proposed osteotomy line is decided, commonly commencing in the mid-coronoid abaxially and running axially to meet the radius at the coronoid incisure. The position of this osteotomy and the size of the osteotomized portion of the medial coronoid can be varied according to pre-surgical CT imaging of subchondral bone density (hypoattenuation of the coronoid process), the delineation of articular cartilage damage and the apparent softness of the subchondral bone matrix during osteotomy passage. Following completion of the osteotomy, the cleaved bone and residual articular cartilage of the process is removed through a combination of rongeur debridement, fine curettage and suction.

Post-operative care includes immediate icing of the surgical site, placement of a soft-support dressing for 48-72 hours to limit swelling and discomfort, analgesic and anti-inflammatory medication for 10 days and gentle ROM exercises. Patients are pen or crate rested with leash-held supervision when not confined for three-to-six weeks post-surgery with a gradual increase in exercise duration and intensity over a further six to ten weeks. The concurrent performance of a distal ulnar osteotomy\textsuperscript{14} in juvenile dogs (<12 months) or sliding humeral osteotomy\textsuperscript{17} in patients with moderate to severe medial compartment disease and a relatively healthy lateral compartment, will alter post-operative management to optimise healing of those procedures.
References

The benefits of animal physiotherapy are now well recognised in the management of canine elbow dysplasia. Many veterinary referral clinics in Australia now employ an animal physiotherapist as part of their team, to help provide multimodal treatment to their patients. Patients with elbow dysplasia referred for physiotherapy can generally be divided into two broad categories: those that have had recent surgery and those with degenerative joint disease that are being managed conservatively. For both patients groups, the aims of physiotherapy treatment are identical: reduce pain, improve mobility and function and restore quality of life to the animal. Treatments selected for each patient are individualised and determined by factors such as onset if clinical signs, time since surgery, extent of degenerative joint disease, degree and history of lameness , muscle atrophy, joint range of motion, comorbidities, current and past exercise level, and home environment. All physiotherapy programs should be administered as part of a team approach to the management of the patient. Adequate medical management of pain, swelling and inflammation is required to enable physiotherapy programs to be completed effectively.

**POST OPERATIVE PATIENTS**

Postoperatively, all patients will have some soft tissue swelling, inflammation and haemarthrosis from the trauma of surgery or arthroscopy. These result in pain, reduced joint ROM and weight bearing. Pain and swelling in affected joints cause reflex muscle inhibition\(^1\). Even once pain has subsided, reflex muscle inhibition continues without specific retraining \(^2\). This results in difficulty strengthening affected muscles and slow return to function. Physiotherapy has been shown to reduce pain, swelling and inflammation and speed recovery in animal patients following joint surgery \(^3\). Various treatments that can be of benefit are discussed below.

**Cryotherapy:** Application of cryotherapy should commence the day of surgery and continue for at least the first 48 hours. Cryotherapy post joint surgery has been associated with significantly lower postoperative pain \(^4,5\), and improved weight bearing \(^5\). Cryotherapy is an effective anti-inflammatory and has been shown to decrease time to recovery by 30% to 60% when used within the first few days of injury or surgery \(^6\). Using repeated, rather than continuous, ice applications of 10 minutes on / off helps sustain reduced muscle temperature without compromising the skin and allows the superficial skin temperature to return to normal while deeper muscle temperature remains low \(^7\). After the initial 48 hours owners can continue cryotherapy for 10-15 minutes, 3 times per day for the first week after surgery. Cryotherapy may be provided using standard ice packs, ice massage, or with icing pumps that circulate continual iced water around the joint within a cuff such, as the ‘Breg Polar Care’ \(^8\).

**Passive ROM:** This can commence day 1 post surgery. Owners are shown how to perform gentle passive flexion and extension of the elbow within the animal’s available pain free range. Repetitions will depend on the patient’s tolerance: 10-20 reps, 3 times a day is recommended as a starting point. As pain and inflammation decreases, joint range of motion can be increased with the aim of restoring normal range of motion and improving joint dynamics.

**Massage:** This can commence 48 hours after surgery. At this stage gentle massage to the periscapular muscles and elbow flexors can assist with muscle relaxation, helping to lower the limb to the ground. Massage is performed well away from any incisions until it they are fully healed. After this time, scar massage can commence if adhesions appear to be limiting motion. Massage is particularly beneficial performed prior to ROM exercise.

**Heat:** After the first 48 hours, heat can be used to assist relaxation of tight and taut musculature or excessive muscle guarding as well as to reduce joint stiffness. Heat and ice contrast can also be used after the first 48 hours, alternating 10 minutes for each modality to assist with circulation, reduction of swelling and pain relief.

**Early controlled weight bearing:** can reduce reflex muscle inhibition and prevention of muscle atrophy. Using the above modalities in conjunction with adequate pain medication can allow the patient to begin early weight bearing \(^5\). This can be
encouraged from day 1 post surgery. The animal must be walked very slowly, on leash, for very short sessions – up to 5 minutes at a time, several times per day. Lameness must be monitored the animal rested if weight bearing deteriorates across the session or day.

**Therapeutic exercise:** Patients should be discharged with a home program of progressive gentle strengthening exercises, appropriate for their lameness and healing time. These should be regularly reviewed and updated as the patient progresses. This can commence with exercises such as weight shifting to the affected limb, and progress to short repeated lift of the ipsilateral hind limb, or contralateral front limb. Progression can continue to walking over cavaletti poles, down ramps and stairs if applicable, only if the patient is improving.

**Home walking program:** Progression of a walking program depends on the degree of lameness and muscle atrophy. An safe guide is to increase daily walking by no more than 5 minutes per week. Increasing too quickly can result in muscle fatigue or an increase in pain, leading to persistent lameness and dysfunction.

**Underwater treadmill:** Is extremely beneficial for strengthening. The load is reduced by up to 60% when immersed to the level of the greater trochanter. Animals can walk with less lameness, using correct movement patterning, allowing normal muscle activation to occur. Increased elbow flexion occurs when walking through water compared to that on land assisting with restoration of normal joint motion. Walking through the resistance of the water with exercise speed and intensity precisely controlled contributes to accelerated strengthening. Treatment using an underwater treadmill is recommended two-three times a week.

**Swimming:** is a great form of exercise with no loading. However as it is an endurance exercise, muscle hypertrophy is clinically slower compared to underwater treadmill therapy. Because some dogs have a vigorous thoracic limb swimming style, occasionally patients with elbow conditions can become more painful and inflamed with swimming, therefore close monitoring is required.

**Home exercise and lifestyle education:** Activity that causes impact to the thoracic limbs should be avoided certainly until lameness has subsided and ideally long term. This includes jumping down from the car, couch or bed, repeated decent of stairs, ball chasing, running in the sand and rough play with other dogs. Building ramps over stairs or using a ramp for the car can be helpful. The activity level appropriate for each patient will vary. As each post surgical patient progresses back through walking, trotting and running off leash, recovery after each exercise session will help determine what the ‘safe’ activity level is for each patient and help guide further exercise. Use of supportive, firm bedding is necessary. Hammock style beds should be avoided as they offer little support to joints. Slippery surfaces need to be avoided with non slip mats placed down in the house or non slip booties applied.

**DJD PATIENTS**

Essentially the management of this patient group is similar. Physiotherapy treatments required will be based on assessment findings and will vary depending on whether the patient is in an acute inflammatory and painful stage at present or in a more chronic, stable state. The aims of treatment are to assist in the reduction of pain and inflammation, to grow muscle to support the degenerated joint/s, to educate the owner about avoidance of aggravating exercise – particularly those that place excessive load on the thoracic limbs, and provide a therapeutic exercise program that is best completed in small doses several times per day. For mild - moderate cases, physiotherapy treatment including a boost of strengthening exercises and underwater treadmill for 6-12 weeks can improve mobility and reduce lameness. These patients can then be placed onto a long term maintenance program, and reviewed every 4-6 months. These patients should also be regularly reviewed by their vet to ensure adequate pain relief and discuss the use of disease modifying agents.

Home modifications are equally as important here and supportive bedding is particularly appropriate. For those dogs that won’t sleep on a bed, using padded support over the elbows such as ‘standard adjustable dog legs’, can be extremely helpful as well as providing warmth to the joints, which in turn can reduce stiffness and discomfort.


**Acupuncture:** can be beneficial in the treatment of joints with and is used widely in people. Physiotherapists that use acupuncture as part of the management of their patients must be qualified in the use of acupuncture.

**Bracing options:** For patients with DJD of the elbow that are not suitable for surgery, another option to assist in pain reduction and enable continued mobility is to fit a custom made brace or orthosis from Orthopets. In humans, custom braces are now commonly used to provide pain relief and prolong mobility in patients waiting for joint replacement surgery, or those with mild symptoms who wish to continue to participate in sport without flare ups. With an orthosis, support is provided to the musculoskeletal system by controlling one or multiple planes of motion within an affected joint. This enables an orthosis to gain control over medial/lateral, rotational and cranial/caudal movement in the joint. The luxury of a custom Orthosis is that you can allow or restrict motion within any plane of motion that you wish. In the elbow joint, a medial compartment with DJD can be unloaded to provide relief from pain and slow progression of degeneration. If extremes of flexion or extension are painful then a limited motion hinge can be placed in the orthosis to ‘block’ these painful ranges. If there is specific weakness of flexor or extensor muscle groups a special hinge can be placed to ‘assist’ the desired motion. Braces are not a solution to elbow DJD but can prolong mobility in patients that have exhausted all their treatment options, or in those that are still very active but become more painful following this activity. Physiotherapy and medical management is still vital in the management of these patients and with reduced pain, muscle strength can be increased and pain medication can be reduced in some patients.

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INTRODUCTION
Ununited anconeal process (UAP) is one of a group of diseases known as elbow dysplasia. However, unlike the other diseases of this group, it occurs most frequently in the German Shepherd Dog. Published evidence would suggest that the disease is associated with delayed growth of the ulna causing increased tension within the elbow joint (Sjostrom et al. 1995). The anconeal process develops as a separate centre of ossification in affected breeds and it should fuse to the proximal ulna by 18 weeks of age; persistence of a radiolucent line between the anconeus and the olecranon, beyond 18 weeks is suggestive of ununited anconeal process. The realisation that a short ulna contributes to the disease has significantly changed the surgical approach to this condition.

Dogs with UAP usually present between 5 and 6 months of age. Although German Shepherd Dogs are most commonly affected, the Bassett Hound and a variety of medium-large breed dogs may suffer this condition. Unilateral thoracic limb lameness with pain on full extension of the joint are typical findings; joint effusion may be prominent.

TREATMENT
Traditional treatment for this condition has been removal of the ununited anconeus. However, this destabilizes the joint and tends to result in progressive osteoarthritis (Roy et al. 1994) and poor function. Fixation of the anconeal process is also reported using lag screws (Fox et al. 1996) or screw plus pin (Meyer-Lindenbeg et al. 2001). Results seem satisfactory but fixation alone can result in implant failure.

Ulna osteotomy has also been advocated as a logical extrapolation of the data on aetiopathogenesis (Sjostrom et al. 1995). Ulna osteotomy alone can result in spontaneous fusion of the anconeus (Sjostrom et al. 1995; Turner et al. 1998) although it appears that the technique is more successful in younger dogs. Ulna osteotomy combined with fixation has been proposed as a technique that may give more predictable results.

A recent study (Pettitt et al. 2009) aimed to determine if internal fixation (IF) of the anconeus combined with a proximal ulnar osteotomy (PUO) was more likely to result in fusion of the anconeus to the ulna compared to a PUO alone. Twelve orthopaedic referral clinics reviewed their clinical databases for cases of ununited anconeal process (UAP). Demographic and clinical parameters were collected along with radiographic follow-up at a minimum of four weeks. Cases treated with PUO alone were compared to those treated with PUO + IF. Both groups were compared for background and disease variables. The authors tested for an association between treatment method and whether radiographic anconeal union had occurred.

A total of 54 cases were identified and, of these, 32 cases (average age 7.6 months) were treated with PUO (of which 8 were stabilised with an intramedullary pin) alone and radiographic outcome data were available for 28. Twenty-two cases (average age 7.1 months) were treated with PUO + IF and radiographic follow-up was available for 19. The two groups were not significantly different in age.

Fourteen of 28 cases with PUO alone displayed anconeal union at follow-up compared with 16 of 19 cases of PUO+IF and this difference was statistically significant (p=0.029, Fisher’s exact test). There was a significant association between frequency of radiographic union and treatment method, in favour of PUO + IF and the estimated odds ratio was 5.333 (95% CI: 1.265 – 22.485). Considering PUO alone as the “standard of care”, the number needed to treat estimate (+/- 95% CI) for PUO+IF was 3 (+/-1.43). The proximal ulna osteotomy failed to radiographically unite in two cases (one from each treatment group) within the 16 week follow-up period.

These data suggest that use of a lag screw to stabilise and compress the ununited anconeal process in addition to PUO produces a better radiographic outcome. One might argue that radiographic union of the anconeus is likely to be associated with better long-term clinical outcome but further studies are required to confirm this.

REFERENCES
Elbow dysplasia is a major cause of front limb lameness in dogs and a number of projects have been initiated – some realised – addressing the issue by a joint replacement. Most notably, TATE, a cementless, total elbow prosthesis has been developed and recently introduced to clinical use by Biomedtrix in collaboration with Dr. Randall Acker.

Kyon, in collaboration with Dr. Kirk Wendelburg, is developing a modular elbow replacement, conceived as primarily medial compartment prosthesis, but then extended to allow for a total, unconstrained replacement, if needed. Until now, there has not been a clinical case operated, but the development is in the final stages and the prosthesis is considered close to being ready for implantation.

Medial surgical approach spares the co-lateral ligaments by an osteotomy of the medial epicondyle from the caudal direction. To allow for precise cutting and reaming the limb is fixed to a baseboard with external fixation pins – the procedure allows for locating and then referencing off the sagittal plane of the elbow – this is a critical issue if only the medial humero-ulnar part of the joint is to be replaced in relative congruency to the rest of the joint. A cylindrical cannulated reamer is used over a guide pin to ream out the medial aspect of the ulna and the corresponding part of the humerus. The surgical procedure to prepare the joint for implantation is thus limited to two steps of bone preparation – osteotomy of the epicondyle, which forms the lid for the prosthesis, and reaming of the cylindrical cavity engaging both the humerus and the ulna, held in their functional, articulating position.

The implant consist of a central post (c.p. titanium, surface coated at articulation to the poly ring) attached to the humerus and a half-ring-shaped ulnar component (also c.p. titanium, surface coated at articulation to the poly ring) attached to the ulna by two screws. In deviation from customary arrangement, the central post carries an UHMWPE ring, which forms the convex articulating member of the joint. This allows for a robust, simple poly part, snap fit over the post. It may articulate against either the cylindrical post or the conical ulnar half-ring component, approximating the natural shape of the ulnar medial surface. The central post is fixed by a screw passing through the center of the post into the lateral epicondyle; the medial epicondyle, covers the prosthesis and is fixed by another, smaller screw, screwed into the lateral screw. Medial epicondyle is additionally fixed to the distal humerus by a locking plate.

Mechanical testing of the implants in cadavers is planned for this summer, and, if satisfying, is expected to be followed by first clinical cases by the fall.
ELBOW REPLACEMENT IN DOGS – AUSTRALIAN EXPERIENCE
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Historically there has been a paucity of successful treatment options for advanced elbow osteoarthritis in dogs. Currently most dogs are managed conservatively with exercise moderation, weight control, strategic use of NSAIDs and long-term chondroprotective agents. Elbow arthrodesis has been reported in twelve dogs with fair to poor clinical results. There have been unreported attempts at developing a system for total elbow replacement in the past (Vasseur, Lewis). More recently the BioMedtrix corporation has developed two commercially available systems that have been used clinically worldwide in selected centers.

The first commercially available system to become available for academic and private surgeons was called the IOWA State prosthesis. Dr Michael Conzemius from the University of Iowa published a series of Veterinary Surgery manuscripts documenting the ability of this system to return normal dogs back to near normal limb loading as assessed by force-plate gait analysis as well as showing 80% of clinical cases do well (20 dogs). The procedure involves a lateral approach with avulsion of the distal insertion of the lateral collateral ligament and aggressive bone resection of the central region of the humeral condyle whilst preserving the medial and lateral epicondyles. A stemmed metal humeral component is cemented in place. The plastic (UHMWPE) radioulnar component has two flexible pegs that are cemented to the medullary cavities of the radius and ulna following resection of their articular surfaces. A tissue anchor placed between the proximal radial and ulnar diaphyses is used to reattach the collateral ligament distally. The implants are categorized as unconstrained whereby joint stability is provided by intact collateral ligaments.

Total elbow replacement started in Melbourne in 2006 with the IOWA State University prosthesis. Initially a workshop was conducted and six patients received cemented metal-on-plastic prostheses under the direct instruction of Dr. Michael Conzemius who had developed the system in conjunction with the BioMedtrix corporation. Subsequently, another six patients were managed with TER over the next few years. Deep wound infections (5), lateral instability (2) and periprosthetic fractures (two medial humeral epicondyle, one ulna) developed and two dogs required elbow arthrodesis. Two dogs were euthanized.

Dr. Randy Acker from Idaho developed a semi-constrained cementless system which can be implanted with less bone removal. The implants have metal-backed porous coated surfaces that encourage osseointegration. A medial epicondylar osteotomy is performed to preserve the MCL and gain adequate exposure to the joint. A patented milling technique is used to remove an arc of bone to a predetermined depth. The humeral and radioulnar components are inserted articulated. The epicondyle is replaced and secured using bone screws.

10 TATE systems have been implanted in Australia (8 Melbourne, 2 Sydney). There have been no instabilities, periprosthetic fractures or infections and all dogs have clinically improved. Subjectively the clinical improvement is more protracted than that following hip replacement surgery and can take several months. Two patients have received bilateral TERs.

The indications for TER surgery have not been clearly defined. Sliding humeral osteotomy has also become available to treat refractory medial compartment disease where the lateral humeroradial articulation appears to be normal. Maybe the moderate OA elbows with partial cartilage loss (medial compartment disease) will be best managed with SHO whereas the severely affected joints will be best managed with TER. Future studies should focus on objective gait analysis following cementless TER. I believe orthopaedists will embrace this new cementless system if large scale reports document repeatably high success with few complications.

Reference
OVERVIEW OF ALGORITHM FOR MANAGEMENT OF ANTEBRACHIAL GROWTH DEFORMITY IN DOGS.
INCLUDING THE DAPPER FRAME AND DOME OSTEOTOMY
Noel Fitzpatrick, DUniv MVB CertSAO CertVR MRCVS
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ETIOPATHOGENESIS
Deformities of the canine antebrachium may occur for a number of reasons and may affect the radius or ulna or both bones. Premature closure of the distal ulnar physis accounts for approximately 75% of deformities, generally perceived to be genetic in origin in predisposed (often chondrodystrophic) breeds, but can often occur following trauma because of the intrinsic susceptibility of the distal ulnar physis to asymmetrical crushing injury imparted by its conical profile and high relative growth rate. Other possibilities include partial or complete premature closure of the distal or proximal radial physis, heritable or genetic disorders (e.g. ectrodactyly), endocrine disorders (e.g. congenital hypothyroidism, pituitary dwarfism), drug reactions (e.g. fluoroquinolones), metabolic or nutritional disorders (e.g. rickets) and other miscellaneous skeletal abnormalities (e.g. synostosis or malunion secondary to fracture or osteotomy, retained cartilaginous cores, hypertrophic or metaphyseal osteopathy, subchondral bone cysts).

In many cases, by the time deformity has developed, the underlying cause cannot be definitively identified or has been overshadowed by secondary changes (e.g. secondary physeal closure), but care should be taken to exclude causes that may require ongoing treatment or affect long-term prognosis such as nutritional or endocrine disorders.

DEFORMITY COMPONENTS
Components of antebrachial growth deformities (ABGD) may be highly complex, largely attributable to the two-bone system of the radius and ulna, including their complex three-dimensional relationship (with the ulna spiralling from caudo-proximal to latero-distal in the normal dog), and biomechanical interaction which includes formation of the elbow articulation, affording stability to the carpus, and attachment via the interosseous and annular ligaments. Such complexity is seldom encountered with the more easily quantified deformities of the tibia and fibula, likely attributable to the relative biomechanical dominance of the tibia.

Deformities may be categorized by the following components:
- Cranio-caudal (radius curvus)
- Medio-lateral (valgus / varus)
- Rotational deformity about the long axis of the antebrachium
- Translation between the elbow and carpal joints

The specific components of osseous deformity may depend largely on the underlying etiopathogenesis, including the complete or partial (and symmetrical) nature of physeal closure, the proximo-distal orientation of major etiopathogenic effect, and age of onset (particularly with reference to strength of surrounding soft-tissues and potential for compensatory growth).

Secondary effects of deformity may include joint incongruity or dysplasia (including humero-ulnar or humero-radial subluxation), carpal deviation and progressive soft-tissue laxity, pain and osteoarthritis of surrounding joints (including of the manus if foot placement is affected).

Many dogs are affected by multiple deformity components, at least at the time of diagnosis, and may have some degree of compensatory change (either osseous or soft tissue).
DEFORMITY CORRECTION
Where deformities are limited to single entities without complex directional change of bone growth, they may be addressed relatively simply, whilst other more complex deformities may require specific configurations of osteotomy and fixation systems.

One of the key interventional elements of some of these techniques is a novel bi-oblique dynamic proximal ulnar osteotomy (BOD-PUO) which has been suggested by the author. The cut is made in the proximal ulnar diaphysis distal enough to the H-R joint to control excessive movement of the proximal ulnar segment via soft-tissue attachments, but proximal enough to facilitate motion of the proximal ulna under pull of the triceps attachment without producing a non-union. The cut is generally 3-6cm distal to the H-U joint, depending on breed, and the saw blade is held parallel with the caudal cortex of the proximal ulna/olecranon (not the distal ulna) and as tightly against the caudal ulnar margin as possible, such that the cut trajectory is long and very oblique – usually 20-40 degrees in both the caudo-proximal to cranio-distal and the proximo-lateral to disto-medial trajectories.

SINGLE-COMPONENT DEFORMITIES

1 Humero-radial incongruity (HRI):
Where this is the only deformity due to disruption of radial physeal growth but there is no angular component to deformity and the ulna is unaffected, the following surgical options may be employed.

A Ulnar shortening performed via PUO: We do not recommend this for HRI > 4-5mm. Ulnar ostectomy can be performed, but is not recommended without pin stabilization proximally and if performed distally may not allow adequate correction.

B Radial distraction osteotomy can be performed transversely or obliquely.
(i) Oblique osteotomy with transarticular distraction is recommended for HRI 4-10mm, depending on patient size, such that the proximal and distal segments stay in contact during lengthening. Distraction in these cases is performed using either wires in the distal humerus and proximal radius tensioned bilaterally using linear fixator components, sprung wires subtended from a proximal ulnar hybrid frame or transverse pins in the humerus, radial head and proximal ulna attached bilaterally using anchors and elastic bands.

(ii) Transverse osteotomy with distraction osteogenesis is recommended for HRI greater than approximately 8mm, depending on patient size, using a standard circular/wire frame.

2 Humero-radial incongruity (HRI) with a short antebrachium:
Transverse proximal diaphyseal radial osteotomy and oblique proximal diaphyseal ulnar osteotomy (at different levels to prevent synostosis) with distraction osteogenesis is recommended using circular/wire frame components. The HRI is corrected first using a two-part circular frame, the bottom portion of which is connected via a rigid linear component to the Olecranon and proximal ulna. When HRI has been addressed, the linear proximal ulnar component is detached from the distal circular frame component and anchored to the proximal circular component. Distraction then continues to facilitate antebrachial lengthening.

3 Humero-ulnar incongruity (HUI) and Ulnar notch incongruity:
The BOD-PUO described, in the author’s experience, can allow motion of the proximal ulna in transverse, sagittal and torsional planes and may address humero-ulnar conflict from several potential etiologies.

4 Premature closure of distal ulnar physes before development of functionally significant radial deformity:
Aggressive distal ulnar osteotomy with removal of periosteum is indicated, especially in young large-breed dogs with a propensity for rapid re-growth which may require repeat osteotomy. Owners should be pre-warned in this regard. Ancillary fixation is unnecessary.

Surgery Chapter
5 Radial Head Luxation:
Relocation of radial head luxation in juvenile patients where bone plasticity may facilitate appropriate remodelling to reconstruct a functional articular surface may be beneficial compared with non-surgical management or radial head excision arthroplasty. This can be achieved by application of various techniques, but the author advocates progressive relocation over a period of days-to-weeks, allowing the bone to remodel prior to full load-bearing. Traction may be applied to the radial head using olive (stopper) wires attached to an external fixation arch component which is driven in the direction of intended translation (disto-medially) by linear motors mounted off a rigid arch-pin frame on the proximo-caudal ulna. Use of an oblique “sliding” radial osteotomy may help retain appropriate osseous contact and callus distraction during translation (callotasis). The technique affords significant control of radial head position by comparison with ostectomy techniques for radial head relocation.

It is also of note that most complex ABGD configurations observed by the author have some degree of radial head subluxation as an integral component of the deformity and that this may significantly contribute to the degree of torsion observed, which can be more related to elbow subluxation in the authors opinion than actual radial torsion as measured on CT scan. This is under-reported in the veterinary literature due to inability to appreciate or measure this phenomenon on standard projectional radiography in the author’s opinion.

COMPLEX DEFORMITIES

Planning
Various methods of pre-surgical planning for the correction of ABGD in dogs have been described and are aimed at identifying and quantifying the components of deformity present. All published veterinary reports to date use the anatomic axis of the radius and a range of landmarks or other axes in order to radiographically identify the point(s) of maximum deformity, and much is derivative of the extensive and seminal published works of Dror Paley MD FRCSC with regard to the human pelvic limb.

The centre of rotation of angulation (CORA) technique has been described for measurement of antebrachial deformities in canine patients (Fox et al, 2006) and represents perhaps the most complete radiographic measurement technique available. The axis around which the bone segments, after an osteotomy, are rotated is called the angulation correction axis (ACA). When the osteotomy and the ACA pass through the CORA, realignment occurs without translation. When the ACA passes through the CORA but the osteotomy is at a different level, the axis will realign with angulation and translation at the osteotomy site. When the osteotomy and the ACA are at a different level from that of the CORA, a translational deformity will result (secondary translation).

While highly reproducible in one-bone models (such as the femur) or in limited two-bone models (such as tibia/fibula), CORA technique has several potential weaknesses when applied to clinical canine ABGD:

1. Joint incongruence or dysplasia (particularly of the elbow) may be a common finding, making measurement of joint angles based on articular landmarks challenging. Deformities are commonly located immediately adjacent to joint surfaces (particularly with physeal injuries), necessitating accurate identification of articular landmarks to localise deformities.
2. Some reported techniques are focussed on identification of radial deformity alone, based on the assumption that ulnar deformities are of lesser clinical significance.
3. Where rotation exists (as it does in almost every case seen in our clinical practice), and particularly when subsequently surgically addressed, there are two major effects:
   a. Magnitude of rotation cannot be accurately identified radiographically.
   b. All measurements of angular and translational deformity are also inevitably (and unpredictably) skewed due to the abnormal spatial relationship of standard landmarks.
4. Radiographic measures are only applicable to assess osseous and static deformities. Dynamic carpal or other soft tissue laxity (common with rotational and varus/valgus deformity) cannot be radiographically evaluated but may be an important factor when considering surgical intervention.
5. CORA methodology identifies changes compared with what might be considered “normal” limb conformation. Unilateral deformities allow comparison with the contralateral limb as a reference, but in many patients, deformity may be bilateral. Furthermore, many affected dogs are of small or chondrodystrophic breeds which may not confirm to reference ranges established for dolichocephalic breeds.
6. Care must be taken to evaluate all bones in the affected limb (particularly the humerus with reference to ABGD) to examine the possibility of compensatory changes, especially with regard to the humeral condylar transverse axis, which might affect the outcome of subsequent surgical management.
Independent segmental orthogonal radiographs of the proximal and distal radius and the use the CORA methodology after conceptual juxtaposition has been described (Dismukes et al, 2008). However, this may be a more speculative rather than accurate method of measuring the magnitude and point of the deformity, and may be challenging in the face of multi-apical deformities.

Computed Tomography (CT) has been reported to assist with preoperative planning (Dismukes et al, 2008) of complex ABGD of the dog, and is considered the gold standard for measurement of rotational deformity in human limbs. Though the technique has obvious advantages, the necessary facilities are not yet available to the majority of veterinary health providers worldwide. Furthermore, although methodology is such that rotation can be accurately estimated in the presence of known frontal or sagittal plane deformity (Meola et al, 2008) using a reconstruction technique, further evaluation of this technique in clinical cases and commonly-affected breeds is warranted.

It is worth remembering that planning need only be as accurate as can be reliably achieved at surgical intervention. Any intra-operative changes to a single component of the proposed “plan” as determined from pre-operative imaging will affect all other components. For example, if rotational deformity is corrected based on visual intra-operative measures, or if an osteotomy is performed proximal or distal to the planned location, all planned measurements for correction of sagittal or frontal plane alignment become invalid.

Stereolithographic prototyping from CT images has been reported (Dismukes et al, 2008) and holds significant advantage regarding pre-operative planning, surgical rehearsal and teaching, but is not widely available, may be financially prohibitive and may fail to provide information regarding soft tissue contributions to limb alignment and function.

In humans, use of “hands-on” measurements, including use of a torsiometer have been shown to be as reliable as CT measures for assessment of tibial torsion (Sestan et al, 2008). The author submits that physical assessment of limb conformation including manipulation of carpal and elbow joints through a full range of movement to assess their rotational relationship and soft tissue contributions to overall limb alignment should be considered equally if not more important than measurements of limb conformation attained from diagnostic imaging. This functional mechanical joint axis realignment technique with appropriate internal or external fixation has been successfully employed by the author in a large case series.

**Aims of surgical intervention**

Major aims of surgical intervention should include restoration of elbow congruity and limitation of progression of elbow and carpal laxity and osteoarthritis. Correction of varus / valgus and rotational anomaly are considered most important in this regard, with management of radius curvus or translational deformity being of lesser significance, although significant translational deformity may result in ectopic joint-loading. The overall goal is to establish the optimal functional limb axis and permit pain-free limb use.

Secondary aims include preservation of cortical alignment to allow bone healing, prevention of further deformity and correction of limb length disparity.

**Treatment options**

In cases where function is minimally compromised and long-term progression of osteoarthritis is expected to be limited, conservative management or appropriately oriented trans-physeal bridging to re-direct and harness residual growth may be justified. Cosmesis alone is never a justifiable reason for intervention and breed conformational differences must be accommodated when considering surgical intervention. Surgical intervention is only ever justified in the opinion of the author if the deformity results in dysfunction impairing quality of life.

Simple transverse, oblique, closing wedge, opening wedge, stairstep, complex wedges and dome osteotomies have been described for the correction of canine antebrachial deformities. Type of osteotomy selected will be dependent on the type of correction required. For simple derotational osteotomies, a transverse osteotomy is ideal. For more complex corrections, opening and closing wedges may be used, but dome osteotomies or oblique osteotomies may be preferable for maintenance of contact of the osteotomized ends to facilitate bone healing. Osteotomies termed “dome” to date have generally involved the use of an arcuate blade which allows motion in one plane primarily, with only limited capacity for ancillary directional orientation. True dome osteotomy is now a reality and clinical application by the author has yielded encouraging results.
Antebrachial shortening may prompt requirement for significant limb lengthening by distraction osteogenesis and may necessitate use of complex external skeletal fixation configurations with different frame units performing different functions at various levels of the antebrachium.

A range of stabilization techniques are available:

1. Internal plate and screw fixation is feasible but can only be performed where acute correction is possible. Plate contouring can be challenging where rotational corrections are performed due to the ellipsoid cross-sectional shape of the radius which creates a step when rotated, and fixation may be challenging where correction very close to the carpus or elbow is required or where implants must be placed through particularly narrow bone dimensions. Generally segments are temporarily stabilized using k-wire fixation before plate and screw application. Maintenance of precise reduction during application of the plate and screws may also be challenging, particularly in smaller patients where placement of temporary interfragmentary pins may be challenging.

2. Locking plate fixation is particularly useful in this application, allowing limited numbers of small diameter screws to provide rigid fixation and avoid soft tissue structures such as the extensor tendons when small juxta-articular segments are anchored. Low-profile implants are recommended.

3. Linear external skeletal fixation (LESF) has been reported for management of antebrachial deformities. Application is typically limited to acute corrections or limited progressive distraction osteogenesis scenarios. Advantages over plate and screw fixation include elimination of requirement for plate contouring and ability to stabilize small bone fragments where corrective osteotomy is performed close to a joint surface. It is significant that Type II medio-lateral or Type III LESF frames are typically considered to be required to afford adequate stability for osteotomy healing, particularly for less stable osteotomy configurations. There is distinct disadvantage to placement of full-pins in the radius, attributable to the ellipsoid shape, both with regard to pin insertion at the most convex surface of the bone, and with regard to potential for fracture through pin tracts. Inter-osseous arterial haemorrhage may be an additional consideration. The author does not recommend this fixation modality due to lack of versatility and availability of superior options.

4. Circular external skeletal fixation (CESF) systems encompass the advantages of LESF regarding stabilization of small or irregularly-shaped bone segments but also allow progressive correction of angular deformities and distraction osteogenesis if required. Biomechanically, axial micromotion afforded may be beneficial for promotion of osseous healing. The major disadvantages are the requirement for specialized instrumentation and skills, bulk of the apparatus required (particularly for multi-apical deformities in small breed dogs requiring progressive correction), potentially prolonged surgical time and requirement for precise and technically demanding pre-operative planning and execution.

5. Hybrid external skeletal fixation (HESF) systems potentially combine the advantages of both LESF and CESF. They are most applicable for acute corrections but can be modified to allow for distraction osteogenesis or progressive corrections if required. Fixation of small fragments with freedom of pin placement in multiple planes is facilitated while frame bulk is generally less than that employed for CESF. Limited axial micromotion is possible dependent on frame design. Application and planning generally require less technical skill and accuracy compared with CESF systems, as there is typically greater potential for post-operative frame adjustment. Linear - Hybrid frame constructs have been reported, using a full ring distally with Type 1A, 1B or 2 linear components proximo-medially and/or proximo-laterally. (Sereda et al, 2009) and can be successfully applied with relatively simple technical application. However, moderate accuracy of distal wire placement and osteotomy location are still required for successful application.

6. A Double Arch Pin Poly-directional External Realignment (DAPPER) frame has recently been evaluated and successfully applied in dogs by the author. The advantages of simplified pre-operative planning, technical application and reduced surgical time are optimized, while retaining versatility of fixation including of small bone segments. Acute correction is necessitated, but manipulation in six degrees of freedom is straightforward, allowing for simultaneous correction of rotational and angular deformity without compromise of stability or fixation. Post-operative manipulation is facilitated. The configuration can be converted via linear motors to a distraction frame where necessary. The author has successfully employed the DAPPER technique using conventional osteotomies at the apex of deformity as defined by CORA methodology and more recently using a novel spherical osteotomy blade, which may allow greater versatility of manipulation of osseous segments. (Abstracts 1 and 2)

A major limitation of all listed management modalities is that they are all directed toward osseous correction. The role of soft tissues in antebrachial deformity cannot be underestimated. Joint laxity, particularly of the carpus may be central to achieving positive clinical outcome, and may require “overcorrection” of valgus osseous deformity to achieve optimal functional limb axis. Occasionally pancarpal arthrodesis is a necessary adjunctive surgery to ensure pain-free limb use. Restrainer on osseous correction intrinsic to antebrachial muscles and tendons, particularly during limb-lengthening procedures and attempts to address profound radius curvus, is a further limitation, and may preclude complete correction in some cases. Recognition of this pre-operatively is essential when employing techniques where intra- or post-operative modification is not straight-forward.
SUMMARY
Identification and management of antebrachial growth deformities in small animals are challenging due to the two-bone model and complex interaction of the radius and ulna, particularly at the elbow joint. Conventional planning techniques developed for application in one-bone or limited two-bone models may have significant weaknesses and should be applied with caution. Management of various deformity components should be carefully prioritized. Failure to correct all components of deformity may still be compatible with functional pain-free outcome and may significantly simplify methodology while reducing financial cost and potential morbidity. Various surgical techniques are available, but use of arch-pin frame configurations or locking plates in conjunction with true spherical dome osteotomies may offer attractive versatility in many circumstances and constitutes the current preference of the author when addressing complex antebrachial deformities.
ABSTRACT 1
Clinical Comparison of Linear-Arch and Double-Arch Pin Fixator constructs for Acute realignment of Antebrachial growth deformity in dogs

INTRODUCTION
Surgical intervention for antebrachial growth disturbance addresses components of frontal, sagittal, rotational and translational deformity. The surgical goals are establishment of functional limb axis and avoidance of elbow and carpal pathology resulting from deformity. Oblique, cuneiform, stair-step and dome osteotomies have been described with internal or external fixation systems. Internal fixation systems require preoperative planning and are limited for correction of rotational deformity. External fixation systems described include linear frames, circular frames with wire fixation and hybrid frames with circular wire and linear pin components. This case series reports the use of linear pin and arch pin component frames or frames with two arch components to acutely address deformity and normalise functional axes.

MATERIALS AND METHODS
Fifteen antebrachii (11 dogs) were operated for growth disturbance. Dogs with significant limb length discrepancy were excluded from the study. All patients were operated in sternal recumbency. Acute realignment of the radial segments was referenced from the transverse plane of the humero-radial joint for frontal, sagittal, rotational and translational components. In all cases a single transverse osteotomy was performed at the apex of deformity of the distal radius, with an ulnar osteotomy. Nine limbs were corrected using 1/3 ring arches and linear frame components and six limbs with two 1/3 ring arch frame components (Linear-Arch-Pin-Frame, LAFP and Double-Arch-Pin-Frame, DAPF respectively). Pin bone fixation was employed for all cases with a minimum of three pins per frame component. Attachment of divergent pins to a single arch was facilitated by applying half pin fixation bolts to either side of the arches, applying washers beneath half pin fixation bolts, or applying half pin fixation bolts to 1 or 2-hole posts elevated from the ring. Frames were applied proximal to the distal radial growth plate if still open. For LAFP the rod was attached to the arch using spherical nuts and washers, half-pin fixation bolts or two-hole post stand-offs. For DAPF, the arches were locked relative to each other using half pin fixation bolts placed on 1 or 2-hole posts which allowed three dimensional manipulation of the segments. Physical therapy was employed in all cases. Orthogonal pre- and post-operative radiographs of the operated limb and the contralateral limb when present were used to determine the Frontal (FPA) and sagittal plane (SPA) anatomic axes. Function and cosmesis were assessed pre- and post-operatively for all cases.

RESULTS
Mean age was 9.2 months (range 5-12 months). Mean weight was 21.1kg (range 4.7 – 58kg). Frame removal was accomplished for all cases by 7.5 weeks (range 5-7.5 weeks). Lameness or pain on manipulation of carpus or elbow through a normal range of movement was not evident for any patient by 10 weeks after frame removal. Radiographic assessment revealed correction of rotational deformity in both frontal and sagittal planes for all cases but less satisfactorily so for LAPF than DAPF. For 15 radii reviewed, the change in FPA (t=2.60, p=0.023) and SPA (t=4.52, p=0.001) following surgery was significant (paired t-test). FPA was corrected or improved in 10/15 dogs (66%); SPA was corrected in 12/15 dogs (80%). Pre-operative FPA range was 40–2° and post-operative 18–3°. Pre-operative SPA was 34–9°, post-operative 10–2°. Correction of radial procurvatum was less successful and minor residual translational deformity was evident in 7 of 15 antebrachii. Preoperatively all dogs had a fair or poor level of function. Postoperatively, all achieved good function and 8 of 15 were deemed functionally normal. Preoperative cosmesis was graded fair or poor and post-operatively all dogs achieved good cosmesis. One dog with bilateral surgery is yet to reach final follow-up evaluation.

DISCUSSION/CONCLUSION
The foci of radial deformities in this study were close to the radio-carpal joint or distal radial physis, leaving little space for implant placement. Pins divergent off frame arches allow maximum bone purchase and avoid growth plates. Half-pin fixation bolts mounted on arches allow complete freedom of movement in three dimensions and are a significant departure from conventional methodologies dependant on pre-operative planning and/or trigonometric calculations. Pin constructs require less technical expertise and less time for application than wire-circular frames. The technique depends on identification of the major apex of deformity and correction referenced off the frontal plane of the humero-radial joint. LAPF constructs allow less scope for three-dimensional correction, are more difficult to successfully apply and achieve less desirable functional and cosmetic results than DAPF constructs. DAPF constructs more readily facilitate correction of rotational deformity than dome osteotomies and obviate iatrogenic juxta-articular segmental translation that can occur with dome and cuneiform osteotomies. Pins placed in the cranial aspect of the distal radial segment allowed manipulation to ameliorate cranial bowing of the radius, which was difficult to address due to flexure contracture but was better facilitated by DAPF. The measurement of FPA from frontal plane radiographs in patients affected by rotational deformity is subjective and potentially inaccurate; in the absence of carpal valgus, rotation only was corrected and hence FPA would not be expected to change. Standard FPA and SPA ranges for clinically normal dogs of the breeds described in this case series have not been established and the contralateral limb is often...
similarly affected, therefore precluding relevant comparison. Pre-operative SPA values for this series were within previously published normals (8-35°) therefore it may not be necessary to address SPA values to achieve satisfactory functional outcomes. Breed variation and measurement technique could potentially affect FPA and SPA values hence their validity as a measure is questionable.

Residual procurvatum and translational deformities were better tolerated than rotational or valgus deformities in this study population and have had no observable effect in terms of pain or lameness. It could be argued that procurvatum and translational deformities are intrinsic to chondrodystrophic breeds and do not justify complex corrective planning. Linear distraction could be applied if necessary following acute angular correction by appropriate application of motors. Visual and radiographic assessment of functional and cosmetic outcomes for these patients was comparable to other methods published. Numbers of cases are small in this series and wider application of DAPF constructs concomitant with assessment of breed normals for procurvatum and translation of the antebrachium are warranted. Information regarding the presence of osteoarthritis at initial surgery and the impact of surgical intervention on the long term development of osteoarthritis would be useful to identify this technique as superior to others.

ABSTRACT 2:
True spherical dome osteotomy for acute correction of sagittal and frontal joint axes in dogs with angular and rotational antebrachial deformities

INTRODUCTION: Straight, oblique, wedge and crescentic osteotomies have been employed for correction of antebrachial growth deformities in human and veterinary patients. To achieve appropriate anatomic axis realignment the angulation correction axis (ACA) must be focused on the centre of rotation of angulation (CORA). Crescentic osteotomies employed in this fashion have been termed focal dome osteotomies, but they do not constitute geometrically true domes and are restricted to motion in the plane of the crescent, allowing very limited capacity for torsional correction without reducing bone apposition. Currently no clinical data is available regarding true spherical dome osteotomies (TDO) for correction of sagittal and frontal joint alignment plus rotational deformities. Additionally, rotational deformities frustrate attempts to apply CORA methodology for pre-operative planning. Our hypothesis was that TDO would allow for unrestrained multi-directional motion of bone segments and optimize bone contact for healing in dogs affected by rotational and valgus deformities of the antebrachium.

MATERIALS AND METHODS: Thirteen antebrachii of nine dogs underwent surgical correction of joint axes alignment. Rotational deformities in all cases precluded application of CORA methodology for surgical planning. Nine limbs were affected by uniapical deformities and four by biapical deformities. All patients were operated in sternal recumbence. A non-focal TDO of the radius at the point of maximum deformity and a bi-oblique caudo-latero-proximal to cranio-medio-distal osteotomy of the ulna at the junction of the proximal and mid thirds of radial length were performed. All osteotomies were made with 12 or 18mm Sphero™ Domesaw™ blades (Matrix Orthopedics Inc., Twin Falls, ID) attached to a reciprocating saw (Whittemore Enterprises Inc. Cucamonga, CA). Two 1.0 mm Kirschner wires or two 1.5-2mm negative profile half-pins were placed parallel to the frontal joint axes of the elbow and carpus and close to the respective joints to serve as reference anchors to correct for varus/valgus, procurvatum/recurvatum and rotational deformities. In all cases the transcondylar axis of the distal humerus and the transverse frontal plane axis of the radio-carpal joints were arbiters of alignment with repeated flexion and extension of the elbow and carpus. Three fixation methodologies were employed: external skeletal fixation (IMEX™ inc., Longview TX) (10 limbs), Compact UniLock™ plates (Synthes, Paoli, PA) plus K-wires (1 limb), and SOP™ plates (Orthomed, Huddersfield, UK) plus K-wires (2 limbs). Where ESF was employed, two arches and three to four divergent half pins were applied to each segment using safe corridors and segments were rotated relative to each other using multidirectional hinges, then locked using a cross-over connecting bar (Double arch pin poly-directional external realignment, DAPPER). For plate fixation, the segments were aligned and a K-wire placed for stabilization before application of plates and screws. Due to excessive valgus and procurvatum, a cranio-medial dome-wedge ostectomy was performed for two cases to improve bone contact. Wedges were morcelised and used as autogenous bone graft. Contact between proximal and distal bone segments was assessed intra-operatively and radiographically post-operatively. All cases were followed until osseous union and lameness resolution. Radiographic measures of sagittal and frontal joint axes, functional outcome and cosmesis were recorded.
RESULTS: Correction of joint axes misalignment and rotation deformities were uneventfully performed in all limbs. Humero-ulnar incongruity was addressed in all cases by ulnar osteotomy. Residual translational deformities were apparent in the frontal plane for three limbs (mean 12.8%, SD 24%, range 0-64%) and in the sagittal plane for two limbs (mean 9%, SD 19%, range 0-50%), but were not deemed clinically relevant, even in cases of biapical deformity. Bone contact was sufficient for uneventful osteotomy healing in all cases. Mean time to bone healing was 2.4 months (SD 0.8 months, range 2-3 months). Seven owners graded functional and cosmetic outcome as excellent and two graded outcome as good. Pain or lameness was not observed for any case after osseous healing. Post-operative radiographic measure of varus/valgus frontal plane joint alignment was mean 12.4° (SD 8.8°, range 0°-28) and of cranial/caudal sagittal plane joint alignment was 18.4° (SD 11.5°, range 2°-40°), which was within range of the control group in a previous study.3

DISCUSSION: The ACA was not centered on the CORA in any of the cases as significant rotational deformities did not allow for valid CORA measurements to be performed preoperatively. Correction for valgus, procurvatum and rotation were addressed via a single osteotomy and in cases affected by biapical deformities, translation was unavoidable, but functional and cosmetic results were satisfactory. Adequate bone contact between proximal and distal segments was achieved whilst the dome geometry allowed segmental manipulation around more than one axis. CT scan and multiple osteotomies should be performed if translational deformities are to be avoided, but for uniaxial deformities results comparable with existing techniques can readily be obtained with TDO. Results are encouraging, but further investigation and mensuration of geometrical alignment consequences of TDO is warranted to guide clinical recommendations.

REFERENCES
APPLICATION OF A VARIABLY PITCHED CANNULATED SCREW AND BIOBLIQUE DYNAMIC PROXIMAL ULNAR OSTEOTOMY FOR TREATMENT OF UNUNITED ANCONEAL PROCESS IN DOGS

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Ununited anconeal process (UAP) in growing dogs is characterized by failure of the process to fuse with the parent bone by 20 weeks of age. UAP has been documented in large, fast-growing or heavy-set breeds with the German Shepherd Dog having the highest incidence, and in chondrodystrophic breeds such as the Basset Hound. Other susceptible breeds include the Labrador Retriever, Rottweiler, Newfoundland, Golden Retriever and Bernese Mountain Dog, although there appears significant geographic variation between incidences in these breeds. Male dogs are affected approximately twice as often as female dogs. UAP is reportedly bilateral in 20-35% of affected dogs. Putative aetiologies include asynchronous growth of the radius and ulna and incongruence of the ulnar trochlear notch relative to the humerus. Torsional incongruity may also be involved and UAP in the author’s experience frequently occurs concomitant with medial coronoid disease. This phenomenon is difficult to explain in terms of purely sagittal aberrant forces, and the author proposes that both pathologies could conceivably arise from torsional incongruity of the ulnar trochlear notch relative to the distal humerus.

Non-surgical management has been associated with persistence of lameness and progression of arthrosis and is seldom considered as a useful therapeutic option. Instability and presence of a free fragment of bone within the joint lead to irritation, abnormal cartilage wear and secondary degenerative joint disease. Changes include joint effusion, cartilage erosion progressing to subchondral bone eburnation, remodelling of the anconeal process, osteophyte production and joint capsule thickening, and may be recognised early in the disease process. Where applied, medical management is aimed at maintaining comfort and function, as far as possible, and current recommendations emphasize body weight limitation, regular controlled exercise routine, provision of nutraceuticals and judicious use of NSAIDs.

Conventional surgical treatment has included removal of the ununited segment and this is still widely practiced. Fragment removal has been associated with poor or inconsistent outcomes with progression of degenerative joint disease and persistence of lameness and pain. In one study with mean 19.5 month follow-up, 70% of the dogs improved clinically, but only 50% were free of lameness. It has been proposed that poor outcomes may be at least partly attributable to resultant joint instability. In a proportion of dogs, particularly where disease has been present for some months prior to presentation, the anconeal process has already become substantially remodeled, or cartilage pathology of the intercondylar groove of the humerus is so severe, that attempts to achieve union will fail to improve clinical status and some dogs may experience increased discomfort due to the effective incongruency created by fixation of the anconeal process. In these dogs, fragment removal may represent the only viable therapeutic option and the author has experienced positive outcomes for fragment removal in such cases.

Osseous union of the ununited segment may be achieved by ulnar osteotomy alone where the anconeal process is minimally loose or displaced. Published studies have reported varying success and have made various recommendations regarding location, obliquity and application of intramedullary stabilisation of the osteotomy, although these have largely been based on conjecture rather than validated biomechanical or clinical data. It is well recognized from cadaveric studies that load bearing impacts both sagittal forces on the proximal ulna by the pull applied to the olecranon by the triceps brachii, but there is also a transverse force component which may result in a degree of varus deformity at this level. The author currently employs a proximal ulnar osteotomy directed obliquely caudo-proximal to cranio-distal and proximo-lateral to disto-medial which appears to counteract both potentially destabilizing force components (Bi-Oblique Dynamic Proximal Ulnar Osteotomy). It is likely that failure of union following ulnar osteotomy alone is attributable to poor case selection rather than technical inadequacy in the majority of cases, provided that cut trajectory is appropriate.

Primary fixation of UAP by compression screw placement may frequently be required and is indicated where the anconeal segment is significantly loose or displaced but has not yet significantly remodeled and where the cartilage of the humeral condylar isthmus is still functionally intact. Critical features influencing successful outcome include precise screw positioning, neutralization of shear forces by correction of joint incongruity and age at intervention. Accurate placement of a standard screw in compressive force is technically challenging - whether inserted from the articular surface into the ulnar metaphysis with the head countersunk into the anconeal process (due to the substantial risk of splitting the anconeal fragment while countersinking or lagging the screw), or inserted in compression/lag fashion from the caudal cortex with threads at the tip embedded in the anconeal process.
Recent developments allow application of the Acutrak screw (Acutrak™, Acumed, Hillsboro, OR, USA), a headless, cannulated tapered compression screw through the articular surface, gaining excellent bone purchase and compression while avoiding the potential difficulties associated with conventional screw placement. The tapered fully-threaded profile maximizes pull-out strength and application by lag technique is not required. Core size of the screw is small compared to conventional alternatives of similar strength, which is useful for application to small fragments. Reliable compression may yield superior results by comparison with ulnar osteotomy alone, especially where a wide fibrocartilage zone exists between the anconeal process and the proximal ulna, where the fragment is loose or where bilateral surgeries are performed simultaneously. Cannulation of the implant allows use of a k-wire to accurately position the fragment and determine screw trajectory and length. The potential for fluoroscopic and arthroscopic assisted application would maximize biologic advantage.

Failure to address joint incongruity by ulnar osteotomy in conjunction with anconeal process fixation will inevitably result in failure to achieve union or will result in sub-optimal clinical outcome. Reattachment must be accurately aligned to avoid perpetuation of cartilage wear. Prognosis following achievement of union of the anconeal process, healing of the ulnar osteotomy and perceived improvement in elbow congruency is considered favourable, provided secondary degenerative changes are not well established before surgical intervention. In a case series operated by the author, reliable stabilization of the UAP bone segment to the proximal ulna was achieved. Persistence of a thin radiolucent line in some cases was likely attributable to persistence of a layer of unmineralised fibrocartilage and was not clinically significant for any case. Progression of periarticular osteophytosis was inevitable in cases which had already sustained significant cartilage erosion or were concomitantly affected by FMCP, but progression of arthrosis compared favorably with that reported for other fixation techniques and owner perception of long-term outcome was very satisfactory.
The humeral condyle in the normal developing dog has two (medial and lateral) centres of ossification, which are separated by a cartilaginous intermediate zone, and appear at a mean (±SD) of 14 ± 8 days after birth. These ossification centres are reported to unite by 70 ± 14 days of age with completion of ossification by 32 weeks of age. A condition affecting the integrity of the humeral condyle in spaniels was reported by Meutstege in 1989 as a rare finding and subsequently to primarily affect medium and large breed dogs. Now commonly termed incomplete ossification of the humeral condyle (IOHC), it is over-represented in the cocker spaniel, in which a recessive mode of inheritance as been proposed. The author and others have seen the condition in several breeds, including the Labrador Retriever, Labradoodle and German Shorthaired Pointer.

IOHC may be a subclinical condition, and has been reported as an uncommon cause of forelimb lameness in dogs. Lameness may be mild and intermittent to non-weight bearing in nature and may precede complete humeral condylar fracture (HCF). It is proposed that IOHC decreases stability of the humeral condyle predisposing to complete fracture often after a minimally traumatic event.

IOHC was first diagnosed radiographically as a linear sagittal radiolucency in the humeral condyle in the region of the developmental cartilage zone separating the two condylar centers of ossification. Subsequently bone scintigraphy and arthroscopic examination were reported useful in establishing a diagnosis but it is now appreciated that diagnosis may prove elusive using these modalities. Magnetic resonance imaging (MRI) or computed tomography (CT) may be necessary for definitive diagnosis. The author has found that both modalities are sensitive and accurate. The author has also found that cases which are clinically affected by lameness generally tend to have intercondylar fissures propagated into the joint itself, and are readily seen arthroscopically, with relative motion of the two condylar segments on pronation and supination.

Management of IOHC remains controversial. Conservative treatment of IOHC is associated with HCF. Marcellin-Little reported that 3/7 condyles (43%) with a partial radiolucent line and 1/12 condyles (8%) with a complete radiolucent line fractured 11 days to 18 months after diagnosis. The author has anecdotally observed high rates of fracture of untreated intercondylar fissures. Surgical treatment aims to prevent HCF, to encourage osseous fusion of the transcondylar fissure and to resolve lameness in the long-term. Current surgical treatment of IOHC generally involves use of a transcondylar screw, either fully or partially threaded, applied in either a position or in lag fashion. Screw placement may be combined with transcondylar bone tunnels created by drilling (forage) to allow vascular in-growth. A single case report prior to the author’s own work on transcondylar bone graft, suggested use of such a graft but this was not performed because of concerns about potential for the bone graft to communicate with the joint via the transcondylar fissure.

After transcondylar screw application, resolution of lameness usually occurs; however, complications include failure to achieve bone union, recurrence of lameness, fissure widening, loss of transcondylar compression, implant failure, and HCF. Failure to achieve bone union and condylar stability may result in cyclic loading of the screw with bending, stress fatigue, and failure. Some surgeons advocate changing the screw at regular intervals such as every other year and others advocate re-examination if lameness recurs, in an effort to prevent osseous fracture if the screw cycles to failure at the non-ossified interface. What is clear is that without biologic augmentation, union is never achieved. Some surgeons therefore advocate placement of screws of significantly large diameter (5.5 or even 6.5 mm).

Histologic features of the fissure site were consistent with atrophic non-union fracture in an English Pointer and were composed of fibrous tissue in two Cocker Spaniels with no evidence of chondrocytes or cartilage matrix. These findings may suggest that IOHC might be approached similarly to treatment of atrophic non-union fractures, so treatment modalities promoting transcondylar bone osseous union are worthy of consideration. Autogenous cancellous bone graft application in the area of incomplete ossification has been proposed to optimize bone formation and remodeling by providing trabeculae necessary for bone conduction and osteoprogenitor cells, as well as cytokines and growth factors for osteoinduction and osteogenesis. No study has reported the effect of IOHC on condylar stability but resultant instability may be in part or wholly responsible for observed lameness. In such cases, use of bone graft alone may not promote bone healing because of the effects of excessive movement at the fissure site inhibiting healing, similar to unstable atrophic non-union where AO principles support the combination of a graft with rigid internal fixation to promote bony union.
The Acutrak™ bone screw (AT screw, AcutrakTM, Acumed, Beaverton, OR) used since 1992 in human patients, is composed of titanium alloy (ASTM F136), and is a cannulated, headless, tapered, variably-pitched, self tapping and fully threaded compression screw. The AT screw is inserted using a customized cannulated application system. The osteochondral autograft transfer system (OATS™, Arthrex, Naples, FL) has been used in humans for treatment of articular cartilage defects including osteochondritis dissecans. The author reasoned that both systems had features that might facilitate graft collection and treatment of IOHC.

Direct visibility of the cranial and caudal aspects of the humeral condyle is achieved and the narrowest isthmus of the articular surface is marked by 2 temporary 1.1mm Kirchner (K)-wires placed within the joint contiguous with the articular surface. A calibrated K-wire (Acumed, Beaverton, OR) is driven medial to lateral across the humeral condyle at its most distal extent, using an inverted AT screw placed over the K-wire as a spacing guide to ensure that the maximal diameter of the screw would not encroach on the articular cartilage at the narrowest part of the isthmus. When the wire has penetrated the trans cortex, bone depth is measured using the etch mark on the calibrated K-wire held against the scale on a customized depth gauge. The base of the inverted AT screw placed over the K-wire acts as a spacer allowing an OATS™ reamer (OATS™, Arthrex, Naples, FL) of maximal diameter to be centralized proximal to the AT screw on the medial aspect of the humeral condyle without encroaching on the intended screw position. The reamer position is maintained by advancing a guide drill across the condyle through the cannulated reamer. Parallelism of the drill guide/reamer and the wire/screw is desirable, but in some dogs with limited humeral condylar bone stock it is necessary to drive the screw parallel to the medial humeral joint surface rather than parallel to the transverse axis of the condyle. In these dogs, the screw passes obliquely from distomedial to proximolateral, craniodistal to the position of the intended bone core as marked by the guide drill. A hole is prepared for the AT screw using the customized AT insertion system (Acumed, Beaverton, OR). The guide K-wire is advanced through the trans cortex, soft tissues and skin and is secured with wire graspers on the lateral aspect of the condyle to minimize wire movement. A customized drill bit is advanced over the guide wire in increments of 3-4 mm and intermittently removed to allow removal of bone debris. External drill calibrated markings measured against the cis cortex allows advancement of the drill tip to within 2-6 mm of the trans-cortex. The reamer is then repositioned on the central guide drill. The intended socket depth is 75% of condylar width and is estimated from preoperative radiographs. Calibrated markings on the external barrel of the reamer allow socket depth measurement during reaming. An AT screw 2 mm shorter than the drill hole depth was threaded over the guide wire and inserted to finger tightness using a customized screw driver.

Core socket depth and alignment are confirmed using a calibrated alignment rod before cancellous bone dowel collection. When free autogenous cancellous bone is used, it may be collected from the proximal aspect of the ipsilateral humerus through a small fenestration created using a bone curette. Corticocancellous bone dowels of appropriate length may also be collected from the proximal aspect of the tibia or distal femur using an OATS™ core harvesting chisel 1mm wider than the transcondylar recipient socket. The core harvester is a calibrated, cylindrical cutting chisel with louvered grooves at 4 equidistant points on the circumference. The louvers engage the bone core when hammer-tapped into the donor site and the bone dowel is extirpatated by a twisting motion axial to the harvester, or by slight rocking (‘toggling’) whereupon the louvers engage the cancellous bone and break the dowel off at its base, which is subsequently removed within the chisel. Graft dowels are trimmed to fit recipient socket length where necessary. Grafts are transferred to the recipient socket by packing the free cancellous graft firmly with a tamping rod to the level of the cis-cortical or placing a dowel as a press fit using the OATS™ system. Humeral epicondylar augmentation may be performed with pin(s) or plates if the intercondylar fissure is deemed significantly unstable.

In a study population of eight dogs operated by the author, time to resolution of lameness ranged from 4 - 84 days (mean, 35 days). Partial (≥50% width of central portion of condyle) or complete bone union was identified in 7/9 elbows by CT examination, 11 – 16 weeks postoperatively. Failure of bone union was observed in one dog where free cancellous graft was employed and the author therefore generally recommends application of trabecular bone dowel cores. 8 of 9 operated limbs in this series were deemed free of lameness up to 45 months postoperatively and several had returned to function as working dogs. Trabecular ‘spot-weld’ was consistently observed in all elbows with corticocancellous dowel grafts evaluated by CT. In contrast to an inert metallic implant which is susceptible to cyclic fatigue, the dowel should theoretically function as a biologically active transcondylar bridge capable of responding to chronic stress by active regeneration, repair, and remodelling in keeping with Wolff’s law.

Bone dowel diameter is intrinsically limited by humeral condylar isthmus dimension and by the concurrent use of a transcondylar screw. Use of an AT screw allows placement of a mechanically robust but narrow implant whilst maximizing bone dowel diameter. The cannulated system allows accurate insertion, using the guide wire of the screw and the reamer centralizer as trajectory guides for the screw and bone dowel respectively, without need for fluoroscopy, although fluoroscopic guidance may further facilitate accurate screw placement. The fully threaded, tapered nature of the screw provides constant new bone purchase as it is inserted, minimizing strip-out and maximizing pullout strength, providing strong internal fixation.
Where it is perceived that a transcondylar bone dowel of diameter 5mm or greater cannot be placed in addition to a screw, the author’s preference is to use a screw only as he does not perceive that a bone graft alone provides adequate structural resilience, in the face of unstable motion of the two condylar segments in a clinically affected patient. Screw diameter is important and where possible the author employs at least a 4.5mm diameter cortical screw, since structural resilience will be dependant on the core diameter of this screw indefinitely. The author prefers to place this screw in a minimally invasive fashion by arthroscopic guidance. Other transcondylar implants are currently being investigated to try preventing cycling to failure in future iterations of technique.

Where IOHC is present, elbow fractures can be difficult to treat because of general inability to achieve osseous union at the intercondylar interface, such that epicondylar structural integrity is important. Non-union is common and can give rise to transcondylar implant loosening and resorption of bone around the implant. In recalcitrant cases this can be overcome using a transcondylar threaded rod and nuts on either side of the humeral condyle (Webb Bolt). Tissue glue may be applied to prevent nut loosening.

Simple condylar fractures usually affect the lateral condyle, with the lateral epicondyle being intrinsically weaker than the medial. The author prefers to reverse drill the fracture fragment from the condylar isthmus to the lateral collateral region, then reversing the drill bit through this fragment, reducing the fracture and driving the drill into the medial aspect of the humeral condyle. Then epicondylar support is provided using a k-wire to hold the segment in orientation allowing a transcondylar screw to be placed either as a position or lag screw. Particular attention must be applied to make sure that the epicondylar region is accurately reconstructed, otherwise mismatch at the intercondylar area is inevitable and fragments with short epicondylar segments are prone to rotate around the condylar screw and become malaligned. Augmentation of the medial epicondylar ridge using locking plates such as the 2.0 or 2.4 mm Synthes LCP™ or the 2.0 mm or 2.7 mm string-of-pearls SOP™ plate may be beneficial and as a general guideline, if the author feels that there is any possibility of aberrant healing or tenuous implant purchase, an epicondylar plate is applied.

Complex T and Y-fractures of the humerus can readily be repaired without olecranon osteotomy and the author does not recommend osteotomy because of difficulties with healing at this tension site. Two approaches are valid – either reconstruction of the medial condylar fracture first, with subsequent repair of the lateral condylar fracture; or repair of the humeral condyle first and then reconstruction of the humerus. The author favours the latter approach and frequently employs a fracture distractor to overcome muscle contracture prohibiting satisfactory reduction. Fixation can be applied using standard or locking plates or plate-rod techniques. The author previously used hybrid 3.5/2.7 pancarpal arthrodesis plates applied medially and laterally but now favours 2.7mm and 3.5mm SOP™ plates. An intramedullary pin placed in the medial epicondyle and exiting the proximal humerus via the subtubercular region can facilitate realignment and may obviate requirement for two plates, facilitating a plate-rod technique. Cerclage wire can be important or vital for re-apposition and stabilisation of spiral fragments, and can be used to sequentially realign long spiral fragments under guidance of a fracture distractor.

In small fragments or comminuted juxtaarticular fractures of cats or dogs, external skeletal fixation may be very useful including application of small half-pins, self-compressing threaded pins or olive wires on arches distally to facilitate condylar reconstruction. Such arches and stretch-rings mounted with linear components further proximally and constituting hybrid fixation systems offer tangible advantages over conventional linear frames and where conventional circular frames cannot be mounted on the proximal thoracic limb. However, external skeletal fixation of the humerus in dogs is a high-maintenance technique in that pin tract discharge and prolonged healing times may be issues. Therefore the author prefers internal fixation unless there is very valid rationale to choose fixator constructs.