Techniques of Application and Initial Clinical Experience with Sliding Humeral Osteotomy for Treatment of Medial Compartment Disease of the Canine Elbow

NOEL FITZPATRICK, MVB, CertVR, CertSAO, RUSSELL YEADON, MA, VetMB, THOMAS SMITH, MA, VetMB, CertSAS, and KURT SCHULZ, DVM, MS, Diplomate ACVS

Objective—To determine medium-term clinical efficacy of sliding humeral osteotomy (SHO) for treatment of lameness and elbow pain associated with clinically diagnosed elbow disease featuring cartilage eburnation of the medial elbow compartment (medial compartment disease—MCD).

Study Design—Case series.

Animals—Dogs (n = 49) with severe or persistent lameness attributable to MCD.

Methods—Signalment, lameness history, and preoperative imaging findings were recorded. A custom, locking, stepped SHO plate was applied to the medial aspect of the humerus, stabilizing a mid-diaphyseal transverse osteotomy, medially translating the distal segment relative to the proximal segment. Three variants of technique of application were used and outcomes compared between respective patient groups. Outcome measures included lameness scoring, anatomic measures, VAS scoring of elbow pain, and owner assessment of function. Measures recorded preoperatively, 12, and 26 weeks postoperatively were compared.

Results—Of 59 limbs that had SHO, 39 had preoperative focal treatment of the diseased medial aspect of the coronoid process. Mean ± SD dog age was 45.5 ± 37.48 months and body weight ranged from 13.6 to 46.7 kg. Mean preoperative duration of lameness was 14.7 ± 18.50 months. Lameness improved for all limbs by 26 weeks, and resolved in 21/32 limbs. Significant improvements in postoperative elbow pain scores and most owner assessments of function were observed. Incidence of major complications requiring surgical intervention was 17.2%, 22.2%, and 4.8% for each of the 3 technique variants described. Histologic examination of 2 elbows at > 12 months revealed fibrocartilage cover of medial aspect of humeral condyle.

Conclusions—Canine SHO with or without focal treatment of the diseased medial aspect of the coronoid process ameliorates lameness and pain associated with MCD at medium-term follow-up. Application technique is critical to minimizing morbidity.

Clinical Relevance—SHO is appropriate for clinical management of pain and lameness in select cases of canine MCD.

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From Fitzpatrick Referrals, Eashing, UK; Burlington Veterinary Specialists, Williston, VT.

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Drs. Fitzpatrick and Schulz hold a proprietary interest in the instrumentation and surgical implants used, and in instructional courses regarding the surgical technique described.

Address reprint requests to Noel Fitzpatrick, Fitzpatrick Referrals, Halfway Lane, Eashing, Surrey GU7 2QQ, UK. E-mail: noelF@fitzpatrickreferrals.co.uk.

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INTRODUCTION

ELBOW DYSPLASIA is an important cause of thoracic limb lameness in large and giant breed dogs. Most frequent pathologic changes are associated with the medial aspect of the coronoid process of the ulna and medial aspect of the humeral condyle. Commonly recognized lesions of the medial aspect of the coronoid process are cartilage malacia, fibrillation, fissuring, and erosion in addition to subchondral bone microfissuring and fragmentation. Frictional erosion (“kissing lesion”) of the medial humeral condyle is frequently associated with coronoid disease, whereas osteochondrosis of the medial aspect of the humeral condyle may give rise to lesions of osteochondritis dissecans. This spectrum of pathology and ensuing full thickness cartilage erosion in the region defined by the medial aspect of the coronoid process and medial aspect of the humeral condyle has been referred to as medial compartment disease (MCD). Elbow incongruity such as radioulnar step defects, humeroulnar incongruence, varus deformity of the humerus, or imbalance between skeletal and muscular mechanics may contribute to medial MCD of the elbow joint in dogs. Pathology of the lateral aspect of the elbow joint is far less commonly observed.

Historically, surgical treatment of elbow disease has either been tailored toward the primary lesion where identified, or has involved radial or ulnar osteotomies to address perceived incongruity or alter load distribution at the elbow. In the case of proximal ulnar osteotomy for incongruity it has been noted that the proximal ulnar articular surface is elevated above the radial articular surface and that varus deformity may result from loading. This could lead to increased medial compartment pressure, cartilage degradation, and subchondral bone pathology. Regardless of the technique used, degenerative changes are progressive for all forms of elbow dysplasia. Where such techniques are unlikely to result in a favorable clinical outcome because of chronicity of the lesions, persistence of frictional abrasion, or severity of cartilage disease of the medial compartment at the time of presentation, there is a rationale and a clinical need for alleviation of pain and if possible, amelioration of disease progression. Many of these dogs are juvenile and within our experience, alternatives such as total elbow arthroplasty or elbow arthrodesis may represent suboptimal therapeutic choices because of potential complications, potentially poor functional outcome, or potential for failure of the implants within the lifetime of the patient.

Unicompartmental osteoarthritis of the human knee (medial compartment gonioarthrosis) has been treated using closing wedge osteotomies for over 40 years. The efficacy of this treatment has been well documented but there is still substantial debate about almost every aspect of the technique including the mechanical basis. However, the ability to redistribute the major joint forces from the medial compartment in favor of the lateral compartment has potential merit in light of the typically unicompartamental nature of elbow dysplasia and this concept of force redistribution within a joint, from an area of profound cartilage and subchondral pathology to a more normal area has been embraced and pursued for the benefit of dogs with elbow dysplasia.

A cadaver study using normal elbows to map and document force distribution across the humeroradial and humeroulnar joints found an ~ 50:50 distribution with 3 distinct contact areas in the elbow joints of normal dogs. There is a radial contact area located on the caudomedial aspect of the proximal radial articular surface with its longest dimension orientated mediolaterally; a 2nd contact area located on the medial aspect of the distal articular surface of the trochlear notch and extending to the lateral edge of the medial coronoid, and a 3rd contact area on the cranialateral surface of the proximal trochlear notch. The force measurement between the humerus and the 2 bones of the antebrachium were significantly different with greater forces associated with the radius than the ulna, but the ratio of the mean force remained close to a 50:50 distribution regardless of applied load. Medial opening wedge osteotomy or lateral sliding osteotomy (lateral translocation of the proximal humeral diaphysis with respect to the elbow) had been proposed to elicit lateral shifting of the load axis. The lateral sliding humeral osteotomy (SHO) and 10° medial opening wedge osteotomy were found to significantly alter joint surface contact regions of the canine elbow joint. Osteotomies resulted in a reduction in the size of the radial, ulnar, and combined radioulnar contact areas. Both osteotomies also resulted in cranialolateral migration of the radial contact area and craniocephalic recession of the ulnar contact area. There was a concern that the induced joint incongruency resulting in decreased overall contact area and increase in transarticular pressure distribution over a smaller area might lead to detrimental effects on the in-contact cartilage areas if forces become supra-physiologic, but as yet no long-term data is available.

In another study, force at the proximal articular surface of the ulna decreased after SHO of 4 and 8 mm by 25% and 28%, respectively. Mean increases of 7–11% in measured forces at the proximal articular surface of the radius were not statistically different for any form of wedge or slide performed, and was considered likely to be insufficient to result in cartilage disease of the radial head. Decrease in force at the proximal ulnar articular contact area was noted from 204.6 N (± 30.1) to 147.9 N (± 63.1) for 8 mm shift. It was suggested that the technique might increase loading of periarticular tissues, accounting for the
apparent discrepancy regarding lack of significant force increase at the proximal articular surface of the radius, and could therefore potentially result in soft tissue or periarticular sequelae.

Application of a 10° lateral closing wedge technique in 9 dogs subjectively resulted in 4 excellent and 4 good results (K. Schulz, unpublished data). One dog had poor outcome associated with septic arthritis. Major complications were experienced in 3 dogs, including implant pull-out, thought to be because of the high moment arch that was generated by the angulation. It was proposed that SHO may address these complications and 2 clinical cases were performed. The 1st case with translocation of 5 mm had no clinical improvement, but the 2nd with 10 mm translocation yielded promising results.

Our purpose is to document early clinical experiences and outcomes with the SHO procedure using a custom-designed stepped locking plate. We hypothesized that SHO, with or without additional focal treatment of the diseased medial aspect of the coronoid process, would decrease pain and alleviate clinical signs or lameness associated with MCD within the first 12 months postoperatively.

MATERIALS AND METHODS

Dogs admitted (November 2005–November 2007) for investigation of severe or persistent thoracic limb lameness, diagnosed with MCD as sole pathology were selected for SHO.

Patient Evaluation

Client and surgeon questionnaires (Appendices A, B) were completed along with clinical and orthopedic examinations to establish lameness history, recent medication requirements, ability to perform specified functions, current level of lameness, and elbow pain. A visual analogue scale (VAS) was used for subjective data. Both owners and clinicians were blinded to scores from previous assessments during questionnaire completion, and were advised to leave answers blank for any questions they did not understand or felt unable to answer. VAS scores were analyzed by using a transparent template allowing a numerical score to be awarded to each assessment as determined by the position of a mark placed along a line of standardized length (100 mm when printed). A value of 0 was awarded for poor and 100 for excellent outcomes.

Clinical examinations were undertaken preoperatively, and at 2, 4, 6, 12, and 26 weeks postoperatively. Gait assessment was documented by video recordings. Lameness was attributed a score by 2 clinicians at the time of assessment, and by 1 other clinician from video recordings of gait. The median of the 3 resulting scores was established for each evaluation and used for subsequent data analysis. Lameness evaluation, including video gait recordings, was performed on a designated outdoor metalled track. The protocol used for all dogs was:

- 30 m walking away from the camera, handler on dog’s left;
- 30 m walking toward the camera, handler on dog’s right;
- 30 m trotting away from the camera, handler on dog’s left;
- 30 m trotting toward the camera, handler on dog’s right;
- 15 m walking left to right across the camera, dog between camera and handler;
- 15 m walking right to left across the camera, dog between camera and handler;
- 15 m trotting left to right across the camera, dog between camera and handler;
- 15 m trotting right to left across the camera, dog between camera and handler.

Trotting assessments were not carried out or were aborted for a small number of severely lame dogs where this level of exercise was considered clinically or ethically inappropriate.

Elbow examination included response to extension, flexion, and to supination and pronation in 90° elbow flexion and were scored by VAS according to degree of perceived pain. Presence of elbow effusion was noted. Maximal extension and flexion angles were measured under general anesthesia. A transparent plastic hand-held goniometer of arm length 18 cm was applied laterally with the hinge centered over the lateral epicondylar eminence, the proximal arm centered over the cranioproximal extent of the greater tubercle of the humerus, and the distal arm centered over the most prominent aspect of the styloid region of the distal ulna. The median of 3 consecutive measurements was recorded. Mid-brachial and maximal antebrachial circumferences were measured under general anesthesia using a flexible tape measure. Physical examinations were performed and evaluated by 1 clinician (N.F.).

Pre- and postoperative radiographic assessment of both elbows were performed for each dog and included flexed and extended mediolateral projections, and craniocaudal projections. Additionally, craniocaudal-parallel-to-tabletop and mediolateral projections of both humeri collimated to include both shoulder and elbow joints were obtained. Radiographic examination was performed under general anesthesia preoperatively, immediately postoperatively, and at 6, 12, and 26 weeks.

Surgical Technique

All major elbow structures were inspected arthroscopically for all dogs (n = 59) immediately preoperatively via a standard medial arthroscopy portal under routine general anesthesia using a 2.4 mm 30° angled arthroscope (Hopkins, Karl Storz, Tuttingen, Germany) connected to a video camera and image-recording device. Arthroscopic findings were assessed and recorded by a single examiner (N.F.). Subtotal coronoid osteotomy (SCO) was performed during surgery if large displaced fragments of the medial aspect of the coronoid process were present. No focal treatment of the medial aspect of the coronoid process was performed in elbows where large displaced fragments were not present, either as a manifestation of the underlying disease process, or as a result of previous focal surgical treatment of the coronoid process. All dogs included in this study had full-thickness (modified Outerbridge grade IV or V) cartilage erosion of the medial compartment.
taneous nerve entering the body of the biceps brachii proximally and distally were preserved, as were direct branches from the brachial vessels.

**Group 1**

Twenty-five dogs (29 humeri; November 2005-December 2006) had 1st generation implants. Plates were available in only 2 configurations, to accept standard NGD locking screws (2.7 or 3.5 mm maximum thread diameter). Step magnitude was 7.5 mm for the 2.7 mm plate \( n = 5/29 \) and 10 mm for the 3.5 mm plate \( n = 24/29 \).

The plate was positioned on the medial aspect of the humerus so that its proximal portion was in contact with the bone and the distal portion was separated by the plate step from the bone. The plate was positioned to avoid impingement of the intertubercular groove proximally or the olecranon fossa distally. The plate was not contoured before application, except at its most distal extent in 1 case. Proximodistal plate positioning was adjusted to optimize plate contact with the medial humeral cortex where a noticeably curved contour was present. Perfect plate-bone apposition is not required to maintain rigidity of the bone-screw-plate construct with locking plates. Positioning of the limb ensured truly medial plate application. Locking drill guides were used for all screw holes to ensure perpendicular and centralized screw placement. Screw holes were numbered 1–8 (most proximal to most distal). Four drill guides were locked into the plate in positions 1, 2, 7, and 8 before application, facilitating handling of the plate and initial drill placement.

Hole 1 was drilled and the drill bit (2.5 mm for the 3.5 mm plate, 2.0 mm for the 2.7 mm plate) and guide left in place. The plate was rotated around this drill bit in a pendulum-like manner to optimize plate position so that all screws would engage maximal cortical bone when placed perpendicular to the plate (Fig 2A). Hole 8 was drilled as for hole 1 through the proximal part of the ovoid hole, and the drill bit and guide again left in place to avoid plate migration. Locking screws were applied to proximal plate holes 2, 3, and 4 to secure the plate (Fig 2B). Holes for standard AO screws were drilled, tapped, and 2 over-long screws applied through the plate to the distal segment at holes 6 and 7 to engage both cortices of the distal humerus while bridging the gap between plate and medial cortex maintained by the plate step (Fig 2C).

A mid-diaphyseal osteotomy was created using the step of the plate as a cutting guide (Fig 2D). The osteotomy cut was created using a microsagittal saw (Stryker, Newbury, UK) and a 5.8 mm saw blade (MMD Medical, Southampton, UK) mounted at \( \sim 35^\circ \) to the saw shaft. The osteotomy site was lavaged with saline (0.9% NaCl) solution during bone cutting to minimize risk of thermal injury. Use of a thin blade allowed improved tactile sensation and minimized loss of bone stock whilst allowing enough kerf such that binding would not occur during translation.

Tightening of nonlocking screws 6 and 7 in the distal segment after unscrewing the drill guide in hole 8 resulted in controlled medial translocation of the distal segment (drill-guide-slide [DGS] technique) without additional translation of
Fig 2. (A) Locking drill guides were preplaced into holes 1, 2, 7, and 8 (1 being most proximal, 8 being most distal). The plate was placed such that its proximal segment was in contact with the humeral diaphysis. Hole 1 was drilled and the drill bit and guide left in situ (a). The plate was then rotated in pendulum fashion (b) to optimize bone engagement of subsequent screws and secured by placement of a drill bit through hole 8 (c). (B) Proximal plate section was secured by insertion of locking screws at holes 2, 3, and 4. (C) Over-long nonlocking screws were placed in holes 6 and 7 to engage cis- and trans-cortices of the distal humeral diaphysis through the plate. (D) Transverse mid-diaphyseal osteotomy was created using plate step as a cutting guide. (E) Alternate tightening of screws 6 and 7 caused medial translation of distal humeral segment until contact with the plate was achieved (drill-guide-slide technique). (F) Distal humeral segment was stabilized by placement of locking screws in holes 5 and 8 (a and b). Drill bit in hole 1 was replaced with locking screw (c). Over-long nonlocking screws 6 and 7 were removed (d and e). (G) Over-long nonlocking screws 6 and 7 were replaced with appropriate length nonlocking screws.
the bone segments (Fig 2E). During development of the technique, misalignment of drill holes 6, 7, or 8, or over-zealous tightening of screws 6 or 7 during DGS application caused breakage of the drill bit in hole 8 in several cases; the broken drill tip was always retrieved. Locking screws were applied to holes 5 and 1, respectively, to secure the plate (Fig 2F). The drill bit in hole 8 was removed and then used to re-drill using the drill guide through the unused distal portion of the combi-hole. This ensured plate–screw perpendicularity in the event of transverse plane rotation of the distal humeral segment resulting from mismatch in plate–bone contour during DGS. Over-long screws 6 and 7 were replaced with appropriate length standard AO screws (Fig 2G). NGD locking screws were not used for this purpose because of variation in thread pitch between NGD and AO screws. Screws were placed in the side of the combi-hole furthest away from the step in all holes except hole 6 which was placed in the side of the hole closest to the step, so that screws 6 and 7 were as far apart as possible to avoid plate “swivel” on the distal bone segment (associated with the fulcrum of 2 closely placed translational screws). If there was any tendency for cranio-caudal migration or rotation of the bone segments during translation, Kern bone clamps were loosely positioned over the osteotomy site so that the jaws of the clamps served as a corrodor for translation of the proximal aspect of the distal segment.

For closure, the superficial pectoral muscle was sutured to its insertion where possible, or to the fascia of the brachiocephalicus muscle using polydioxanone suture. The deep fascia, subcutaneous fascia and fat, and skin edges were apposed in layers.

**Group 2**

Nine dogs (9 humeri; January 2007–July 2007) had 2nd generation implants. This involved application of either 1 or 2 nonlocking screws of larger diameter than the locking screws originally intended through holes 3 and/or 4 of the plate (ie, 3.5 mm AO-style nonlocking screws through the 2.7 mm plate, 4.5 mm AO-style nonlocking screws through the 3.5 mm plate) in 7/9 humeri, or placement of 2 NGD locking nonthreaded rods of 3.5 mm diameter through screw holes 3 and 4 in 2/9 humeri. Step magnitude was 7.5 mm for the 2.7 mm plate (n = 1), 10 mm for the standard 3.5 mm plate (n = 5), and 7.5 mm for a reduced-step 3.5 mm plate (n = 3).

Drill guides were preplaced on the plate in positions 1, 4, 6, and 7. New narrower profile drill-guides allowed greater flexibility for preplaced positioning of 2 guides in adjacent sides of combi-holes. Hole 4 was drilled first, initially monocortical only and the drill guide and bit were left in position so that the plate was optimally positioned both cranio-caudally and proximodistally. The plate was then rotated around the drill bit in hole 4 in pendulum fashion to ensure optimization of plate positioning on the distal segment before application of screws 6 and 7. Then a monocortical screw was placed in hole 4 to oppose the plate to the bone and a drill bit was placed in hole 1 resulting in definitive plate alignment (Fig 3A and B). DGS technique and subsequent screw application were performed as described for Group 1 with the exception that hole 8 was not drilled until after segmental translation and the trans-cortex of hole 4 was not drilled until anchorage of the plate with screws in holes 1, 6, and 7.

**Group 3**

Sixteen dogs (21 humeri; August 2007–November 2007) had 3rd generation implants. These featured redesign of the...
2.7 mm plate so that it accepted 3.5 mm NGD locking screws in holes 3 and 4 (n = 1) and design of a 4.0 mm NGD locking screw with the same locking head profile as the 3.5 mm NGD locking screw. The 4.0 mm locking screw could therefore be used interchangeably with 3.5 mm screws in the unmodified 3.5 mm plate. Two 4.0 mm locking screws were used in plate holes 3 and 4 in all other cases (n = 20; Fig 4) and were additionally used in plate hole 2 in 3 cases. Step magnitude was 7.5 mm for the 2.7 mm plate (n = 1), 10 mm for the standard 3.5 mm plate (n = 12), and 7.5 mm for a reduced-step 3.5 mm plate (n = 8). Surgical technique with regard to sequence of drill bit and screw placement was otherwise as for Group 2.

Postoperative Radiographic Assessment

Assessment for all groups included screw length, screw position with particular reference to the olecranon fossa and intertubercular groove, plate alignment, extent of contact between the distal surface of the plate step and the cut bone end of the distal segment and percentage cortical overlap at the osteotomy site. Figure 5A and B show typical immediate postoperative appearance. A brachial plexus nerve block (Marcain™ Polyamp Steripack 0.5%, AstraZeneca, Luton, UK) was performed intraoperatively at the start of the procedure for all dogs in Groups 2 and 3.

Postoperative Care

A self-adhesive wound dressing (Primapore™, Smith and Nephew, Hull, UK) was applied to the surgical site for 2 days postoperatively. Perioperative analgesia included methadone (0.2 mg/kg intramuscularly [IM] every 4–6 hours as needed) or buprenorphine (0.02 mg/kg IM every 8–12 hours as needed) for the first 24–72 hours. All dogs were administered fentanyl (3–5 μg/h as a trans-dermal patch) for 3–6 days postoperatively. Carprofen (4 mg/kg orally daily for 1 week and 2 mg/kg daily for 2–6 further weeks) was administered by owners after discharge. Postoperative management included cage confinement for 6 weeks and leash-only exercise for 12 weeks, increasing periods of exercise by 5 minutes weekly, 4–6 times daily starting with 10 minutes.

Statistical Analysis

Analysis of both owner-assessed and clinician-assessed objective measurements and VAS scores was performed with statistical software (Minitab™ Release 14.20, State College, PA, and Graphpad Prism Version 5, La Jolla, CA). Descriptive statistics for relevant data including signalment variables and quantitative clinical- and owner-assessed measures were calculated. For comparison of lameness scores, ranges of movement, and brachial and antebrachial circumferences at 0, 12, and 26 weeks, Friedman’s test was applied followed by Dunn’s multiple comparison test for differences between means. For comparison of clinical and owner VAS-scored evaluations at 0, 12, and 26 weeks, 1-way ANOVA followed by Bonferroni’s post hoc test was performed. Descriptive statistics alone were calculated for clinical and owner evaluation data at 52 weeks as insufficient data were available to establish clinical significance.

Associations between presence of effusion and scores for lameness or scores for pain on elbow manipulation for each evaluation time-point were investigated by logistic regression. Pearson’s correlation coefficients within a stepwise multiple regression analysis were used to express associations of outcome variables (specifically lameness score at 26 weeks, and differences between lameness scores, scores for pain on elbow manipulations and owner-assessed VAS scores preoperatively and at 12 or 26 weeks postoperatively) with potential independent variables (age at surgery, body weight, previous surgical intervention, implant dimensions, preoperative duration of lameness). P-values of < .05 were considered significant.

Histology

Specimens were available from 2 elbows. One gross specimen was obtained at necropsy from a dog with a neoplastic lesion of the contralateral brachial nerve plexus 17 months postoperatively. One needle core biopsy from the medial humeral condyle was obtained under arthroscopic guidance from a dog undergoing surgical treatment for cranial cruciate ligament disease 12 months postoperatively. Specimens were fixed and prepared for undecalcified resin-embedded histology before sectioning at 5 μm intervals and staining with hematoxylin and eosin, toluidine blue alone, or combined toluidine blue and fuchsin. Examination was performed by a histopathologist familiar with cellular anatomy of this region.
RESULTS

Dogs

Fifty-nine humeri (33 left, 26 right) in 49 dogs were treated by SHO (group 1 = 24 dogs, 29 humeri; group 2 = 9 dogs, 9 humeri; group 3 = 16 dogs, 21 humeri). Breeds included Labrador (n = 30), Golden Retriever (3), Labrador-cross (3), German Shepherd dog (3), Springer Spaniel (2), and 8 other breeds (1 each). There were 31 male (16 neutered) and 18 female (13 spayed) dogs with body weight ranging from 13.6 to 46.7 kg. Mean (± SD) body weight did not differ significantly between groups (group 1 = 29.8 kg ± 7.97; group 2 = 29.1 kg ± 8.55; group 3 = 33.8 kg ± 5.91). Mean age at SHO was 45.5 ± 37.48 months. Age profiled 2 distinct major ranges, with 27 dogs <3 years old, 15 dogs >7 years old, and only 7 dogs between 3 and 7 years; 11 dogs were <1 year old. No significant difference in age distribution was noted between groups. Four dogs had been worked as gun dogs until 12–48 months before SHO, whereas the others were household pets. Bilateral procedures were performed simultaneously in 3 dogs and staged by 4–24 weeks in 7 dogs.

Follow-up data was excluded for 4 dogs (group 1 = 3 and group 2 = 1), each operated unilaterally. One dog was euthanatized at 5 weeks for unrelated reasons, 2 dogs had catastrophic humeral fracture of the operated limb 3 and 9 days postoperatively necessitating surgical revision including stabilization with external skeletal fixation, and 1 dog had polytrauma including medial glenohumeral ligament rupture of the operated limb at 11 weeks. Follow-up data was available for 45/45 dogs (55/55 limbs) at 3 months, 26/45 dogs (32/55 limbs) at 6 months and 4/45 dogs at 1 year.

Preoperative Findings

All treated elbows had MCD as the primary pathology; 9 elbows had been previously diagnosed radiographically or arthroscopically with concomitant osteochondrosis/osteochondritis dissecans of the medial humeral condyle. In 15 dogs, 19 elbows had surgical intervention (including coronoid fragment removal, coronoid abrasion arthroplasty and osteochondritis dissecans lesion debridement) 2–91 months before SHO. In 17 dogs, 20 elbows had SCO performed immediately before SHO, whereas 17 dogs (20 elbows) had no focal treatment of the coronoid process.

Preoperative lameness duration ranged from 6 weeks to 88 months. Mean lameness duration did not differ significantly between groups (group 1 = 14.1 ± 19.42 months; group 2 = 12.2 ± 13.43 months; group 3 = 16.9 ± 20.33 months). Preoperative veterinary assessment documented varied levels of lameness and gait abnormalities. Pain upon manipulation, particularly during maximal flexion, supination and pronation in 90° of flexion, was consistently noted. Effusion and crepitus were frequent but inconsistent clinical findings. Preoperative

Fig 6. Catastrophic fracture of the proximal humerus 9 days postoperatively in an 11-month-old German Shepherd Dog.

Fig 7. Stabilization of fracture documented in Fig 6 achieved by screw replacement and hybrid external skeletal fixation.
Fig 8. Multiple screw fracture 4 days postoperatively in a 7-year-old Springer Spaniel, subsequently stabilized by screw replacement.

owner-assessed VAS scores were consistently low indicating poor dog ability to perform specified functions. Thirty-four of 45 dogs were being administered daily nonsteroidal anti-inflammatory drugs at admission, whereas 21/45 were administered nutraceuticals (glucosamine and/or chondroitin sulfate) and/or pentosan polysulfate injections on a regular basis.

Preoperative elbow goniometry values were reduced compared with anticipated “normal” ranges with most noticeable decrease in maximal flexion angle for most dogs although we are unaware of validated ranges for breeds other than Labradors.

Complications

Complications included:

- Humeral fracture (n = 2) 3 and 9 days postoperatively, in 1 case associated with patient non-compliance with postoperative exercise restriction (Figs 6 and 7) and in 1 case associated with suboptimal implant placement so that screw holes 3 and 4 were located too close to the caudal cortex of the proximal humeral segment.
- Multiple screw breakage (n = 5; Fig 8) requiring revision by screw replacement (n = 3) or screw replacement and cerclage wire application (n = 2), occurring 4, 10, 14, 35, and 40 days postoperatively.
- Multiple screw breakage not requiring revision (n = 2), occurring 28 and 34 days postoperatively.
- Single screw breakage observed as incidental finding at 6-week radiography (n = 3).
- Delayed osteotomy union (n = 2) observed at 8 weeks which healed after application of autogenous bone graft (n = 1), or which healed spontaneously after 5 weeks further exercise restriction (n = 1).
- Minor surgical wound breakdown (n = 1) requiring debridement and re-suturing 14 days postoperatively.
- Hematoma formation at the surgical wound (n = 1) noted 2 days postoperatively, which resolved spontaneously by 10 days postoperatively.

Complications such as neurogenic or major vascular injury and infection were not observed. Total complication rate for group 1 was 34.5% (10/29 humeri); for group 2 was 22.2% (2/9 humeri); and for group 3 was 19.0% (4/21 humeri). Rate of complications requiring major surgical revision for group 1 was 17.2% (5/29 humeri), for group 2 was 22.2% (2/9 humeri); and for group 3 was 4.8% (1/21 humeri). Most complications were associated with failure or instability of the bone-implant construct. Mean percentage of cortical overlap at the osteotomy was 31.45% for humeri with no complications, 30.92% for dogs with multiple screw breakage or humeral fracture, 32.60% for dogs with single screw breakage and 28.3% for dogs with delayed union at the osteotomy. Incidence of complications did not correlate with any dog factors recorded, although 2/3 dogs undergoing single-session bilateral procedures in group 1 went on to develop major complications.

Postoperative Clinical Evaluation

Duration of hospitalization postoperatively for provision of opioid analgesia or to monitor and assist ambulatory function ranged from 2 to 8 days.

Lameness. By 2 weeks postoperatively, all dogs were weight bearing with good ambulatory function. Several dogs had circumduction of the operated limb in the early preoperative period. Lameness score significantly improved across preoperative, 12- and 26-week postoperative evaluations (Friedman’s test; P < .0001). Lameness score at 12 weeks had improved compared with preoperatively for 40/55 elbows, remained the same for 11 elbows and was worse for 4 elbows. Lameness score at 12 weeks was not significant compared with preoperative score (Dunn’s multiple comparisons test). At 26 weeks, severity of lameness had improved for all dogs. Lameness had resolved in 21/32 elbows, was graded as 1/5 for 10 elbows, and 2/5 for 1 elbow (Fig 7). Improvements in lameness score at 26 weeks were significant compared
Table 1. Summary of Clinician VAS Scores for Pain on Elbow Manipulation

<table>
<thead>
<tr>
<th></th>
<th>Flexion</th>
<th>Extension</th>
<th>Supination</th>
<th>Pronation</th>
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<tr>
<td>Mean (± SD) VAS score (maximum 100)</td>
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<tr>
<td>Preoperative</td>
<td>59.59 ± 29.16</td>
<td>33.85 ± 30.26</td>
<td>73.32 ± 25.57</td>
<td>49.07 ± 27.99</td>
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<tr>
<td>12 weeks</td>
<td>27.90 ± 21.40</td>
<td>6.70 ± 11.66</td>
<td>38.90 ± 28.65</td>
<td>28.50 ± 30.86</td>
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<tr>
<td>26 weeks</td>
<td>15.92 ± 16.67</td>
<td>4.69 ± 9.71</td>
<td>17.35 ± 20.56</td>
<td>15.38 ± 22.01</td>
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<tr>
<td>P-value (1-way ANOVA – difference between preoperative, 12-week and 26-week scores)</td>
<td>&lt;.0001</td>
<td>.0053</td>
<td>&lt;.0001</td>
<td>.0003</td>
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<tr>
<td>Clinical significance (Bonferroni post hoc test)</td>
<td></td>
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<td>Preoperative versus 12 weeks</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Preoperative versus 26 weeks</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>12 weeks versus 26 weeks</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*Signifies statistical significance.

VAS, visual analogue scale.

with both preoperative and 12 week evaluations (Dunn’s multiple comparisons test. \( P < .05 \)).

**VAS.** Clinician VAS scores improved with significant decreases in pain on elbow manipulation between preoperative, 12- and 26-week assessments (Friedman’s test). Dunn’s multiple comparisons test showed that pain on elbow pronation was the only manipulation not significantly improved between preoperative and 12-week assessments, whereas all manipulations manifested improvement between preoperative and 26-week assessments. Pain on supination was the only manipulation variable to manifest significant improvement between 12- and 26-week evaluations (Table 1, Fig 9).

**Limb Morphology.** No significant differences in midbrachial circumference or maximum antebrachial circumference were detected at 12 or 26 weeks. Similarly, no significant changes in range of movement on elbow goniometry were observed throughout the follow-up period. Palpable effusion was present in 22/55 elbows preoperatively, 7/55 elbows at 12 weeks, and only 1/32 elbows at 26 weeks. Presence of effusion was not associated with either grade of lameness or scores of elbow pain on manipulation at any evaluation time point by logistic regression.

**Postoperative Owner Assessment**

Owner-assessed VAS function scores revealed that all dogs had improvement across the majority of functional variables at 12- and 26-week evaluations compared with preoperative scores. This was confirmed by 1-way ANOVA with only 4 owner-assessed functions (characterizing ability to climb up stairs, ability to sit down without pain, and owner interpretations of head nod at walk and run, respectively) not demonstrating significant improvements (Table 2). Bonferroni correction documented significant improvements between preoperative and 26-week assessments for all relevant assessments whereas significance of improvements between preoperative and 12 week assessments were more variable. No assessment variable had significant improvements between 12 and 26 weeks. Overall measures of owner satisfaction were universally high (Table 3).
Table 2. Summary of Owner-Assessed VAS Score Data

<table>
<thead>
<tr>
<th>Function Variable</th>
<th>12 weeks</th>
<th>26 weeks</th>
<th>52 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk without pain</td>
<td>76.34 ± 17.68</td>
<td>76.87 ± 15.40</td>
<td>76.90 ± 14.22</td>
</tr>
<tr>
<td>Run without pain</td>
<td>76.84 ± 13.94</td>
<td>77.14 ± 11.43</td>
<td>77.12 ± 10.73</td>
</tr>
<tr>
<td>Climb up stairs</td>
<td>70.12 ± 12.3</td>
<td>70.29 ± 11.48</td>
<td>70.78 ± 10.4</td>
</tr>
<tr>
<td>Climb down stairs</td>
<td>70.14 ± 11.97</td>
<td>70.24 ± 11.23</td>
<td>70.79 ± 10.6</td>
</tr>
<tr>
<td>Sit down on floor</td>
<td>69.00 ± 13.76</td>
<td>69.39 ± 12.82</td>
<td>69.96 ± 12.02</td>
</tr>
<tr>
<td>Stand on one leg</td>
<td>69.00 ± 13.76</td>
<td>69.39 ± 12.82</td>
<td>69.96 ± 12.02</td>
</tr>
<tr>
<td>ELA score</td>
<td>56.01 ± 29.30</td>
<td>57.01 ± 27.22</td>
<td>57.04 ± 29.49</td>
</tr>
<tr>
<td>ELA score (out of core)</td>
<td>56.01 ± 29.30</td>
<td>57.01 ± 27.22</td>
<td>57.04 ± 29.49</td>
</tr>
</tbody>
</table>

Table 3. Summary of Owner-Assessed VAS Scores for Overall Outcome

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Mean ± SD VAS score (maximum 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 weeks</td>
</tr>
<tr>
<td>Success of operation</td>
<td>79.40 ± 20.89</td>
</tr>
<tr>
<td>Would have operation</td>
<td>78.95 ± 23.37</td>
</tr>
</tbody>
</table>

VAS, visual analogue scale.

Neither clinician nor owner measures of postoperative outcome were found to associate with dog factors (body weight, age at surgery, gender, diagnosis of OCD), surgical factors (plate dimensions, application or timing of focal treatment of the coronoid process, surgical group) or historical factors (preoperative duration of lameness, preoperative administration of NSAIDs or nutraceuticals) by multiple regression analysis.

Radiographic Outcomes

Radiographic evidence of union and bone modeling between proximal and distal segments was documented.

Fig 10. Typical radiographic appearance showing callus formation 6 weeks postoperatively (A) and cortical modelling 26 weeks postoperatively (B) in a 2-year-old Labrador.
Fig 11. Arthroscopic image of elbow of 2-year-old Rottweiler 12 months postoperatively. Medial aspect of humeral condyle has complete fibrocartilage cover of previously eburnated subchondral bone. Lateral joint compartment remains visibly undiseased.

by 12 weeks for 53/55 humeri. By 26 weeks, 32/32 humeri had radiographic evidence of union at the osteotomy and adaptive changes in cortical contour. Figure 10A and B show typical radiographic findings 6 weeks postoperatively and 26 weeks postoperatively, respectively, for group 1 dogs. Significant changes in periarticular osteophytosis were not observed within the time-scale of this case series.

Fig 12. Humeral condyle of 8-year-old Labrador euthanati-zed 17 months postoperatively. Medial humeral condyle has fibrocartilage cover of previously eburnated subchondral bone. Lateral joint compartment remains visibly undiseased.

Fig 13. Lateral aspect of humeral condyle 17 months postoperatively showing healthy hyaline cartilage and subchondral bone.

Arthroscopic and Histologic Outcomes

Arthroscopic appearance in 1 dog at 12 months postoperatively, 2 dogs at 6 months postoperatively (bilaterally) and necropsy appearance in one dog 17 months postoperatively was consistent with substantial and palpably robust fibrocartilaginous cover of the previously eburnated medial joint compartment (Figs 11 and 12). The lateral joint compartment was not visibly diseased. Histologic examination confirmed that the lateral humeral condyle of the necropsy specimen (Fig 13) had maintained healthy hyaline cartilage cover with minimal indications of disease. Both specimens from the medial humeral condyle had diffuse, complete, healthy fibrocartilaginous cover with significant numbers of chondrocytes.

Fig 14. Medial aspect of humeral condyle 17 months postoperatively showing healthy fibrocartilage cover with significant chondrocyte activity, particularly at the osteochondral junction.
emanating from the region of the osteochondral junction (Fig 14).

DISCUSSION

Medium-term outcome measures indicated that SHO was associated with significant improvements in lameness, signs of elbow pain, and owner assessments of functional ability and lifestyle. Detectable lameness resolved in most dogs by 26 weeks. In spite of absence of autogenous bone graft at the osteotomy site, radiographic union of the osteotomy was complete by 12 weeks in 53 of 55 humeri and delayed union requiring intervention occurred in only 1 dog. Only 1 of 21 humeri operated by the currently adopted technique (group 3) had complication requiring revision and this failure could be attributed to technical error.

Arthroscopic and histologic evidence of de novo fibrocartilage cover of the previously eburnated subchondral bone without direct mechanical (eg. microfracture, osteitis) or biologic (eg. growth factor administration) stimulation may support the hypothesis that SHO can reduce loading of the medial joint compartment and may account at least in part for the clinical improvements identified, although further investigation is required to establish the clinical significance of this finding. Whereas similar cartilage generation has been documented in the human arthritis-affected knee following high tibial osteotomy and in experimental dogs after procedures designed to limit or prevent articular contact forces, to our knowledge these cases represent the first documented clinical canine cases of de novo cartilage generation without direct exogenous stimulation. Associations between degree of cartilage generation and clinical outcome associated with high tibial osteotomy in humans have not been reliably documented.

The secondary changes recognized in medial gonarthrosis of the human knee joint resemble in nature and extent the cartilage changes seen in MCD of the canine elbow and have been demonstrated to occur because of chronic overloading of the medial compartment. Radiolunar step defects, humerolunar incongruence, mechanical radiolunar–humeral varus deformity, or imbalances between skeletal and muscular mechanics may all contribute to medial compartment overload of the canine elbow. Although the pattern of disease is similar between the human knee and the canine elbow and though the initial concept for unloading the medial compartment of the elbow derived from this human analogue, pathogenesis is likely disparate and direct comparison between the 2-bone human and the 3-bone canine paradigms is not appropriate. Decreased pressure on the medial compartment of the human knee has resulted in documented clinical improvement but the technique and outcomes are still the subject of much debate. High tibial wedge osteotomy is used particularly in young patients where the obvious preference is to delay total knee replacement as long as possible. A similar strategy may be indicated for canine patients.

SHO has been viewed primarily as a salvage procedure in this case series and medical management, conventional surgical management, exercise modulation, and body-weight control was considered for all dogs before SHO. This recommendation is based on the possibility for complications in the early part of the learning curve, albeit that the refinements in surgical technique can be expected to limit morbidity considerably. Appropriate case selection criteria have yet to be fully elucidated for SHO and direct comparison with alternative management techniques including focal treatment of the coronoid process and antebrachial osteotomies has yet to be performed within affected candidate populations. However, in selected younger dogs with pronounced discomfort and impairment of quality of life associated with full-thickness cartilage loss of the medial compartment, SHO may represent a viable first line treatment option as demonstrated by positive outcomes in a number of dogs in this case series. It is notable that 27 dogs were <3 years old and 11 were <1 year old. Physical and aquatic therapies may assist rehabilitation, but the effects have not been objectively evaluated to date. Compatibility of SHO-operated humeri for conversion to total elbow replacement is currently unknown and should be considered as a factor in case selection. We do not perceive that SHO would be a precluding factor for later surgical revision to total elbow replacement if this eventuality were to be deemed necessary. Additionally, SHO is potentially associated with significant short-term postoperative discomfort in some patients. This prompted administration of a brachial plexus nerve block in all dogs after group 1.

Intensive perioperative nursing care is justified as is an aggressive proactive postoperative analgesia protocol.

The clinical outcomes we report are very encouraging, particularly the high incidence of resolution of lameness and marked improvements in discomfort on elbow manipulation. It is of note that 2 cases that had catastrophic humeral fracture and were subsequently stabilized by external skeletal fixation were excluded from subsequent outcome analysis providing a potential source of bias within the results. Their exclusion was necessitated by limitations posed by the external fixation system and associated imposed strict exercise restriction on completion of both clinician and owner outcome evaluations.

Consistent clinical improvement was documented for certain outcome variables including amelioration of lameness, subsequent to radiographic union of the osteotomy
without requirement for ongoing medication, which intimates amelioration of joint discomfort on an ongoing basis. Whether this is associated with “unloading” of exposed subchondral bone, amelioration of inflammation, fibrocartilage healing of the joint surface, or ongoing peri-articular soft tissue adaptation to biomechanical change has yet to be established. Outcome measures over a more prolonged timescale would be beneficial in further documenting this phenomenon, and ongoing monitoring of the reported cohort of dogs and subsequent cases is planned.

The lack of apparent associations between patient or surgical variables with outcome measures may be an artifact of the relatively limited case numbers and corresponding wide array of potential independent variables available for statistical analysis, or more probably could be attributed to the relative insensitivity of outcomes measures applied. Further work is therefore required to elucidate specific selection criteria for case-suitability and prognostic criteria, particularly in terms of clinical and arthroscopic findings. Our current recommendation based on documented outcomes for this case series is that SHO may be indicated for any elbow affected by full-thickness cartilage loss of the medial compartment. Focal treatment of medial coronoid disease is not required unless a free fragment is detached and may produce further frictional abrasion in spite of unloading of the medial compartment. In this case fragment removal may be beneficial and SCO is unlikely to be necessary, but definitive evidence for such recommendation is lacking. In this case series, no adverse sequelae were observed if no focal coronoid treatment was adopted in the absence of free fragments.

Technical application of SHO is considered clinically feasible. We strongly advocate arthroscopic evaluation as the gold-standard for thorough investigation of the joint, which must always precede surgical intervention by SHO. Confirmation of intact lateral articular surface (humero-radial) cartilage is a presumed prerequisite. Typical surgical time after the initial learning curve was ~ 25-40 minutes. DGS technique facilitates reproducible implant positioning with minimal migration of bone segments during plate application. There is structural disadvantage associated with the use of 2 nonlocking screws in the distal segment, although implant failure in this region was not observed. The pattern of screw breakage observed was in a sequential fashion from hole 4 through holes 3 and 2. Only isolated cases with known traumatic incidents during rehabilitation were exceptions to this trend.

We reasoned that this phenomenon was likely attributable to a mismatch in implant structural strength and load applied in a nonloadsharing construct, because all of the screws sheared at the junction of the screw with the cis-cortex of the proximal humeral segment, with the head staying locked in the plate. We also reasoned that eccentric loading of the humeral diaphysis produced a bending moment in the caudocranial direction, which contributed to cyclical failure of the screws at the junction between bone and plate. By increasing core diameter of the implants in screw holes 3 and 4, complication rate without known trauma or misapplication of technique declined dramatically between group 1 and group 3 cases.

Centering the plate around screw 4 contributed to more reliable plate positioning; avoidance of placement of the drill bit in hole 8 before translation circumvented issues with drill bit breakage; placement of a monocortical screw in hole 4 facilitated close apposition of the plate to the bone before translation and avoided potential errors with screw trajectory when drilling hole 1, where there is a tendency for the drill bit to slide down the sloping cortex of the proximal humerus, a factor not perceived with hole 4 where the plate is flush with the bone cortex. All of these modifications in technique reduce potential for error in plate placement and ensure screw placement perpendicular to the plate for maximum locking efficacy. Narrower profile drill guides now allow all eight holes to be pre-loaded with locking drill guides such that time spent placing drill-guides intra-operatively is minimized. Placing all screws in the end of the ‘combi-hole’ furthest from the step both proximally and distally maximizes working length of the plate-screw construct (except for the translational screw in hole 6 which needs to be as far apart as possible from screw 7 to prevent aberrant bone/plate motion during translation).

The stepped bone plate we used acted as a buttress plate with no or minimal force being shared by the cut ends. The use of a locking screw/plate bridging construct maximized construct stiffness. Cortical compression at the overlap of the cut ends, or compression of the cut end of the distal humeral segment and plate step may have lessened the stress placed upon the bone–screw–plate construct. When the distal humeral segment is translated by DGS technique, its most proximal portion migrates further medially than its most distal portion, because of the shape of the humerus relative to the plate and this may provide some compression, as well as mild valgus potentially resulting in additional unloading of the medial compartment. With further adaptation of technique it may also be possible to use the combi-holes as compression holes through development of “loading” drill guides for standard screws in positions 6 and 7. Prevention of relative migration of the bone segments was satisfactorily achieved using Kern bone clamps. This can also be achieved by placing a monocortical drill bit via a drill guide in hole 5 before tightening screws in positions 6 and 7. Within this series, variation in degree of cortical overlap was not associated with an increase in
complications. However, a minimum of 25% overlap is recommended, and we currently aim to achieve at least 33% overlap by use of the 7.5 mm stepped 3.5 mm plate in selected cases, based on preoperative radiographic measurements of diaphyseal diameter.

Complication rate in group 1 was considered excessive for clinical use, although most major complications could be attributed to technical errors during development of technique (such as cranio medial plate application or failure to engage maximal bone stock by suboptimal plate alignment) or failure of patient compliance with postoperative exercise restriction. Single-session bilateral procedures are contraindicated because of the incidence of major complications in 2/3 dogs operated in this manner in group 1. The initial high complication rate led to the modifications in technique and instrumentation documented for groups 2 and 3. The only complications in group 3 were 1 case of multiple screw breakage requiring revision 6 weeks postoperatively in an 8-year-old Bearded Collie, 1 delayed union in a 4-year-old Labrador operated bilaterally in procedures staged by 4 weeks (which healed by 13 weeks postoperatively without surgical intervention), 1 case of single screw breakage noted as an incidental finding at 6-week radiography, and immediate postoperative hematoma formation. The case of multiple screw breakage was attributed to a combination of technical error featuring cranial orientation of the proximal portion of the plate such that screws 1 and 2 needed to be angled slightly caudally and placed in nonlocking fashion, together with delayed clinical union consistent with relatively high patient age. The complication rate reported in group 3 is considered acceptable for widespread clinical application.

Lack of validation of the owner and clinical evaluation forms is a limitation of our study but validated outcomes instruments are not widely available in veterinary orthopedics. Similar results regarding timescale of improvements noted between owner and clinical evaluations help to support their application within this study. Force plate analysis would have provided additional outcome information and may prove to be a useful measure for identification of appropriate selection and prognostic criteria, but was not available. It is pertinent that the first author was the primary surgeon for all cases, performed the physical examination and evaluation for all cases, and was involved as 1 of the individuals scoring postoperative lameness of all cases. Though consistency of operating technique may be a beneficial commonality among cases, a degree of bias based in patient recognition cannot be excluded. However, consistent prospective application of the clinical evaluation questionnaire, consistency of the gait assessment protocol, addition of client-evaluation scores, and additional observers for postoperative lameness assessment in addition to blinding to scores from previous evaluations were all measures designed to optimize objectivity insofar as possible for this case series.

Optimal dimension of plate-step with regard to mediolateral load redistribution has yet to be determined, as have long-term biomechanical and clinical effects of the procedure. Fujita et al26 noted that individual variation between limbs was substantial, so biomechanical predictors may be difficult to fully elucidate. Mason et al24 suggested that abduction or adduction of the limb during weight bearing could also be associated with significant variation in biomechanical load distribution. Whereas circumduction of the operated limb was observed for most dogs in the immediate postoperative period, subjectively, video gait analysis suggested that paw placement by 6 months postoperatively was similar to that of normal dogs, with the paw being placed vertically below the glenohumeral joint. However, this cannot be verified without kinematic gait analysis and is a further limitation of this study.

Early results support our hypothesis regarding amelioration of pain and lameness in both juvenile and mature dogs after SHO, with or without focal treatment of the diseased medial aspect of the coronoid process, but further investigation is necessary to determine effect on long-term disease progression and to confirm recommended case selection criteria. SHO is a valid treatment for MCD and warrants consideration in cases affected by intractable pain of the medial compartment of the elbow. Demonstration of de novo fibrocartilage generation on the medial aspect of the humeral condyle via histopathology without application of exogenous factors acts as proof of principle regarding medial compartment unloading and supports further developments of this technique.

ACKNOWLEDGMENTS

We would like to thank Prof. G W Blunn PhD, Centre for Biomedical Engineering, Institute of Orthopaedics and Musculo-Skeletal Science, University College London, for histopathologic interpretation; Tim Vojt for rendering Figs 2–4; New Generation Devices for support and advice during development of the technique and implant design and the veterinary surgeons responsible for referral of patients included in this study.

REFERENCES

Appendix A: Owner questionnaire for Sliding Humeral Osteotomy

Appendix 1: Owner questionnaire for Sliding Humeral Osteotomy

Surname:........................... Animal Name:.................... Date:.../.../....

Please circle time of reassessment:
Pre-op 3 months 6 months Other.............

Leg(s) operated on......................

Purpose (i.e. pet, gun dog, agility dog, service dog).................................

Present Medication(s) and doses (includes drugs such as Rimadyl, Metacam, Zubern or food supplements such as Synoquin or Mobility Support tablets):
........................................................................................................
If any medication is used, how often to you use it .................................

Please answer the following questions by marking on the line how well or poorly your pet can perform each of the following. Mark an ‘X’ to indicate levels NOW:

| Example: How well can your dog eat biscuits? | Poorly | X | Very well |
| How well can your dog walk without pain? | Painful | Not painful |
| How well can your dog run without pain? | Painful | Not painful |
| How well can your dog climb UP stairs? | Poorly | Very well |
| How well can your dog climb DOWN stairs? | Poorly | Very well |
| How well can your dog jump up (for example, into the car)? | Poorly | Very well |
| How well can your dog jump down (for example, out of the car)? | Poorly | Very well |
| What is your dog’s exercise tolerance (ability to go for walks without stopping or tiring)? | Struggles on short walks | Copes fine with long walks |
| How well can your dog sit down without pain or hesitation? | Poorly | Very well |
| How well can your dog lie down without pain or hesitation? | Poorly | Very well |
| How well can your dog rise on front legs without pain or hesitation? | Poorly | Very well |
| Does your dog nod his/her head at walk? | Lots | Not at all |
| Does your dog nod his/her head at run? | Lots | Not at all |
| How would you grade the success of the operation? | Poor | Excellent |
| Would you have this operation done again in the same circumstances? | Never | Definitely |

Any further comments:.............................................................................................
.............................................................................................................................
.............................................................................................................................

.....
Appendix B: Clinician Questionnaire for Sliding Humeral Osteotomy

Appendix 2: Clinician Questionnaire for Sliding Humeral Osteotomy

Surname:.......................... Animal Name:.................. Date:....../....../....

Assessor:.........................

Please circle assessment time

<table>
<thead>
<tr>
<th>Pre-op</th>
<th>3 month</th>
<th>6 month</th>
<th>Other ...........</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Lameness score (0=sound, 1=intermittent mild weight bearing lameness, 2=consistent mild weight-bearing lameness, 3=moderate weight-bearing lameness, change in gait, 4=severe weight bearing lameness, toe-touching, 5=non-weight bearing)

<table>
<thead>
<tr>
<th>Pain on flexion</th>
<th>None L</th>
<th>R</th>
<th>Could not be more painful</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Pain on extension</th>
<th>None L</th>
<th>R</th>
<th>Could not be more painful</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Pain on supination (internal rotation)</th>
<th>None L</th>
<th>R</th>
<th>Could not be more painful</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Pain on pronation (external rotation)</th>
<th>None L</th>
<th>R</th>
<th>Could not be more painful</th>
</tr>
</thead>
</table>

Elbow goniometry (sedated)

- Left – extension..................
- Left – flexion....................
- Right – extension.................
- Right – flexion...................

Muscle mass measurement:

- Mid Brachial L ..................
- Mid Brachial R ..................
- Max. Antebrachial L ..........
- Max. Antebrachial R ...........

Elbow effusion (0=none, 1=noticeable, 2=severe standing)

- L: 0 1 2
- R: 0 1 2

Comments..................................................................................................................................................................................................

Please check owner questionnaire has been completed