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Mid- to Long-Term Outcome after Arthroscopy and Proximal Abducting Ulnar Osteotomy Versus Arthroscopy Alone in Dogs with Medial Compartment Disease: Thirty Cases

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Abstract

Objective The aim of this study was to determine owner-assessed mid- to long-term outcome for dogs with medial compartment disease treated arthroscopically with fragment removal with or without proximal abducting ulnar osteotomy (PAUL).

Study Design This was a retrospective clinical study.

Materials and Methods Records from 30 dogs with medial compartment disease treated with arthroscopy with or without PAUL were retrospectively reviewed over a 5-year period. Proximal abducting ulnar osteotomy cases were matched to arthroscopy-alone controls based on bodyweight and modified Outerbridge score. Outcome was assessed via owner questionnaire using the Canine Brief Pain Inventory (CBPI), frequency of non-steroidal anti-inflammatory drug (NSAID) administration and owner-assessed overall improvement.

Results Canine Brief Pain Inventory score for dogs in the PAUL group was not significantly different from the control group ($p = 0.54$). Non-steroidal anti-inflammatory drug administration was similar between groups ($p = 0.61$) and there was no significant difference between modified Outerbridge score and outcome ($p = 0.57$) over a median of 43 months post-surgically (range: 7–66 months). Canine Brief Pain Inventory and NSAID use were affected by the age of the dog with dogs greater than 3 years of age at the time of surgery having a higher CBPI score and increased NSAID use regardless of the surgery that was performed. Overall, owner-assessed improvement was not different between groups ($p = 0.72$).

Clinical Significance Proximal abducting ulnar osteotomy showed no owner-assessed benefit over arthroscopic medial coronoid fragment removal for dogs with medial compartment disease and modified Outerbridge score of 3 or greater. A prospective, blinded, controlled clinical trial is warranted to determine the appropriate clinical application of the PAUL procedure.

Keywords
- medial compartment disease
- elbow dysplasia
- proximal abducting ulnar osteotomy
- arthroscopy
- dogs

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Introduction

Developmental elbow disease is a broad term encompassing ununited anconeal process, osteochondritis dissecans and medial compartment disease. Medial compartment disease is the most frequently encountered component and is the most common cause of elbow pain and thoracic limb lameness in young, medium-to-giant breed dogs.[1,2] Medial compartment disease encompasses a heterogenous group of pathologies including subchondral bone sclerosis, medial coronoid microfracture or fissure, medial coronoid fragmentation and cartilage erosion. Any of the pathologies may occur independently or concomitantly within the medial compartment of the joint.[3,4]

Medial compartment disease is a heritable condition.[5] Affected puppies are born with normal elbows, developing delayed endochondral ossification of the medial coronoid process detectable as early as 14 weeks of age.[6] As maturation continues, trabeculae bone of the coronoid develops in an altered orientation to normal, indicating the presence of abnormal physiological forces. The orientation pattern has been shown to differ between fissures and fragmentation that occur at the level of the coronoid apex compared with those occurring along the radial incisure of the medial coronoid process.[7] Multiple theories have been proposed as to the origin of the supra-physiological forces through the joint, including dynamic humero-ulnar incongruency, humero-radio-ulnar varus instability, static and dynamic axial radio-ulnar incongruency and alteration in diameter of ulnar supracondylar notch. Recent kinematic studies have shown dogs with medial compartment disease have humero-ulnar incongruency and not radio-ulnar incongruency as previously hypothesized.[8] Excessive pronation during weight-bearing may result in supraphysiological forces at the level of the lateral aspect of the medial coronoid process, and in some cases, both axial incongruency and increased internal rotational shear stress are contributors to the development of fragmented medial coronoid process.[7,9] The pathophysiological variations in disease found between affected animals demonstrate that the pathogenesis of medial compartment disease is not fully understood, and it is likely that several aetiologies exist. Although different aetiologies for the various components of medial compartment disease are likely, similar surgical interventions have been advocated as all have the common goal in the prevention of progressive osteoarthritis.

Treatment options to prevent or minimize the progression of osteoarthritis in dogs with medial compartment disease have included arthroscopic removal of the fragmented medial coronoid process, local subtotal coronoid ostectomy, release of the biceps tendon or distant osteotomy of the humerus or ulnar.[4,10–13] Arthroscopic removal of the fragmented medial coronoid process is a common surgical treatment. However, conflicting reports cite improved outcomes or no benefit over conservative, non-surgical management and some reports indicate arthroscopic debridement and fragment removal as inferior to conservative management.[3,14–16] Multiple osteotomy techniques have been reported for the treatment of medial compartment disease, with the aim to redistribute contact forces away from the diseased medial compartment of the elbow in addition to or in place of fragment removal.[13,17] Sliding humeral osteotomy,[11,18] dynamic proximal ulnar osteotomy,[19] bioblique proximal ulnar osteotomy,[12] canine elbow realignment osteotomy[20] and proximal abducting ulnar osteotomy (PAUL)[17,21,22] have all been described. To date, evidence-based medicine for clinical application of these procedures is sparse. Additionally, the progression of osteoarthritis in the elbow is inevitable regardless of intervention.

The PAUL procedure (KYON Veterinary Products, Zurich, Switzerland) was first reported in in 2010.[23] Further proceedings published in 2012, 2014 and 2016 report the acceptance and use of PAUL in the clinical setting.[17,22,24] The procedure involves a proximal transverse ulnar ostectomy with the application of a custom 2 or 3 mm stepped plate that induces a 4- to 6-degree abduction of the proximal segment resulting in caudal tipping and medial axial rotation of the proximal ulna. The manufacturer claims the procedure unloads the medial compartment by shifting contact to the lateral compartment, thereby alleviating lameness, stiffness and joint pain.[25] The effect of PAUL procedure on pressure distribution has been assessed in an *ex vivo* cadaveric study; however, lateralization of the contact force did not occur and unloading of the medial compartment was not demonstrated.[26] To the authors' knowledge, no peer-reviewed reports currently exist on clinical outcome following the PAUL procedure.

The objective of this study was to report the owner-assessed mid- to long-term outcome for dogs with medial compartment disease treated with fragmented medial coronoid process removal and PAUL procedure compared with dogs treated with arthroscopy and fragmented medial coronoid process removal alone. Our null hypothesis was that the surgical procedure (PAUL or arthroscopy) would have no significant difference on owner assessment of outcome, owner questionnaire (Canine Brief Pain Inventory [CBPI]) or frequency of non-steroidal anti-inflammatory drug (NSAID) administration.

Materials and Methods

Sample Collection

A priori power analysis was performed using GPower 3.1.9.2 to determine the ability of the current study to find a treatment effect. Preliminary data obtained from a review of cases over a 2-year period were analysed and found a statistical power of 0.80 with $\alpha = 0.05$ each group required at least 15 pairs. Therefore, records of the Animal Referral Hospital Canberra database were searched for all dogs undergoing arthroscopy of the elbow for medial compartment disease or PAUL procedure over a 5-year period (2013–2018). Records were included if they contained comprehensive treatment and cartilage descriptions using the modified Outerbridge score (►**Table 1**).[27] Only cases with medial compartment disease comprising of cartilage erosion (modified Outerbridge score >3) and fragmented medial coronoid process were included. Dogs were excluded if concurrent elbow pathology existed in addition to medial compartment disease. Dogs presenting with bilateral disease were included with only one elbow used for data analysis so that a single dog was not included for analysis twice. The data recorded for each case included signalment, arthroscopic evaluation and graded description of cartilage using modified Outerbridge score,

Table 1 Modified Outerbridge score classification system[28]

Grade	Cartilage description
0	Normal cartilage
1	Chondromalacia (cartilage softening and swelling)
2	Fibrillation Superficial erosions with pitting or 'cobblestone' appearance Lesions that do not reach subchondral bone
3	Deep ulceration that does not reach the subchondral bone
4	Full-thickness cartilage loss with exposure of the subchondral bone
5	Eburnated bone

surgeon, time since surgery, complete CBPI questionnaire, record of current NSAID use and owner overall assessment of outcome (►**Appendix Table 1**, available online only).

Treatment Groups

In all dogs, arthroscopy was performed by one of two Diplomate, American College of Veterinary Surgeons (DACVS)-boarded surgeons (JM or BAS). Arthroscopy involved joint inspection, grading of articular cartilage, removal of bone fragment and coronoid debridement. In the PAUL treatment group, surgery was performed by one DACVS boarded surgeon (JM). All owners of dogs with medial compartment disease were offered the PAUL procedure in addition to arthroscopic fragment removal. The decision to treat with PAUL or fragment removal only was by owner choice. Postoperative care was identical between the groups and consisted of opioid analgesia for 12 hours postoperatively, then a course of carprofen (Rimadyl, Zoetis Rhodes, NSW, Australia) 2 mg/kg every 12 hours or meloxicam (Metacam, Boehringer Ingelheim North Ryde, NSW, Australia) 0.1 mg/kg every 24 hours for 10 days following surgery, crate rest for the first 2 weeks postoperatively, then increasing leash exercise for a subsequent 8 weeks.

Questionnaire

The CBPI questionnaire was used unaltered as a validated clinical metrology tool for assessing pain by owners of dogs with elbow osteoarthritis.[28] In addition to the CBPI questions, owners were asked how frequently NSAID medication was given and their overall assessment of outcome. Non-steroidal anti-inflammatory drug use and perceived improvement were both ordinal questions with a range from 1 to 5. For NSAID use, 1= *never,2= rarely, 3 = occasionally,4= regularly and 5 = daily*. For perceived improvement, 1= *poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent*. Owners were contacted by telephone. At the beginning of the telephone interview, the study aims and methodology was explained and consent obtained before reading the questions and recording owner answers.

Statistical Analysis

Statistical software (R v 3.0.2 R Foundation for Statistical Computing, Vienna, Austria, 2013; IBM SPSS Statistics for Windows, Version 25.0., IBM Corp, Armonk, New York, United States) was used for data analysis. All numeric continuous data were assessed for normality (Shapiro–Wilk test) and for homogeneity of variance (Levene's test). Data sets in non-normal distribution were summarized by using median and interquartile range (IQR). For ordinal outcomes (NSAID use and owner-assessed outcome), ordinal logistic regression was used, and general linear regression was used for the normally distributed CPBI. The effect of age on outcome parameters was determined by grouping dogs as <1 year, 1 to 3 years and >3years. For all analyses, $p < 0.05$ was considered statistically significant.

Results

A total of 17 dogs met the inclusion criteria for the PAUL group. A pool of 23 dogs met the inclusion criteria for the arthroscopy alone group. Dogs were selected from the arthroscopy alone group and case matched with the 17 dogs in the PAUL group based on their body weight and modified Outerbridge score. Two dogs were excluded due to inability to contact owners; therefore, two paired data dogs from the groups were removed, leaving 30 dogs for the final analysis.

Thirteen breeds were represented with the Labrador the most common (14/30) (►**Appendix Table 1**, available online only). There were five neutered female, two male and eight neutered male dogs in the PAUL group. The arthroscopy alone group comprised one female and five neutered female, two male and seven neutered male dogs. Nine dogs in the PAUL group had bilateral disease and eight dogs in the arthroscopy alone group had bilateral disease. Body weight ranged from 20 to 67 kg in the PAUL group (median: 30kg [IQR] 26–34kg) and from 18 to 62 kg in the arthroscopy alone group (median: 32kg [IQR] 27.5–33.5kg).

Body weight and modified Outerbridge score were not significantly different between groups. The PAUL group included two dogs with grade 3, eight dogs with grade 4 and five dogs with grade 5 modified Outerbridge score. The arthroscopy alone group included three dogs with grade 3; seven dogs with grade 4 and five dogs with grade 5 modified Outerbridge score (►**Appendix Table 1**, available online only). Modified Outerbridge score had no effect on CBPI, NSAID use and owner-assessed outcome regardless of the length of time of follow-up ($p = 0.21$, $p = 0.15$ and $p = 0.56$ respectively).

Age at time of surgery ranged from 0.5 to 7 years (median: 1.8 years) in the PAUL group and 0.6 to 8 years in the arthroscopy alone group (median: 1.5 years). The follow-up time ranged from 7 to 66 months (median: 43 months). The PAUL group had a median follow-up time of 36 months (7–66 months) and the arthroscopy alone group was 43 months (7–63 months). For every month longer in follow-up after surgery the chance of increasing NSAID use increases by a factor of 0.014.

The effect of PAUL compared with arthroscopy alone was assessed using three outcome measurements: CBPI, NSAID administration and owner-assessed outcome (►**Appendix Table 1**, available online only). Treatment with either PAUL or arthroscopy alone had no significant effect on any variable ($p = 0.54$, 0.61, 0.72 respectively).

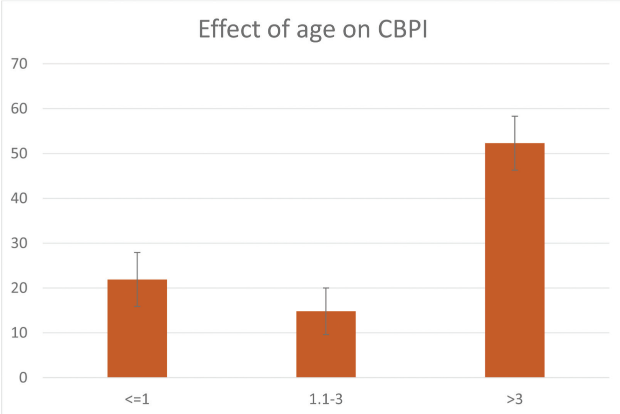

Fig. 1 Effect of age on Canine Brief Pain Inventory (CPBI). Animals older than 3 have a significantly higher CBPI score compared with animals younger than 3. There is no statistical difference in CBPI between the two younger age groups ($p = 0.654$).

Canine Brief Pain Inventory and NSAID use were significantly affected by age at the time of surgery ($p < 0.001$ and $p = 0.02$ respectively). Dogs > 3 years at the time of surgery had a significantly higher CBPI score at follow-up, compared with younger dogs ($p < 0.001$). Dogs < 3 years of age had a predicted mean CBPI of 14.8 ± 5.21, dogs aged 1–3 years had a predicted mean CBPI 21.9 ± 6.02 and dogs > 3 had a predicted mean CPBI of 52.3 ± 6.02. Canine Brief Pain Inventory score was similar in younger dogs aged < 1 or 1 to 3 years old ($p = 0.65$) (►**Fig. 1**). Non-steroidal anti-inflammatory drug use was more likely to be higher in dogs >3 years of age compared with younger dogs ($p = 0.01$) (►**Fig. 2**).

Discussion

The null hypothesis was accepted because no difference in owner-assessed outcome, CBPI scores or frequency of NSAID administration was found in dogs with medial compartment disease treated with arthroscopic intervention with or without PAUL. A good-to-excellent outcome was recorded for 22 of 30 dogs irrespective of treatment group in the median follow-up of 43 months postoperatively (►**Fig. 3**). Similar

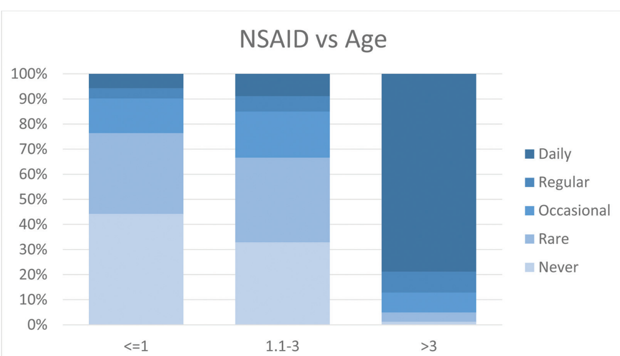

Fig. 2 Effect of age on non-steroidal anti-inflammatory drug (NSAID) use. Percentage of population and relative frequency of NSAID use by age group. Dogs >3 years have a significantly higher chance of increased NSAID use compared with both the younger age groups ($p = 0.0013$ and $p = 0.0024$).

Fig. 3 Owner-assessed overall outcome. No difference existed between treatment groups ($p = 0.72$). PAUL, Proximal abducting ulna osteotomy.

outcomes have been reported in dogs treated with arthroscopic intervention and recorded in proceedings for dogs treated with PAUL procedure.[14,15,24]

The median CBPI scores were the same for both groups. A recent study by Dempsey and colleagues used CBPI to compare arthroscopy and conservative management in dogs with medial compartment disease, and also showed no significant difference in long-term outcome. In that cohort of dogs, the median CBPI was lower (11/100) compared with this study (25/100).[15] This may be due to increased severity of joint disease in the current population as the inclusion criteria were set to exclude mildly affected dogs with modified Outerbridge score < 3. The Dempsey study[15] did not report the severity of cartilage erosion making comparison of these findings difficult.

No significant difference in NSAID administration existed between treatment groups. However, CBPI and NSAID use were affected by the age of the dog with dogs greater than 3 years of age at the time of surgery having a higher CBPI score and increased NSAID use at follow-up, regardless of treatment. The length of follow-up was longer in some dogs than others and this was found to affect the frequency of NSAID use but not the CBPI score or owner overall assessment of outcome. For every month of longer follow-up time, the use of NSAIDS increased in frequency by 0.014-fold. This indicates that there is a small correlation in increasing NSAID use over time regardless of treatment group ($p = 0.04$). This finding demonstrates that pain associated with elbow disease progresses with time irrespective of treatment. Previous non-peer reviewed studies on the PAUL procedure have reported a poor response rate in older dogs which is consistent with the findings reported here.[22] Older dogs presenting with medial compartment disease may have a different disease aetiology than younger dogs. Dogs presenting with medial compartment disease > 6 years of age have differing joint pathology compared with younger dogs.[4] Alternatively, older dogs may have a poor response to treatment due to the advanced stage of osteoarthritis present. All of the dogs in this study had advanced cartilage lesions (modified Outerbridge score > 3) at the time of surgery. It is unknown if early intervention with PAUL, prior to the onset of osteoarthritis, would improve outcome in dogs with medial compartment disease.

In this study, PAUL and arthroscopy failed to improve owner-assessed outcome, NSAID use and CBPI compared with arthroscopic fragment removal alone. Reasons for the lack of improvement may include incorrect application of the PAUL plate, such that an insufficient step was applied at the time of surgery resulting in under-abduction of the proximal ulnar, or that the PAUL procedure may not have altered the contact area of the joint adequately to reduce or suspend disease progression. Postoperative radiographs did not identify any inadequate plate application. McConkey and colleagues recently demonstrated that the contact area in the joint decreased in the medial compartment, but was not increased in the lateral compartment following PAUL procedure.[26] They hypothesized a pressure transfer to the anconeal process.[26] No improvement in outcome in the PAUL group in this study may have been due to increased pressure on the anconeal contact area resulting in a poorer outcome.

Limitations of this study included the small sample size, lack of control dogs without medial compartment disease, retrospective design and lack of preoperative assessments. The small sample size may have allowed for a type II error to occur; however, the inclusion of 15 matched pairs by body weight and modified Outerbridge score increased the power of the study and enable analysis. The clinical metrology tool used in the current study has been successfully validated for application in owner assessment of elbow disease.[29] The retrospective nature precluded randomized treatment groups, and no objective data were obtained at follow-up. Not all records contained a description of axial congruence and some records lacked description of coronoid process fragmentation as either tip or radial incisure. Accurate descriptions of the elbow pathology and limitation of study groups to one pathology may help to facilitate comparison of procedures and outcome in the future. Inclusion of dogs with modified Outerbridge score < 3 and no other joint pathology except medial compartment disease would enable determination of the effects of PAUL over time and its potential for slowing or inhibiting the progression of elbow disease due to medial compartment disease.

Conclusion

The PAUL procedure along with arthroscopy had no significant benefit over arthroscopy alone for this cohort of dogs with medial compartment disease, with respect to CBPI, NASID use and owner-assessed outcome. Increased age at the time of surgery increased the CBPI score and the incidence of NSAID use at follow-up for all dogs. A prospective, randomized, controlled clinical trial is warranted to determine whether some aspects of the complex medial compartment disease might benefit from PAUL.

Authors' Contributions

Fiona J. Coghill contributed to conception of study, acquisition of data and data analysis and interpretation. Louisa K. Ho-Eckart contributed to study design. Wendy I. Baltzer contributed to data analysis and interpretation. All authors drafted, revised and approved the submitted manuscript.

Conflict of Interest

None declared.

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