Evaluation of Lameness Associated with Arthroscopy and Arthrotomy of the Normal Canine Cubital Joint

by

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(ABSTRACT)

This study compared lameness and post-operative recovery in animals undergoing arthroscopy or arthrotomy of the cubital joint. It was a prospective, randomized, experimental study in which fourteen mature, healthy dogs were evaluated. Dogs were randomly assigned to treatment groups with seven undergoing arthrotomy and seven undergoing arthroscopy of the left cubital joint. Dogs were evaluated using kinetic gait assessment, subjective evaluation scores, and cubital joint range of motion (ROM). Evaluations were performed prior to surgery and on days 2, 4, 7, 15, 22, and 29 after surgery. Preoperative radiographs of both cubital joints and postoperative radiographs of the operated limb were evaluated. Significant differences in peak vertical force and vertical impulse force were not observed between surgery groups ($p=0.88$ and 0.49, respectively). Joint ROM was not significantly different between groups ($p = 0.09$ for flexion and 0.91 for extension). For all dogs, joint ROM and radiographic evaluations remained within normal range throughout the study period. Additionally, significant differences in subjective lameness scores, weight bearing and pain were not observed

between groups ($p \geq 0.19$ for all variables). Therefore, post-operative morbidity may not be an important factor when making a decision to perform either arthroscopy or arthrotomy for exploration of the medial aspect of the canine cubital joint.

DEDICATION

This project is dedicated to the faithful research dogs that served in it. They were always eager to work and always willing to lend a wagging tail. It was their dedication and willingness to walk time after time across the force plate that made this project possible. The unconditional love and energy they shared will not be forgotten.

Chloe

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INTRODUCTION

The demand for arthroscopy in veterinary surgery is increasing as veterinarians and their clients become aware of its availability and effectiveness as a tool in the treatment of various joint conditions. Historically, canine arthroscopy was limited due to large scope sizes as compared to the relatively small size of canine joints[1]. However, with the evolution of arthroscopy in human orthopedic surgery, smaller arthroscopes are now available, making arthroscopy a viable option for joint exploration in some dogs. The development of smaller scope sizes and the increasing demand for minimally invasive surgical techniques has lead to expansions in the field of veterinary arthroscopy.

Indications for intra-articular surgery in veterinary patients include diagnosis and treatment of intraarticular disease, obtaining samples for histopathologic evaluation, and an adjunctive treatment for arthritis. Both arthroscopy and arthrotomy are effective when used for those purposes. However, when compared to arthrotomy, arthroscopy has been reported to have several advantages when used in the canine patient. These include reduced scarring, a more rapid return of the patient to function, improved joint visualization, and providing a less invasive means for diagnosis of intra-articular disease[2-7].

Arthroscopy also has some disadvantages when compared to arthrotomy for the treatment of intra-articular disease. Arthrotomy requires few instruments compared to the specialized equipment required for arthroscopy[8], and arthroscopic equipment is

expensive, making it cost prohibitive for many practitioners. Effective use of arthroscopic procedures in the treatment of intra-articular disease requires advanced training and experience[9]. In clinical cases with severe degenerative joint disease, it can be difficult, or even impossible, to insert the arthroscope within a joint for evaluation[3, 4, 9]. Additionally, in those cases where arthroscopy is ineffective for its intended purpose of treatment, it may be necessary to perform an arthrotomy in order to provide adequate treatment[10, 11].

ARTHROSCOPY

Background

Arthroscopy in the dog was first reported in 1978[12]. Since that time, the use of arthroscopy in small animal surgery has greatly expanded. Arthroscopic procedures have been employed for the treatment of osteochondritis dissecans (OCD) of the hock, stifle, shoulder, and elbow; treatment of fragmented medial coronoid processes of the ulna (FMCP); arthroscopic cranial cruciate ligament reconstruction; meniscectomies of the stifle; biopsies of various intra-articular structures; and as an aid in the diagnosis of intra-articular disease[2-5, 9, 13-16].

Arthroscopes are available in various external diameter sizes, including 1.7 mm, 2.2 mm, 2.7 mm, and 3.5 mm, with a wide variety of scope cannula sizes as well. The 2.7 mm arthroscope is commonly employed in small animal veterinary surgery due to the small size of canine joints[17]. Larger scope sizes have a larger field of vision. However, the effective field of vision of smaller arthroscopes can be increased by having the end optic of the scope offset at an angle and by rotating the scope within the joint about its longitudinal axis. The angle the scope is offset is called the foreoblique angle and can be defined as the angle between the long axis of the arthroscope and the center of the field of view[18]. Although larger angles could potentially increase the field of vision, the greater the angle, the more difficult the image becomes to orient. A 25 to 30 degree foreoblique angle is most often used in veterinary surgery and provides an adequate intra-articular

view. Arthroscopes attached to an eyepiece (direct-viewing scopes) are available, but scopes with camera attachments and viewing monitors are more commonly employed since they are easier to use. Additionally, arthroscopes can operate with a variety of light sources including tungsten, metal halide, and xenon; listed in order of increasing intensity and usefulness[18]. Tungsten bulbs are the least expensive, but are also the least powerful. The color range for this light source is in the yellow–orange range and it operates at 150 watts. Metal halide bulbs run at 300 watts with a much whiter light. However, they are more expensive than the tungsten light sources. Although the most expensive, xenon light sources are the most powerful. They provide the most accurate color definition and run at 300 watts.

Fluid or gas(CO_2 or N_2O) may be used for joint distension[19]. Gas distension has the advantage of a larger field of view and sharp delineation of details. However, gas distension requires special equipment, hemorrhage can obscure the field of view, and post-operative periarticular emphysema can develop[20, 21]. Fluid joint distension systems are most commonly employed in human orthopedics, and, besides experimentally, always employed in veterinary surgery[1].

In veterinary surgery, an arthroscopic procedure begins with sterile preparation of the affected limb. The joint is generally distended with a balanced electrolyte solution prior to scope insertion. Some surgeons prefer to place bupivicaine and/or epinephrine within the solution to aid in pain control and hemorrhage, respectively. After joint

distension, the arthroscope and arthroscopic instruments are placed within the joint through portals created with blunt or sharp trocars. Arthroscopic surgery is generally performed using a triangulation technique. This requires that the arthroscope be placed in one area of the joint and the instruments in another such that a triangle is formed between the field of view and the instrument portals (see figure 1, p. 49). This technique increases maneuverability and optimizes the view[1].

Complications

Reported complications associated with arthroscopy include pericapsular fluid accumulation, obstruction of the visual field by intra-articular elements and hemorrhage, difficult arthroscope insertion, infection, pain, seroma, cartilage scarification, trauma to periarticular soft tissues, inability to correct the patients problem without additional arthrotomy, and iatrogenic instrument damage[3-5, 10, 11]. In human medicine, iatrogenic nerve damage is also a concern, but that has not been reported in veterinary medicine[22, 23].

Iatrogenic cartilage damage from arthroscope insertion is a concern during arthroscopic procedures. The healing of articular cartilage following arthroscope scarification has been evaluated[24]. This study evaluated the healing of articular cartilage over a four-week time period. Superficial lesions smoothed, but did not completely heal during this time[24]. Deeper lesions also showed superficial smoothing, but they typically filled in with fibrocartilage[24]. With insertion of the scope into canine stifle joints, the tip

of the arthroscope created only superficial lesions, and these lesions showed little, if any, inflammatory reaction[24].

Cubital Joint Arthroscopy

Arthroscopy of the cubital joint in small animal surgery is rapidly growing in popularity. In 1993, Van Ryssen evaluated a medial approach to the cubital joint in dogs[4]. The arthroscope was inserted caudodistal to the medial epicondyle of the humerus. Cadaver studies found that the trocar for arthroscope placement passed through or between the muscles of the deep digital flexor and superficial digital flexor and that minimal cartilage damage occurred with arthroscope insertion at that site. Neurovascular injury was not noted. Additionally, animals were minimally affected, minimally lame and minimal problems with the surgical site, by the procedure and visualization was adequate for evaluation of the medial aspect of the cubital joint.

Bardet, et. al. also reported on a craniolateral approach to the cubital joint[25]. In this approach, the arthroscope was placed craniolateral to the lateral humeral epicondyle. All the medial structures of the joint could be visualized; however, the lateral component of the cubital joint could be visualized more readily than with the medial approach. With this approach, the trocar passed cranial to the pronator teres muscle or through the insertion of the pronator teres muscle. Again, no neurovascular damage was noted and minimal cartilage damage was visualized.

Both the medial and craniolateral approach provide adequate exposure of the cubital joint for arthroscopic procedures. The medial approach is most commonly employed in veterinary surgery due to superior exposure of the medial aspect of the joint, where clinical problems occur commonly in small animals[1, 7]. Using this approach, Van Ryssen evaluated 148 cubital joints in dogs with clinical forelimb lamenesses[7]. In that study it was found that lesions were adequately identifiable and that treatment of diseases such as fragmented coronoid process of the ulna and ODC through the scope was consistently possible. Visualized lesions included cartilage fissures, FMCP, chondromalacia, OCD, and kissing lesions on the humerus. Other studies have also found arthroscopic treatment of cubital joint diseases such as FMCP and OCD through this approach to be beneficial in that the procedure could be performed easily and animals were using the limbs postoperative[11].

KINETIC GAIT ASSESSMENT

Biomechanics

Kinesiology, the science of motion, can be divided into kinematics and kinetics[26, 27]. Kinematics describes motion irrespective of mass and force, while Kinetics describes motion and its relationship with the forces that generate it. Although subjective gait assessment is a basis for many veterinary studies, kinetic and kinematic gait analyses have become more reliable and conclusive when it comes to comparing limb abnormalities from one animal to the next. Kinetic gait assessment is now a routine part of many analyses such as those that evaluate recovery in animals undergoing orthopedic procedures and those comparing orthopedic procedures with respect to recovery[28-31].

The force plate is a specialized scale that measures external forces between an object and the ground. These forces are called ground reaction forces. Force transducers support the plate[26]. When a force is applied to the force plate, the plate deforms, triggering the transducers. The amount of deformation is expressed as a percentage of the plate's original dimension (strain)[26]. Strain is transmitted through the force transducers and a computer converts the amount and direction of plate (or force transducer) deformation to a force. Computed force variables include the stance duration; the magnitude of the vertical (Fz), craniocaudal (Fy), and mediolateral (Fx) forces in the stance phase; the time when the peak forces occur; the impulse (area under the curve) in

all three directions; and the point of application of the force on the plate (center of pressure)[26].

Vertical forces most directly measure weight bearing, have the greatest magnitude, and are the most consistent[26, 32]. Therefore, these forces are the most widely used descriptors of pathologic gait[32]. Impulse forces are also commonly used and are a measure of function throughout the stance phase of the gait cycle. While vertical force is a good indicator of lameness, impulse force is a good indicator of overall limb function.

Most gait studies are performed with the animal at a walk or trot. These are considered symmetric gaits and are characterized by repeated movements on both sides of the body[33]. The vertical forces of the trot in the dog are graphed as single, sharp peaks for the fore and rear foot, whereas those for the walk are flatter and each peak has a characteristic "M" shape, at least for the rear limb[34, 35].

Force Plate Data in Experimental Design

When considering the use of kinetic gait assessment in experimental evaluation, many factors must be considered. Subject size, velocity, acceleration, and lameness can affect the computed data from force plate analyses. Size is directly proportional to breaking, propulsion, and vertical impulse force, but is inversely proportional to peak vertical force[34]. Therefore, larger subjects have a lower peak force on each limb, but a higher total impulse during the stance phase. Peak vertical forelimb and hind limb forces increase and vertical impulses decrease with increasing subject velocity[36]. Changes in

velocity of greater than 0.3 m/s will significantly alter those forces[36]. Alterations in acceleration can also significantly affect data collected in the craniocaudal axis of the forelimb and can potentially affect vertical data collected for the rear limb[37]. Lameness may also affect force plate data in that weight redistribution to unaffected limbs may occur[31, 38, 39]. Rear limb lamenesses are more predictable than forelimb lamenesses in that redistribution of forces from a rear limb lameness occurs primarily to the opposite rear limb[31, 39]. However, multiple force redistribution can occur with forelimb lameness[40].

In addition to the above-mentioned factors, sources of variation associated with kinetic gait assessment have also been evaluated. Possible sources of variation in kinetic gait assessment include the dog, the dog handler, inter-day variation, and trial repetitions. Total variation associated with kinetic gait assessment is relatively small, varying between 5.8% and 8.5 %[41]. The percent contribution of each variable ranges, but that attributed to the dog was the greatest and that to the dog handler was the smallest[41, 42]. Limb symmetry has been evaluated and it was found that variance attributable to paired limb variation was approximately 3 percent[32]. Coefficients of variation for the cranial and caudal impulses was of greater magnitude than were those for the vertical forces or impulses, mainly due to the difference in magnitude between these forces[41].

The number of repetitions and dogs required to minimize variation attributed to repetition was also evaluated[41]. If a difference of 10% is to be detected between treatment

groups and the study has a power of 80% with p set at 0.05, then approximately 11 dogs per group would be needed with each dog undergoing at least 5 valid trials across the force plate[41]. Although this was calculated for a specific experimental study, the guidelines set forth can be considered for all studies involving kinetic gait assessment.

ARTHROSCOPY VERSUS ARTHROTOMY

Cubital Joint

Stabilizers of the elbow joint include the collateral ligaments, joint configuration, joint capsule, and surrounding muscles and tendons[43]. Elbow joint configuration contributes to stability by allowing an interlock between the anconeal process, trochlea and the olecranon fossa. Chronic joint instability can lead to degenerative joint disease[44]. Therefore, it is reasonable to think that the optimal approach to the medial aspect of the cubital joint would be one that causes minimal morbidity and allows for the greatest post-operative stability. Additionally, ligaments and tendons take an extended period of time to regain full strength because collagen synthesis and the remodeling phase of these tissues are slow[45]. Therefore, minimal tissue disruption would be ideal.

Several approaches to the medial aspect of the canine cubital joint have been described to treat diseases such as FMCP, UAP, OCD, articular fractures, and cubital joint luxations. These approaches include olecranon osteotomy [46, 47], triceps tenotomy[48, 49], muscle splitting/separation[50], transection of the medial collateral ligament[51], osteotomy of the medial epicondyle[52], myotomy of the flexor carpi radialis muscle[53], and medial and lateral arthroscopic approaches[4, 25].

Complications associated with arthrotomy include potential joint destabilization, pain, seroma, infection, dehiscence, and the development of degenerative changes[43, 51, 54]. Additionally, during arthrotomy with subsequent air exposure, mature articular cartilage

is deprived of synovial fluid, it only source of nutrition. Even brief air exposure can cause cartilage to darken and develop a dehydrate appearance if joint irrigation is not appropriately performed[55]. Therefore, when using various arthrotomy techniques, one should consider the potential adverse affects on the joint.

Elbow arthroses can result in devastating osteoarthritis and debilitating lamenesses in those animals affected. Developmental conditions such a FMCP, OCD, ununited anconeal process (UAP), or joint incongruity are frequent initiators of cubital joint degeneration, and arthroscopy or arthrotomy are frequently used in the surgical management of these conditions. The progression of these diseases is one of continued joint degeneration through the process of cartilage breakdown, synovitis and alteration of the joint environment[56]. The underlying cause of the various components of elbow dysplasia is somewhat controversial but has included failure of endochondral ossification and asynchronous growth between the radius and ulna[57, 58]. Whatever the underlying etiology, osteoarthritis generally ensues[56].

Treatment of elbow dysplasia has been a controversial subject. Some recommend surgical intervention[7, 51, 56, 59, 60], while others consider conservative management adequate[61, 62]. The premise behind surgical intervention for elbow dysplasia is that it will help alleviate pain associated with the underlying condition and that limb function will be improved in spite of continued development of osteoarthritis[56, 63]. Intuitively, a surgical

approach that would minimize joint trauma, and therefore minimize the effect of surgery on disease progression, would be ideal.

Comparative Studies

A number of veterinary studies have described and compared arthroscopy and arthrotomy[2, 3, 5, 6, 13]. However, with respect to postoperative lameness and return to function, most of these studies were limited to subjective evaluations[2, 4, 9, 64, 65]. Bertrand *et al.* subjectively evaluated lameness and return to function in dogs that had undergone arthroscopy or arthrotomy of the stifle joint to treat osteochondritic lesions[2]. In this study, it was determined that dogs undergoing arthroscopic treatment recovered sooner and were less lame than those undergoing arthrotomy. Miller, *et al.* Found the same thing when he evaluated normal stifle joints of dogs, but he also objectively evaluated recovery in those animals[64]. In Miller's study, synovial fluid from the stifle joint of normal dogs was evaluated for abnormalities following arthrotomy or arthroscopy. The dogs that underwent arthroscopic evaluation had fewer initial synovial fluid abnormalities and showed earlier resolution of those abnormalities than those that underwent arthrotomy[64]. Although the arthroscopy group exhibited reduced lameness on subjective evaluations, objective information regarding return to function in that study was not available. Person objectively evaluated return to function in small animals that underwent arthroscopy of the glenohumeral joint for treatment of OCD[5]. Although this study evaluated lameness

using kinetic gait assessment, only 10/23 animals were evaluated at follow-up and a direct comparison to animals that had undergone arthrotomy was not performed.

In the veterinary literature, few reports have evaluated the use of arthroscopy to treat cubital joint diseases, and most of these lack a direct comparison between arthroscopy and arthrotomy with respect to recovery[4, 66, 67]. Schwarz, *et al.* published an abstract comparing arthroscopic treatment of FMCP to treatment with arthrotomy and found that arthroscopically treated dogs were less lame as determined by kinetic gait analysis in the immediate postoperative period[11]. From the information available, it is not known what type of arthrotomy was performed and dogs were only followed for 48 hours postoperatively. Furthermore, animals in that study had pre-existing elbow disease making a direct comparison between groups difficult since it is not known what effect disease had on lameness in the pre and post-operative period.

PURPOSE

The purpose of the study reported here was to provide objective and subjective data regarding lameness and post-operative recovery in normal dogs that have undergone either arthroscopy or arthrotomy of the normal cubital joint. Based on review of the available literature, the study hypothesis was that animals undergoing arthroscopic exploration of the cubital joint would recover sooner and be less lame than those undergoing arthrotomy.

MATERIALS AND METHODS

Dogs

Fourteen, random source, mature dogs with a median weight of 27 kg (22.7 kg to 34.1 kg) were evaluated in the study. Dogs were housed in 1.5 x 3 m runs and allowed to acclimate to their environment for at least two weeks prior to initiation of the project. Dogs underwent physical examinations, including complete neurologic and orthopedic examinations. Additionally, blood was drawn from each dog for packed cell volume, total plasma protein concentration, and blood urea nitrogen concentration determination. Bilateral cubital joint radiographs were also taken for joint evaluation. Dogs were determined to be healthy and free of orthopedic and neurologic disease based on the findings of these examinations. All dogs were evaluated subjectively and objectively for

lameness and morbidity prior to and after arthroscopy or arthrotomy of the left cubital joint. All procedures were approved by the Animal Care Committee of Virginia Tech.

Surgery

Dogs were randomly assigned to a surgery group. Seven dogs underwent arthroscopy of the left cubital joint and seven underwent arthrotomy of the left cubital joint. For all dogs, both the right and left forelimbs were clipped and aseptically prepared for surgery. Dogs were premedicated with acepromazine maleate (PromAce®, Fort Dodge Animal Health, Fort Dodge, IA 50501, USA), 0.05 mg/kg; and morphine sulfate (Elkins-sinn Inc., Cherry Hill, NJ 08003-4099, USA), 0.5 mg/kg, intramuscularly. Anesthetic induction was achieved with 2.5% thiopental (Pentothal®, Abbott Laboratories, North Chicago, IL 60064, USA), 10 mg/kg intravenously to effect, and maintained with isoflurane (Isoflo®, Abbott Laboratories, North Chicago, IL 60064, USA) after orotracheal intubation. Dogs received 1 dose of cefazolin sodium (Apothecon®, Bristol-Myers SQUIBB Co., Princeton, NJ 08540, USA), 22 mg/kg, at induction of anesthesia. Following completion of the surgical procedure, each dog was given an intra-articular injection of 0.75% bupivacaine (Marcaine®, Abbott Laboratories, North Chicago, IL 60064, USA), 1 ml diluted in 2 ml of sterile saline, followed by a subcutaneous injection of morphine sulfate, 0.5 mg/kg. The morphine sulfate injection was repeated 6 hours after the first dose.

Arthroscopy

A 2.7 mm arthroscope attached to a video system was used for the arthroscopic procedures (Smith & Nephew Dyonics® Inc. Andover, MA 01810, USA). The arthroscope was equipped with a 30-degree foreoblique angle and the scope cannula was 2.9 mm in diameter. The dogs were placed in left lateral recumbency with the right limb pulled caudal and out of the way. Each joint was manually held abducted throughout the procedure. A towel pack was placed under the lateral aspect of the limb in the region of the elbow. This acted as a fulcrum while the distal limb was manually abducted to cause medial opening of the cubital joint and facilitate instrument placement and manipulation. A medial, two portal triangulation technique was used[51]. Joints were distended with 15-20 ml of sterile Lactated Ringer's (USP, Baxter Healthcare Corp., Deerfield, IL 60015, USA) solution prior to scope insertion. The arthroscope portal was placed approximately 0.5 cm caudal and 1.0 cm distal to the medial epicondyle such that it passed into the joint near the proximal aspect of the flexor carpi radialis and deep digital flexor muscles. The arthroscope was positioned caudomedial to the medial coronoid process of the ulna. The instrument portal was placed along the craniomedial aspect of the cubital joint approximately 1 to 2 cm cranial to the arthroscope portal, just caudal to the medial collateral ligament (see figure 1, p. 49). The radial head, medial coronoid process, medial aspect of the humeral condyle, and medial collateral ligament were visualized with the arthroscope (see figure 2, p. 50).

In order to mimic a clinical procedure, arthroscopic instruments were placed in and out of the instrument portal a total of 10 times, each time touching the radial head. Instruments included a 2.9 mm shaver blade (non-powered) and various small joint forceps and rongeurs designed for arthroscopic use (Smith & Nephew Dyonics® Inc. Andover, MA 01810, USA)(see figure 3, p. 51). Joints were irrigated with a total of 1.5 L of Lactated Ringer's solution during the procedure. Flushing was accomplished with the InteliJET™ fluid pump system (Smith & Nephew Dyonics® Inc. Andover, MA 01810, USA). This fluid management system was programmed to maintain an intra-articular pressure of 40 mm Hg[68-70].

After the procedure, instrument and scope portals were closed with interrupted cruciate sutures of 3-0 monofilament nylon (Dermalon, Sherwood Davis & Geck, Sherwood Medical, St. Louis, MO 63103, USA).

Arthrotomy

The dogs were placed in left lateral recumbency with the right limb pulled caudal and out of the way. A towel pack was placed under the lateral aspect of the limb in the region of the elbow to facilitate medial opening of the cubital joint, and each joint was manually held abducted and supinated throughout the procedure. A modified intermuscular approach to the medial aspect of the cubital joint was used[51]. The original approach described separating between the pronator teres and flexor carpi radialis muscles and required a desmotomy of the medial collateral ligament. In the study reported here, and incision was made from just proximal to the medial humeral epicondyle, ending near the proximal fourth of the radius. The antebrachial fascia was incised along the same line. Blunt dissection was used to divide between the flexor carpi radialis and deep digital flexor muscles to expose the joint capsule (see figure 4, p. 52). The joint capsule was incised from the cranial aspect of the deep digital flexor to the caudal aspect of the medial collateral ligament. Desmotomy was not performed. The radial head, medial coronoid process, medial aspect of the humeral condyle, and medial collateral ligament were visualized (see figure 2, p. 50). Each joint was manually held supinated and abducted for a total of 13 minutes such that all the above structures could be visualized at the same time. Gelpi retractors were used to hold soft tissue structures out of the way while the joint was visualized. The length of time for joint exposure was based on average times required to remove FMCP from the cubital joint at the teaching

hospital once arthrotomy had been performed. Joints were flushed with 0.9 percent sodium chloride solution (USP, Baxter Healthcare Corp., Deerfield, IL 60015, USA) prior to closing. The joint capsule was closed with 3-0 polydioxanone (PDS II, Ethicon Inc., Somerville, NJ 08876-0151, USA) in an interrupted pattern. The fascia overlying the flexor carpi radialis and deep digital flexor muscles was apposed with 3-0 polydioxanone in a continuous pattern. An intradermal closure was accomplished with a continuous pattern using 3-0 polydioxanone. An interrupted cruciate pattern of 3-0 monofilament nylon was used for the skin and placement mimicked that for the arthroscopy group dogs.

Kinetic Gait Assessment

Animals from both surgery groups underwent kinetic gait analysis prior to surgery and on days 2, 4, 7, 15, 22, and 29 after surgery. A walkway 15 m in length was used to collect the data. A force plate was mounted flush with the surface and in the center of the walkway. Three photoelectric sensors positioned 1 m apart were used to determine velocity and acceleration changes over a 2 m region with the force plate centered in the middle. The middle sensor was positioned so that it bisected the force platform. The three sensors and force plate were connected to a dedicated computer and software program (Acquire Version 6.03W, Sharon Software, Dewitt, MI 48820).

A trial across the force platform was considered valid if the dog's appropriate paw was completely on the plate, the dog was trotting at a velocity of 1.7- 2.0 m/s while

maintaining an acceleration of -0.5 to +0.5 m/s/s, and the dog was not distracted during the trial. A video camera was used to record each evaluation. Recorded information was reviewed to ensure that each trial was correctly determined to be valid.

Peak vertical force (PVF) and vertical impulse force (VIF) were recorded for all limbs of each dog. Dogs were trotted across the force plate until seven valid trials for each limb were obtained. The first five valid trials from operated limbs were used for statistical evaluation. Forces were collected as a percent of body weight (kg).

Cubital Joint Range of Motion

Joint range of motion (ROM) was determined for each dog before the onset of the study, and on days 2, 4, 7, 15, 22, and 29 after surgery. Cubital joint ROM was measured with a goniometer by an observer blinded to the surgical procedure performed. Range of motion was calculated with the limb held at a 90-degree angle while measuring flexion and extension from that point[71].

Subjective Evaluations

For each dog, subjective lameness, weight bearing, and pain response were evaluated. An observer that was blinded to the surgical procedure performed the evaluations. Evaluations were performed prior to surgery and on days 2, 4, 7, 15, 22, and 29 after surgery. Lameness, weight bearing, and pain were assigned a score according to criteria defined in table 1, p. 46. In brief, lameness, weight bearing, and pain were assigned scores that varied from 0 to 5, 0 to 4, and 0 to 3, respectively. In all cases, 0

indicated normal, and the greater the number, the more affected the patient was from surgery. Statistical evaluations were based on score assignments for each dog.

Radiographic Evaluations

Prior to surgery, each dog also underwent radiographic evaluation of each cubital joint. Craniocaudal, lateral and flexed lateral radiographic projections were taken for each joint. At the conclusion of the study, all operated joints were again radiographed using the same views.

All radiographs were evaluated by one of the primary investigators. Joints were evaluated for evidence of degenerative change. They were considered normal if no evidence of degenerative change was apparent; minimally affected if only joint effusion was present; mildly affected if early osteophyte production was evident; moderately affected if joint space was narrowed, osteophyte production was present, and bone remodeling was apparent; and severely affected if the joint space was minimal, osteophyte production was excessive, and bone remodeling was excessive. Radiographic findings were noted, but were not subjected to statistical evaluation.

Statistical Evaluation

Subjective and objective data were evaluated separately. Peak vertical force, vertical impulse force, and joint ROM were evaluated using repeated measures analysis of variance (SAS; SAS Institute Inc., Cary, NC. Version 6.12). Raw data were used to

determine return to normalcy for all dogs and data as a percent change were used to determine significance between groups.

The Fisher's Exact test was used to determine relationships between subjective data and treatment groups. Kendall's correlation was used to determine relationships between subjective and objective data. For this study, p values ≤ 0.05 were considered significant.

RESULTS

Pre and Post-study Observations

No orthopedic, neurologic or significant physical examination abnormalities were found in any dog. In addition, packed cell volume, total plasma protein and blood urea nitrogen concentrations were within reference ranges for all dogs. The median weight of arthroscopy group dogs was 26.5 kg with a range of 22.7 to 30.8 kg, and the median weight of the arthrotomy group dogs was 30.0 kg with a range of 22.7 to 34.1 kg. Cubital joint radiographic evaluations were normal prior to and at the conclusion of the study.

No dog showed evidence of self-mutilation of the surgery site. Sutures remained intact until suture removal seven days following surgery. Joints exhibited only minimal erythema along the incision line. For all dogs, joints were only minimally swollen following surgery and swelling subsisted within 48-72 hours for all dogs.

Cubital Joint Range of Motion

There was no statistical difference in cubital joint range of motion for operated limbs between groups ($p = 0.09$ and 0.91 for flexion and extension, respectively). Additionally, range of motion remained normal for all dogs throughout the study period. Median cubital joint range of motion was 75 degrees for both flexion and extension in all dogs.

Kinetic Gait Assessment

There was no statistical difference in PVF or VIF between surgery groups for operated limbs (p=0.88 and 0.49, respectively)(see figure 5, p. 53). Since no difference was identified between groups, dogs were combined and evaluated as a whole to determine return to function. Combined groups were identified as having a significant decrease in PVF on days 2 and 7 after surgery (p=0.03 and 0.04 respectively). Peak vertical force was not significantly decreased on day 4 (p=0.1). Additionally, for day 15, and every evaluation day thereafter, no significant decrease in peak vertical force was noted ($p \geq 0.22$ for all days). For dogs as a whole, a significant decrease in VIF was observed on days 2, 4, 7, 15, 22, and 29 of the study period (p=0.03, 0.02, 0.01, 0.01, 0.005, and 0.05, respectively). For all dogs, median percent decrease of PVF for operated limbs on days 2,4, 7, 15, 22, and 29 was 3.3, 3.2, 3.2, 3.0,1.8, and 2.0, respectively (see figure 6, p. 54). Median percent decrease of VIF for operated limbs on those same days was 5.1, 5.2, 4.7, 4.1, 4.3, and 3.3, respectively (see figure 6, p. 54). Results for dogs that showed a ≥ 10 % decrease in PVF and VIF are summarized in table 2, p. 47.

Subjective Evaluations

Data for subjective evaluations are summarized in table 3, p. 48. There was no significant difference in subjective lameness evaluations, pain or weight bearing scores between groups on any day during the study period ($p \geq 0.19$ for all days).

Correlation

Although the correlation coefficient was small, pain associated with cubital joint manipulation correlated with a decrease in PVF ($R = -0.20$ with $p = 0.01$). Additionally, a decrease in PVF also correlated with a change in cubital joint ROM ($R = -0.32$ with $P = 0.001$ for extension, $R = -0.20$ with $p = 0.04$ for flexion).

DISCUSSION

In this study, we objectively compared lameness in dogs that had undergone arthroscopy or arthrotomy of the cubital joint. All animals in this study were using the operated limbs following surgery as has been reported previously for animals undergoing similar procedures[4, 7, 51, 53]. Previously reported studies comparing arthroscopy and arthrotomy of the stifle and glenohumeral joints suggested earlier return to function for subjects undergoing arthroscopy versus arthrotomy[2, 6, 72]. Schwarz, *et al.* reported less postoperative lameness in dogs that had undergone arthroscopic removal of FMCP of the ulna as compared to arthrotomy[11]. In contrast, our study did not demonstrate a significant difference between animals undergoing arthroscopy or arthrotomy of the cubital joint in post-operative lameness or return to function as determined by PVF or VIF.

When force plate gait assessment is used to evaluate lameness in dogs, normal variation from baseline may be as much as 5.5 to 8.5 percent[32, 41]. Therefore, a pathologic change in gait can be considered in any animal showing a variation in vertical forces beyond that which is expected. After surgery, 2 arthrotomy group dogs and 1 arthroscopy group dog showed a greater than 20 percent decrease in PVF from baseline in the post-operative period, and one in each group was still 10 percent below baseline at the conclusion of the study. Additionally, the same dogs showed a greater than 20 percent decrease in VIF from baseline with one in each group still 10 percent below baseline at the conclusion of the study. This degree of variation from baseline was associated with

an obvious lameness on subjective evaluations. There was a relatively even distribution of severely lame dogs within each surgery group with only a few dogs affected as a whole. These findings suggest that the surgical approach used for the arthrotomy caused no greater morbidity than that caused by scope insertion and arthroscopic manipulation.

A possible explanation for the lack of difference between groups in this study is iatrogenic cubital joint trauma during arthroscopy due to the relatively small intra-articular space of the cubital joint compared to the size of the arthroscope used in this study. A 2.7 mm scope with a 2.9 mm sleeve was used. Subjects in the arthroscopy group were of varying sizes, and some of the smaller subjects exhibited the most lameness. The two dogs that exhibited the most severe lameness in the arthroscopy group were 24.0 kg and 25.4 kg, which were the third and second lowest body weights in the group.

Iatrogenic scope lesions have been reported to be mostly superficial in nature in joints that have been evaluated for this[4, 24]. Superficial lesions heal incompletely, but the lesions become smoothed and covered with a thin superficial tissue layer and result in little, if any, inflammatory response in the synovial membrane[24]. Perhaps in smaller subjects or joints, the scope lesions are deeper and, in turn, cause more tissue damage and inflammation with associated pain. However, in this study, none of the iatrogenic scope lesions created resulted in gross subchondral bone exposure. Subchondral bone exposure could be expected to cause more pain and inflammation than superficial cartilage lesions

since there are no pain receptors in articular cartilage and less of an inflammatory response is initiated with superficial cartilage lesions[24]. The use of a smaller scope may have resulted in less iatrogenic trauma. Previous authors have reported good success with the 2.7 mm diameter arthroscope for examining the cubital joint in dogs of this weight range,[7, 24, 25] and others have reported the potential for iatrogenic arthroscope damage with smaller scope sizes[17, 73].

We did not evaluate the depth or severity of lesions in this group of dogs, nor did we evaluate them histologically, to determine differences between lame and non-lame dogs. Although patient and scope size may have played a role, pain and lameness in this group of animals was most likely associated with general arthroscopic technique and individual animal variation since the smallest dog in the arthroscopy group showed no lameness. Further studies would be needed to evaluate scope size, patient size and degree of post-operative lameness before any conclusions can be drawn regarding their affect on lameness.

An alternative explanation for the lack of difference between surgery groups in this study is that the intermuscular arthrotomy approach used here caused less morbidity than expected. This technique required few, if any, muscle fibers to be transected. Desmotomy of the medial collateral ligament or osteotomy of the medial epicondyle were not performed. Desmotomy and osteotomy were purposely avoided here in an attempt to compare the least invasive method of arthrotomy to arthroscopy. When compared with

other approaches to the elbow that involve tenotomy or osteotomy, the intermuscular approach is associated with minimal morbidity[51]. The intermuscular approach allowed adequate exposure of the medial compartment of the joint for visualization of all the necessary structures in this study.

Kinetic gait analysis is an accepted method of gait assessment in the veterinary field[27, 29-31]. Less observational bias and improved accuracy in determination of gait abnormalities make force plate gait analysis more ideal than subjective evaluations[27]. However, inherent variabilities exist with this method of gait assessment, which can influence the results obtained. Variations in data that occurs with the use of force plate gait analysis can be attributed to dogs, dog handlers, trial repetitions, and days[32, 41, 42]. Overall, variance has been reported to range from 5.5 to 8.5 percent for mean vertical indices[32, 41]. Coefficients of variation for the cranial and caudal impulses have been determined to be greater in magnitude than that for the vertical indices. Hence, vertical indices are most often used as measures of pathologic gait, as was done in this study[27, 41].

Several limitations were placed on this study, in an attempt to control some of the inherent variances introduced with the use of force plate gait assessment. Body weight is known to affect stance time and vertical forces[34]. Therefore, all calculations in this study were based on force as a percent of body weight. The range of body weight in this study was 22.7 kg to 34.1 kg with a median weight of 27 kg. In addition, vertical force indices are influenced by velocity[36, 74]. A variation of 0.3 m/s in dog velocity has been shown to

significantly alter ground reaction forces[36]. In order to be included in the study, dogs had to be able to maintain a velocity of 1.7 to 2.0 m/s during trial collection. Although data supporting a minimal influence of minor variations in acceleration affecting total vertical force of the forelimbs exists, acceleration in this study was also controlled and ranged between -0.5 and + 0.5 m/s/s[37].

Although animals did not show a significant decrease in PVF after day 15, VIF was significantly decreased throughout the study period for dogs as a whole. This indicates that even after 4 weeks post surgery, animals in this study were not maintaining full weight bearing on operated limbs for the same length of time they were prior to surgery. Since it can take 4 to 6 weeks for animals to fully recover from intra-articular procedures, it is not surprising that residual gait deficiencies were present at the conclusion of the study[2].

Subject number was limited in this study. The p values for this study are fairly high for direct group comparisons (p=0.88 and 0.49 for PVF and VIF, respectively). To detect a significant difference within the first 7 days of the study for VIF and PVF, a minimum of 32 and 100 animals, respectively, would be needed. These numbers were considered temporally, financially, and humanely impractical for a study of this nature. Overall, we considered our findings to be clinically relevant. Other studies have compared surgical procedures with a small number of animals and have reported clinically useful information[2, 28].

Cubital joint range of motion was measured on every evaluation day throughout the study. Accepted cubital joint range of motion varies from 70 to 75 degrees for flexion and 70 to 75 degrees for extension[71]. Although range of motion slightly varied from day to day, dogs remained normal throughout the study period. There was no statistical difference between surgery groups for flexion, but p = 0.09 for that variable, which is close to our cut off of 0.05 for this group of dogs. Little emphasis was placed on this relatively small p value since all dogs were still normal. For flexion, median joint range of motion prior to surgery was 70 and 75 degrees in the arthroscopy and arthrotomy groups, respectively. On day 2 following surgery, median joint range of motion for flexion was 75 degrees for both the arthroscopy and arthrotomy groups. Additionally, on day 29, median range of motion for flexion was again 75 degrees for both groups. Although joint range of motion for flexion changed following surgery, it actually improved. The difference seen here may reflect the adaptability of these dogs to being handled over time, allowing greater manipulation of their limbs, rather than a true surgical effect.

In this study, only the radial head, the medial coronoid process, the medial aspect of the humeral condyle, and the medial collateral ligament were evaluated consistently for both groups. Structures that can be visualized arthroscopically with a medial approach include the medial humeral condyle, medial collateral ligament, medial coronoid process, middle and caudal part of the radial head, lateral humeral condyle, lateral coronoid

process, ulnar head, anconeal process, synovial membrane, and zona nudata[4]. The intermuscular approach limited our ability to visualize the anconeal process and structures on the lateral aspect of the joint. A more aggressive arthrotomy could have been performed to enhance intra-articular visualization[43]. However, the arthrotomy approach used in this study is used routinely in clinical cases for the treatment of FMCP and OCD, and we feel that the exposure was adequate for its intended purpose.

Although we made no attempt to measure visibility, subjectively we recognized that intra-articular structures could be visualized more easily with the arthroscope than could be visualized during arthrotomy in this study. This is consistent with previous reports[4, 5]. Although subjectively we feel that arthroscopy provided superior visualization in this study, our focus was on postoperative morbidity in this group of animals. Further studies would be necessary to compare visualization between groups to make definitive conclusions regarding the benefits of arthroscopy over arthrotomy with respect to joint visualization.

CONCLUSIONS

Arthroscopy of the cubital joint did not provide a significant advantage over arthrotomy in postoperative pain, weight bearing, joint range of motion, or temporal improvement of ground reaction forces for this group of normal dogs. Pain associated with cubital joint manipulation only minimally correlated with a decrease in peak vertical force for this group of dogs. Also, a decrease in PVF minimally correlated with a change in cubital joint range of motion.

Comparative conclusions regarding joint visualization, expense, and length of surgery time between arthroscopy and arthrotomy cannot be made from this study. Further studies would be necessary to adequately assess those parameters.

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APPENDIX A

Table 1: Subjective evaluation scores

Variable	Subjective Evaluation	Score
Lameness	No lameness, normal stance	0
	Lameness after exercise, normal stance	1
	Slight lameness at a walk, normal stance	2
	Moderate lameness at a walk, normal stance	3
	Severe lameness at a walk, abnormal stance	4
	Reluctance to walk, reluctance to rise/stand	5
Weight bearing	Full weight bearing	0
	Slight favoring of limb, lameness barely detectable	1
	Partial weight bearing, obvious lameness	2
	Toe-touching, bears little weight on limb	3
	Non-weight bearing on limb	4
Pain	No pain	0
	Mild pain: turns head, slight reluctance of palpation	1
	Moderate pain: pulls limb away, obvious discomfort, slight whimper	2
	Severe pain: vocalization, aggression, won't allow limb palpation	3

This table shows the score assignments for each subjective evaluation category.

Table 2: Animals that varied ten percent or more from baseline in PVF and VIF

Procedure	Day 0	Day 2	Day 4	Day 7	Day 15	Day 22	Day 29
Arthroscopy							
PVF	0	2	1	2	1	0	1
VIF	0	2	1	2	2	0	1
Arthrotomy							
PVF	0	3	2	1	1	1	1
VIF	0	2	2	2	1	1	1

Numbers represent the number of dogs out of 7 in each surgery group that showed a ≥ 10 % reduction in peak vertical force (PVF) and vertical impulse force (VIF) for each evaluation day. Only a few number of dogs in each group showed a decrease in vertical force indices of this magnitude, and differences were not significantly different between surgery groups.

Table 3: Summary of subjective lameness evaluations.

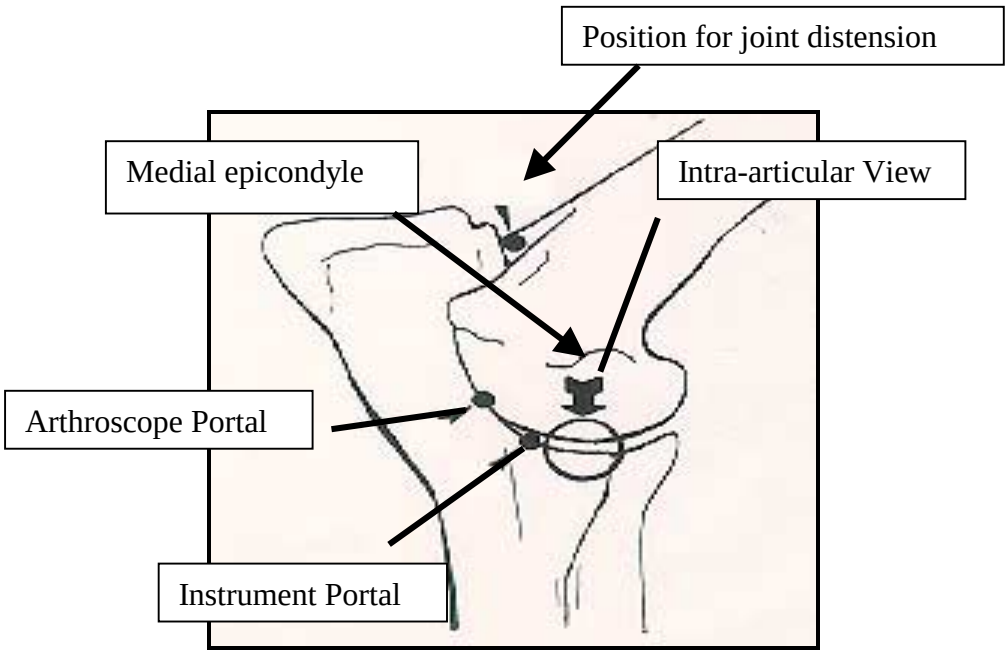
Arthroscopy	Day 0	Day 2	Day 4	Day 7	Day 15	Day 22	Day 29
Lameness	0	2	3	1	1	0	0
Wt-bear	0	2	3	1	1	0	0
Pain	0	0	1	0	0	1	1

Arthrotomy	Day 0	Day 2	Day 4	Day 7	Day 15	Day 22	Day 29
Lameness	0	4	2	2	1	0	0
Wt-bear	0	4	2	2	1	0	0
Pain	0	3	0	0	0	0	0

The numbers represent the number of animals in the arthroscopy group (first data set) and the arthrotomy group (second data set) that were subjectively abnormal on each evaluation day. There was no statistical difference between surgery groups. Wt-bear = weight bearing.

APPENDIX B

Figure 1: Schematic of arthroscopic instrument portals



The arthroscope is inserted into the joint caudodistal to the medial epicondyle of the humerus and the instrument portal is placed into the joint cranial to the scope portal such that the region of the medial coronoid process of the ulna is in view.

Figure 2: Intra-operative views

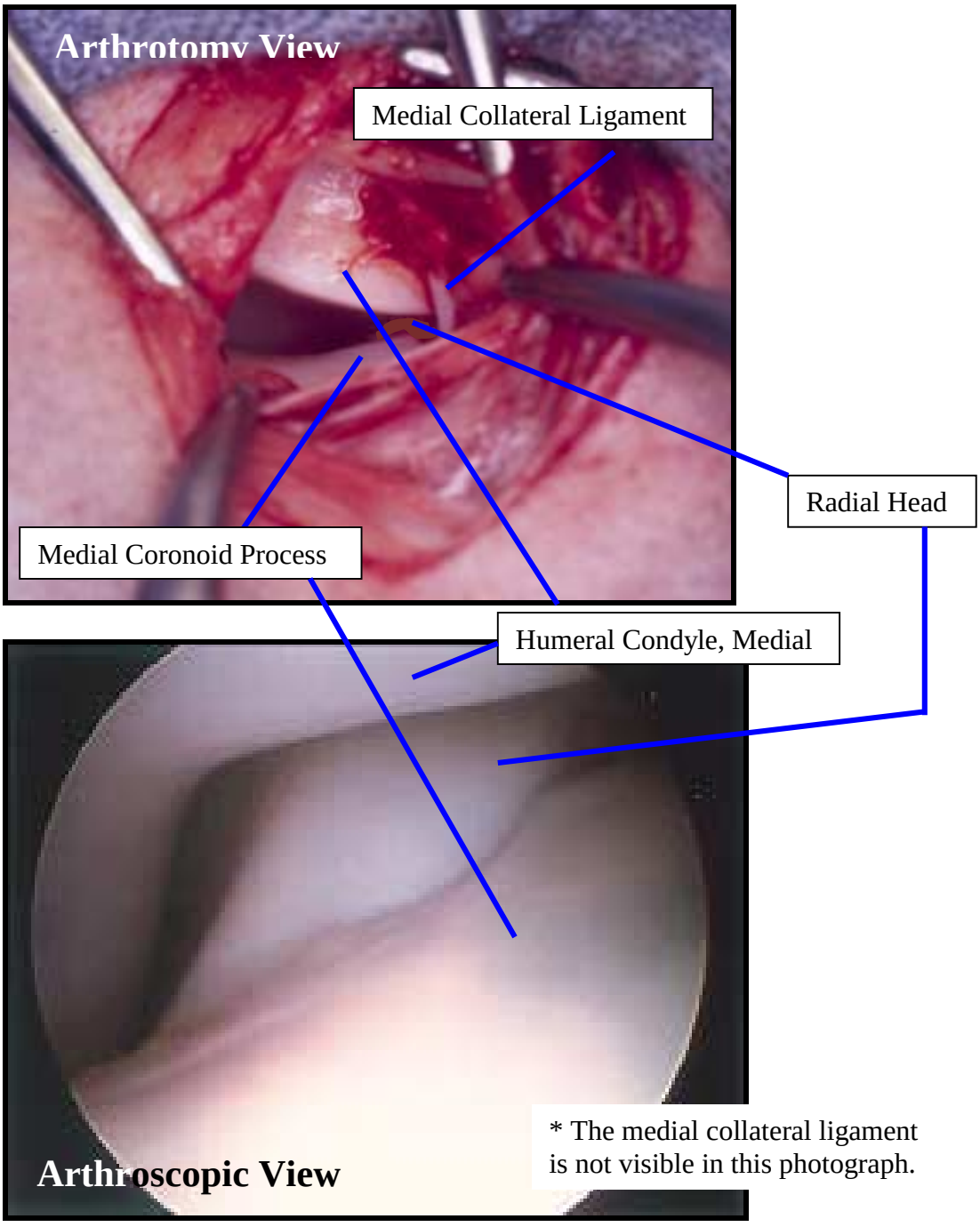
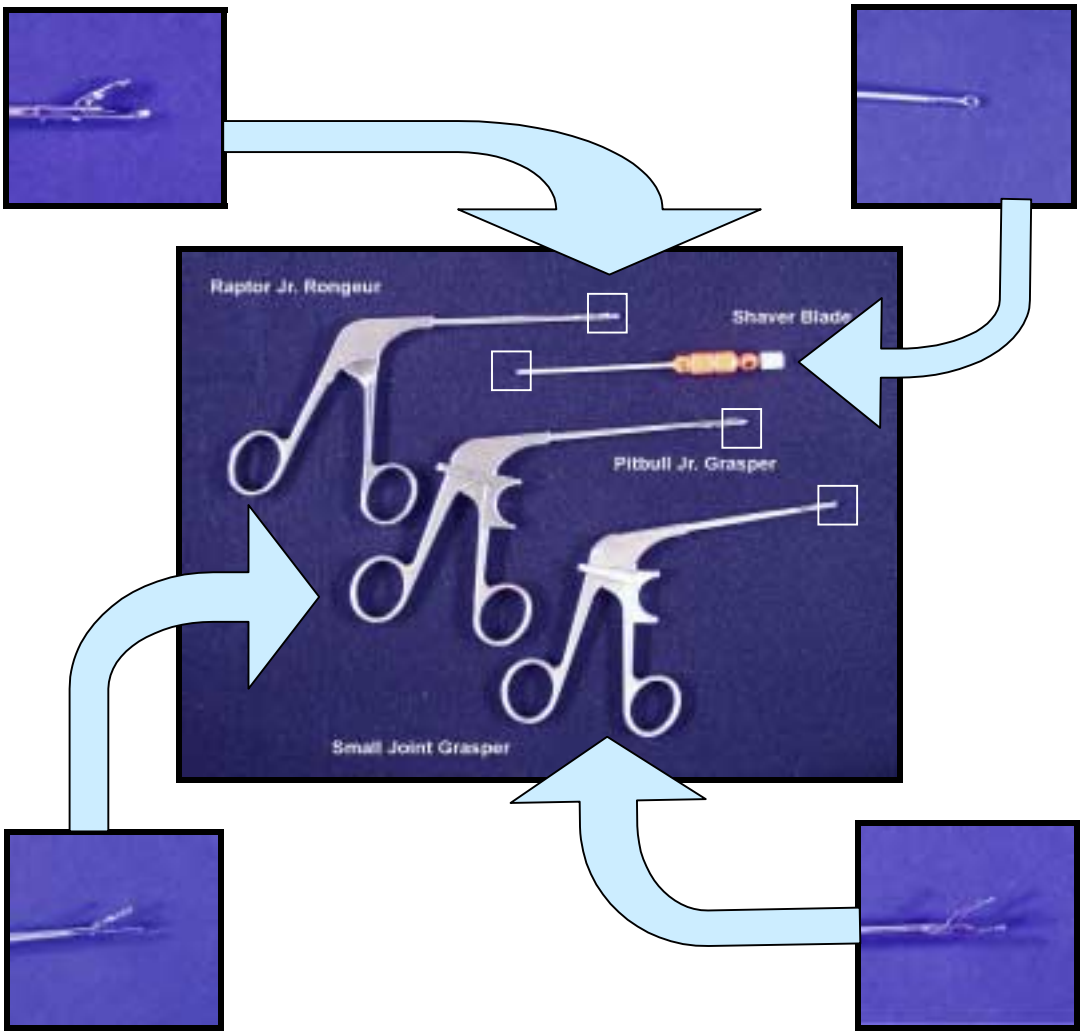
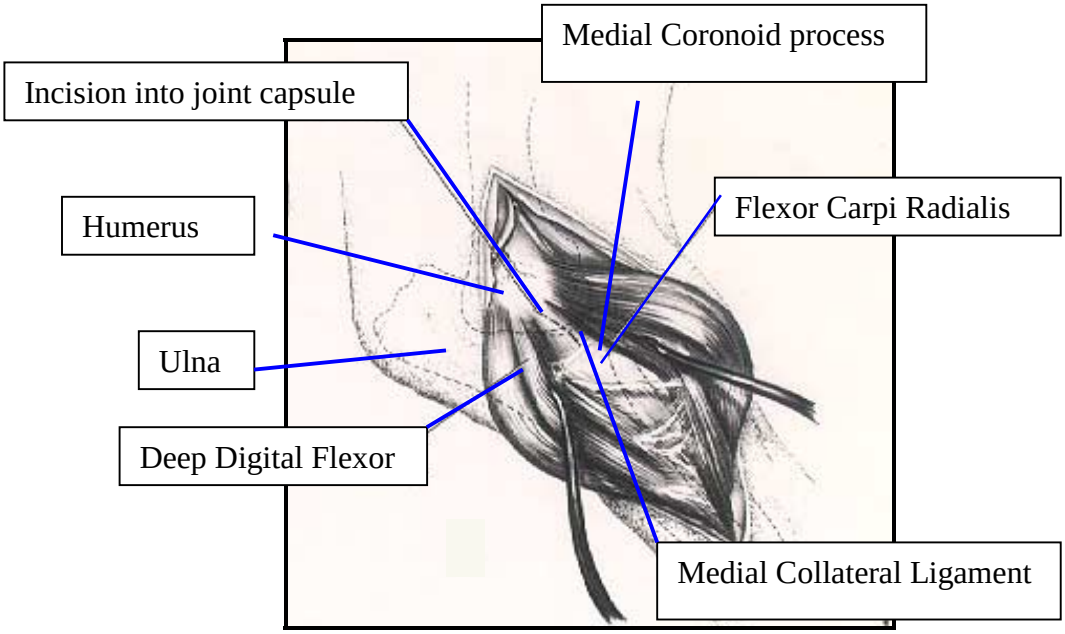


Figure 3: Arthroscopic instruments



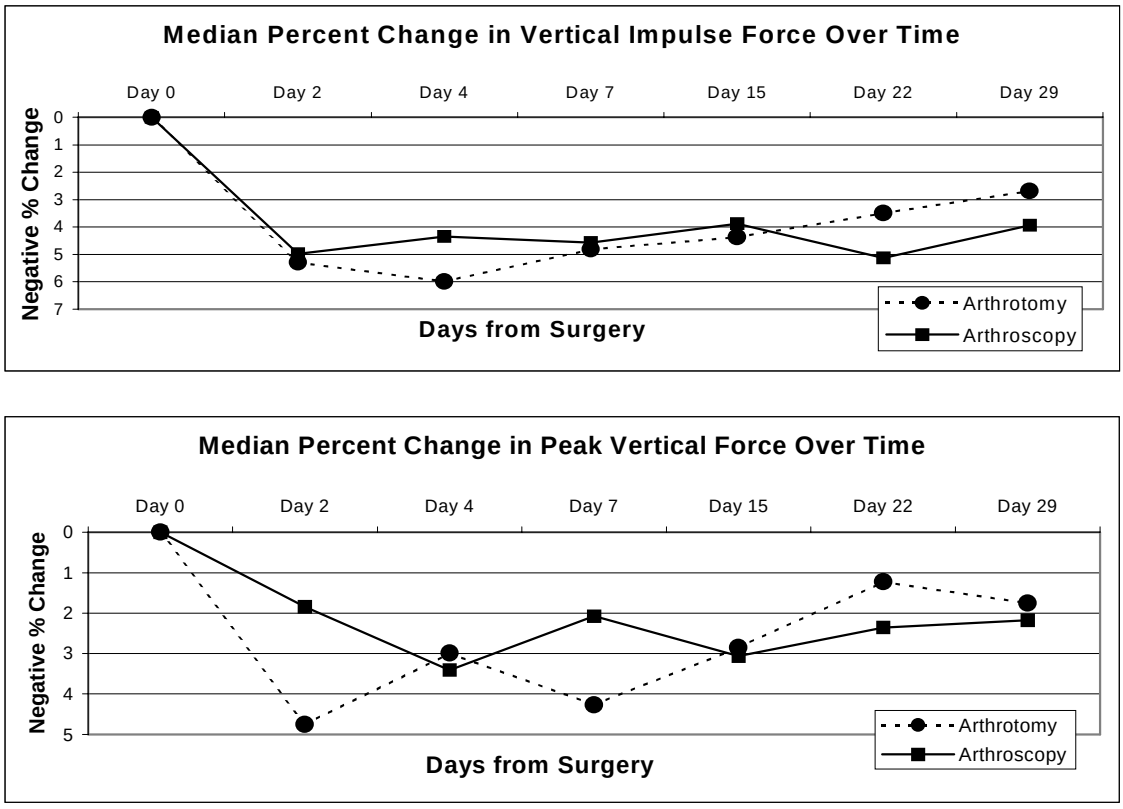
This photograph shows the instruments used during the arthroscopy procedure.

Figure 4: Medial arthrotomy



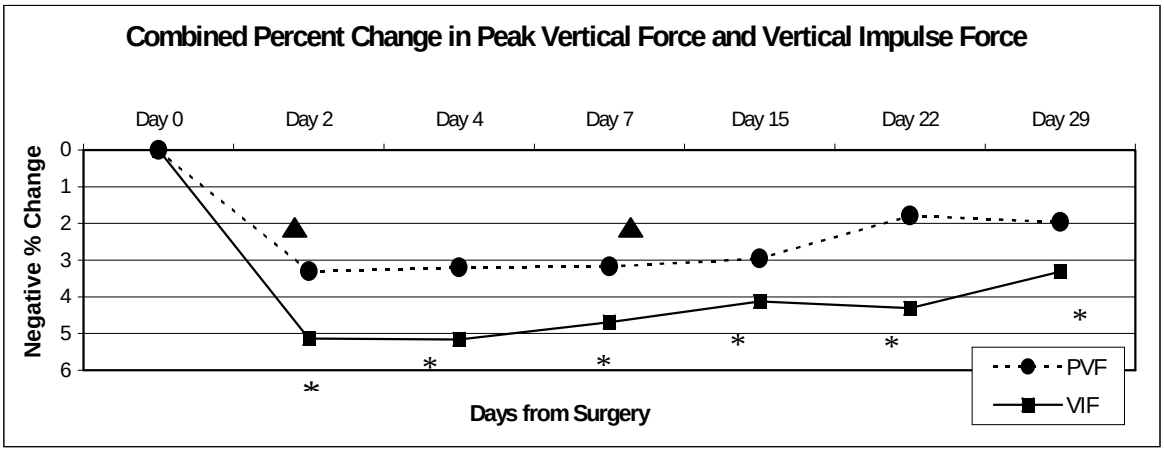
This is a schematic of the left cubital joint with the joint capsule exposed. A muscle splitting technique between the flexor carpi radialis and the deep digital flexor muscles was used. An incision is made in the joint capsule from the cranial edge of the deep digital flexor muscle and the caudal edge of the medial collateral ligament to expose the medial joint compartment.

Figure 5: Graphic representation of PVF and VIF over time



These charts show the graphic representation of percent change from baseline in peak vertical force (PVF) and vertical impulse force (VIF) over time for each surgery group. The more lameness detected per a group, the greater the change from baseline (0).

Figure 6: Graphic representation of percent change in peak vertical force and vertical impulse force for all dogs over time



This chart shows the graphic representation of percent change in peak vertical force (PVF) and vertical impulse force (VIF) for all dogs over time. For dogs as a whole, PVF was significantly altered from baseline on days 2 and 7, denoted with triangles. VIF was significantly altered from baseline on all days denoted with asterisks.

APPENDIX C

SAS Results for the Left Forelimb (Objective Data)

Peak Vertical Force

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.23176693	3.8671	6	7	0.0500
Pillai's Trace	0.76823307	3.8671	6	7	0.0500
Hotelling-Lawley Trace	3.31467933	3.8671	6	7	0.0500
Roy's Greatest Root	3.31467933	3.8671	6	7	0.0500

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.56064733	0.9143	6	7	0.5354
Pillai's Trace	0.43935267	0.9143	6	7	0.5354
Hotelling-Lawley Trace	0.78365249	0.9143	6	7	0.5354
Roy's Greatest Root	0.78365249	0.9143	6	7	0.5354

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	566.77192172	566.77192172	0.57	0.4653
Error	12	11960.22128804	996.68510734		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F

MEAN	1	1280.48570579	1280.48570579	5.83	0.0326
GROUP	1	21.05532579	21.05532579	0.10	0.7621
Error	12	2635.14240543	219.59520045		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	615.71488114	615.71488114	3.23	0.0975
GROUP	1	90.07872457	90.07872457	0.47	0.5049
Error	1	2287.98461829	190.66538486		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	562.40876829	562.40876829	5.59	0.0358
GROUP	1	2.42777857	2.42777857	0.02	0.8792
Error	12	1208.27751314	100.68979276		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	71.12722400	71.12722400	1.67	0.2201
GROUP	1	9.42672457	9.42672457	0.22	0.6461
Error	12	509.97337943	42.49778162		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	26.21635457	26.21635457	1.40	0.2589
GROUP	1	12.02319114	12.02319114	0.64	0.4378
Error	12	223.98812229	18.66567686		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	25.62311429	25.62311429	1.08	0.3199
GROUP	1	0.11412114	0.11412114	0.00	0.9459
Error	12	285.64046857	23.80337238		

Vertical Impulse Force

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect

H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.33628740	2.3026	6	7	0.1498
Pillai's Trace	0.66371260	2.3026	6	7	0.1498
Hotelling-Lawley Trace	1.97364697	2.3026	6	7	0.1498
Roy's Greatest Root	1.97364697	2.3026	6	7	0.1498

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.77906937	0.3308	6	7	0.9005
Pillai's Trace	0.22093063	0.3308	6	7	0.9005
Hotelling-Lawley Trace	0.28358275	0.3308	6	7	0.9005
Roy's Greatest Root	0.28358275	0.3308	6	7	0.9005

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	8.39387511	8.39387511	0.64	0.4386
Error	12	156.92149988	13.07679166		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	34.71615114	34.71615114	5.83	0.0327
GROUP	1	0.61153400	0.61153400	0.10	0.7542
Error	12	71.48331086	5.95694257		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	35.94247314	35.94247314	7.99	0.0153
GROUP	1	1.54845257	1.54845257	0.34	0.5684

Error	12	54.00808229	4.50067352		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	23.46281257	23.46281257	8.44	0.0132
GROUP	1	0.11702857	0.11702857	0.04	0.8409
Error	12	33.37879886	2.78156657		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	13.50053600	13.50053600	8.29	0.0139
GROUP	1	0.51609600	0.51609600	0.32	0.5839
Error	12	19.54683200	1.62890267		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	6.91049257	6.91049257	11.79	0.0050
GROUP	1	0.20160000	0.20160000	0.34	0.5684
Error	12	7.03376343	0.58614695		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	4.90294464	4.90294464	4.89	0.0473
GROUP	1	0.01491779	0.01491779	0.01	0.9050
Error	12	12.04387057	1.00365588		

Breaking Force

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.42955032	1.5494	6	7	0.2888
Pillai's Trace	0.57044968	1.5494	6	7	0.2888
Hotelling-Lawley Trace	1.32801597	1.5494	6	7	0.2888
Roy's Greatest Root	1.32801597	1.5494	6	7	0.2888

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.59701694	0.7875	6	7	0.6066
Pillai's Trace	0.40298306	0.7875	6	7	0.6066
Hotelling-Lawley Trace	0.67499434	0.7875	6	7	0.6066
Roy's Greatest Root	0.67499434	0.7875	6	7	0.6066

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	0.79524065	0.79524065	0.04	0.8467
Error	12	244.46815461	20.37234622		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	27.71508600	27.71508600	7.02	0.0212
GROUP	1	1.79859457	1.79859457	0.46	0.5125
Error	12	47.37569143	3.94797429		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	25.00457857	25.00457857	8.14	0.0145
GROUP	1	0.51379457	0.51379457	0.17	0.6897
Error	12	36.83976686	3.06998057		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	19.60704457	19.60704457	5.23	0.0412
GROUP	1	0.01673257	0.01673257	0.00	0.9479
Error	12	45.01403086	3.75116924		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	5.41637600	5.41637600	1.43	0.2554
GROUP	1	0.02113829	0.02113829	0.01	0.9417
Error	12	45.55487771	3.79623981		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	3.99859457	3.99859457	2.06	0.1771
GROUP	1	0.09315457	0.09315457	0.05	0.8304
Error	12	23.32821486	1.94401790		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.65577857	0.65577857	0.34	0.5686
GROUP	1	0.96626314	0.96626314	0.51	0.4904
Error	12	22.90226629	1.90852219		

Propulsion Force

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.57468928	0.8634	6	7	0.5630
Pillai's Trace	0.42531072	0.8634	6	7	0.5630
Hotelling-Lawley Trace	0.74007074	0.8634	6	7	0.5630
Roy's Greatest Root	0.74007074	0.8634	6	7	0.5630

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.41487252	1.6454	6	7	0.2642

Pillai's Trace	0.58512748	1.6454	6	7	0.2642
Hotelling-Lawley Trace	1.41037897	1.6454	6	7	0.2642
Roy's Greatest Root	1.41037897	1.6454	6	7	0.2642

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	2.06364123	2.06364123	0.21	0.6583
Error	12	120.45810869	10.03817572		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	9.05384445	9.05384445	4.08	0.0662
GROUP	1	0.30149787	0.30149787	0.14	0.7188
Error	12	26.61709593	2.21809133		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	6.26050314	6.26050314	3.27	0.0957
GROUP	1	0.77315000	0.77315000	0.40	0.5371
Error	12	22.97558286	1.91463190		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	7.00425045	7.00425045	4.17	0.0637
GROUP	1	0.18966216	0.18966216	0.11	0.7426
Error	12	20.14847764	1.67903980		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.11107207	0.11107207	0.07	0.7915
GROUP	1	0.03430350	0.03430350	0.02	0.8831
Error	12	18.24129743	1.52010812		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00969945	0.00969945	0.01	0.9339
GROUP	1	2.40327145	2.40327145	1.78	0.2069
Error	12	16.20317736	1.35026478		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	1.55144716	1.55144716	2.44	0.1446
GROUP	1	0.99085002	0.99085002	1.56	0.2362
Error	12	7.64540107	0.63711676		

Breaking Impulse

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.27150410	3.1304	6	7	0.0806
Pillai's Trace	0.72849590	3.1304	6	7	0.0806
Hotelling-Lawley Trace	2.68318556	3.1304	6	7	0.0806
Roy's Greatest Root	2.68318556	3.1304	6	7	0.0806

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.52801898	1.0428	6	7	0.4713
Pillai's Trace	0.47198102	1.0428	6	7	0.4713
Hotelling-Lawley Trace	0.89387131	1.0428	6	7	0.4713
Roy's Greatest Root	0.89387131	1.0428	6	7	0.4713

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F

GROUP	1	0.00617637	0.00617637	0.03	0.8588
Error	12	2.24319069	0.18693256		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.17338314	0.17338314	1.87	0.1963
GROUP	1	0.00315000	0.00315000	0.03	0.8568
Error	12	1.11146286	0.09262190		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.24658314	0.24658314	3.52	0.0853
GROUP	1	0.00027457	0.00027457	0.00	0.9511
Error	12	0.84120229	0.07010019		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.13445600	0.13445600	1.53	0.2401
GROUP	1	0.00497829	0.00497829	0.06	0.8160
Error	12	1.05591771	0.08799314		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.01472257	0.01472257	0.24	0.6355
GROUP	1	0.00144029	0.00144029	0.02	0.8816
Error	12	0.74708914	0.06225743		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.01604829	0.01604829	0.25	0.6267
GROUP	1	0.00080257	0.00080257	0.01	0.9130
Error	12	0.77281714	0.06440143		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00731429	0.00731429	0.15	0.7060
GROUP	1	0.04617257	0.04617257	0.94	0.3508
Error	12	0.58792114	0.04899343		

Propulsion Impulse

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.36342916	2.0435	6	7	0.1858
Pillai's Trace	0.63657084	2.0435	6	7	0.1858
Hotelling-Lawley Trace	1.75156791	2.0435	6	7	0.1858
Roy's Greatest Root	1.75156791	2.0435	6	7	0.1858

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.56424250	0.9010	6	7	0.5425
Pillai's Trace	0.43575750	0.9010	6	7	0.5425
Hotelling-Lawley Trace	0.77228764	0.9010	6	7	0.5425
Roy's Greatest Root	0.77228764	0.9010	6	7	0.5425

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	0.00958123	0.00958123	0.15	0.7093
Error	12	0.78907612	0.06575634		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.10406064	0.10406064	6.65	0.0241
GROUP	1	0.01414464	0.01414464	0.90	0.3603
Error	12	0.18766371	0.01563864		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.08674314	0.08674314	5.59	0.0358
GROUP	1	0.00008257	0.00008257	0.01	0.9431
Error	12	0.18633029	0.01552752		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.07577857	0.07577857	9.64	0.0091
GROUP	1	0.00027457	0.00027457	0.03	0.8549
Error	12	0.09431886	0.00785990		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.02853029	0.02853029	3.50	0.0858
GROUP	1	0.00029257	0.00029257	0.04	0.8528
Error	12	0.09769714	0.00814143		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00297257	0.00297257	0.22	0.6453
GROUP	1	0.02436114	0.02436114	1.83	0.2014
Error	12	0.16000229	0.01333352		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.04279114	0.04279114	4.61	0.0530
GROUP	1	0.01154314	0.01154314	1.24	0.2867
Error	12	0.11142971	0.00928581		

Extension

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.06569343	16.5926	6	7	0.0008
Pillai's Trace	0.93430657	16.5926	6	7	0.0008
Hotelling-Lawley Trace	14.22222222	16.5926	6	7	0.0008
Roy's Greatest Root	14.22222222	16.5926	6	7	0.0008

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.11266900	9.1881	6	7	0.0049
Pillai's Trace	0.88733100	9.1881	6	7	0.0049
Hotelling-Lawley Trace	7.87555556	9.1881	6	7	0.0049
Roy's Greatest Root	7.87555556	9.1881	6	7	0.0049

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	0.25510204	0.25510204	0.01	0.9094
Error	12	226.53061224	18.87755102		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00000000	0.00000000	0.00	1.0000
GROUP	1	7.14285714	7.14285714	0.35	0.5635
Error	12	242.85714286	20.23809524		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	28.57142857	28.57142857	1.09	0.3169
GROUP	1	7.14285714	7.14285714	0.27	0.6110
Error	12	314.28571429	26.19047619		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00000000	0.00000000	0.00	1.0000
GROUP	1	7.14285714	7.14285714	0.25	0.6261
Error	12	342.85714286	28.57142857		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	1.78571429	1.78571429	0.10	0.7611
GROUP	1	1.78571429	1.78571429	0.10	0.7611
Error	12	221.42857143	18.45238095		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	0.00000000	0.00000000	0.00	1.0000
GROUP	1	7.14285714	7.14285714	0.25	0.6261
Error	12	342.85714286	28.57142857		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	16.07142857	16.07142857	0.75	0.4035
GROUP	1	1.78571429	1.78571429	0.08	0.7778
Error	12	257.14285714	21.42857143		

Flexion

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F

Wilks' Lambda	0.38549134	1.8598	6	7	0.2178
Pillai's Trace	0.61450866	1.8598	6	7	0.2178
Hotelling-Lawley Trace	1.59409200	1.8598	6	7	0.2178
Roy's Greatest Root	1.59409200	1.8598	6	7	0.2178

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME*GROUP Effect
H = Type III SS&CP Matrix for TIME*GROUP E = Error SS&CP Matrix

S=1 M=2 N=2.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.56395203	0.9021	6	7	0.5419
Pillai's Trace	0.43604797	0.9021	6	7	0.5419
Hotelling-Lawley Trace	0.77320046	0.9021	6	7	0.5419
Roy's Greatest Root	0.77320046	0.9021	6	7	0.5419

General Linear Models Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GROUP	1	20.66326531	20.66326531	3.37	0.0911
Error	12	73.46938776	6.12244898		

TIME.N represents the contrast between the nth level of TIME and the 1st

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	16.07142857	16.07142857	0.93	0.3536
GROUP	1	1.78571429	1.78571429	0.10	0.7533
Error	12	207.14285714	17.26190476		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	114.28571429	114.28571429	16.00	0.0018
GROUP	1	0.00000000	0.00000000	0.00	1.0000
Error	12	85.71428571	7.14285714		

Contrast Variable: TIME.4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	28.57142857	28.57142857	3.00	0.1089
GROUP	1	7.14285714	7.14285714	0.75	0.4035
Error	12	114.28571429	9.52380952		

Contrast Variable: TIME.5

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	87.50000000	87.50000000	7.35	0.0189
GROUP	1	44.64285714	44.64285714	3.75	0.0767
Error	12	142.85714286	11.90476190		

Contrast Variable: TIME.6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	64.28571429	64.28571429	9.82	0.0086
GROUP	1	7.14285714	7.14285714	1.09	0.3169
Error	12	78.57142857	6.54761905		

Contrast Variable: TIME.7

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	28.57142857	28.57142857	1.78	0.2072
GROUP	1	28.57142857	28.57142857	1.78	0.2072
Error	12	192.85714286	16.07142857		

Subjective Data for the Left Forelimb Limb

P-Values →	Day2	Day4	Day 7	Day 15	Day 22	Day 29
Lameness	0.59	1.00	1.00	1.00	1.00	1.00
Wt-Bear	0.59	1.00	1.00	1.00	1.00	1.00
Pain	0.19	1.00	1.00	1.00	1.00	1.00

These are the P values from the 2-tailed Fisher's Exact test performed on the subjective data. Wt. Bear = weight bearing.

Correlation Data

	Lameness	Wt-Bearing	Pain	
Peak Vertical Force	-0.05927 0.4769	-0.05535 0.5045	-0.20393 0.0137	*Correlation* *P-value*
Vertical Impulse	0.12256 0.1414	0.12625 0.128	-0.14088 0.0885	*Correlation* *P-value*
Breaking Force	0.04885 0.5577	0.04579 0.5809	0.13657 0.0987	*Correlation* *P-value*
Propulsion Force	0.01121 0.893	0.01235 0.8817	-0.08453 0.3068	*Correlation* *P-value*
Breaking Impulse	-0.08384 0.3151	-0.08855 0.2865	0.0546 0.5098	*Correlation* *P-value*
Propulsion Impulse	0.04177 0.6172	0.04113 0.6209	-0.02334 0.7784	*Correlation* *P-value*
Extension	0.14419 0.1404	0.14107 0.1473	-0.31526 0.0712	*Correlation* *P-value*
Flexion	0.13453 0.1762	0.13377 0.1766	-0.20183 0.0409	*Correlation* *P-value*

Correlation coefficients and P values

APPENDIX D

Abbreviations

FMCP	Fragmented medial coronoid process of the ulna
PVF	Peak vertical force
VIF	Vertical impulse force
ROM	Range of motion
Fz	Vertical forces
Fy	Craniocaudal forces
Fx	Mediolateral forces
OCD	Osteochondritis dissecans
UAP	Ununited anconeal process
m	Meters
cm	Centimeters
mm	Millimeters
kg	Kilograms
Hg	Mercury
WT	Weight
Bear	Bearing

VITA

In March of 1971, Loretta Bubenik was born in Bethesda, Maryland to her parents, Charlie and Carolyn Bubenik. Her father's military career took her to several places including Hawaii, California, and Florida. Her father retired from the Navy in 1992 and settled in Panama City, Florida. It was there that Loretta completed her high school education, graduating from Mosley High School in 1989.

Following high school, Loretta began working as a veterinary technician while obtaining an Associate of the Arts degree from Gulf Coast Community College in Panama City. In 1991 she was accepted to the University of Florida from which she graduated in 1993 with a Bachelor's of Science degree in Microbiology and a minor in Chemistry. Loretta was accepted to the University of Florida's College of Veterinary Medicine in 1993 and graduated in 1997 with honors. Through her veterinary schooling, she worked as a veterinary technician in a local small animal hospital and as a lab technician in the research facilities at the university.

Upon completion of her senior year in veterinary school, Loretta accepted a rotating small animal internship at the Virginia-Maryland Regional College of Veterinary Medicine that was completed in June of 1998. She continued her education at the Veterinary College as a Small Animal Surgery Resident. At that time, she also initiated studies in the graduate school to obtain a Master's Degree in Veterinary Science. Her Master's work lead to a publication in Veterinary Surgery, the official journal of the American College of Veterinary Surgeons, and she also published a chapter in Slatter's Textbook of Small Animal Surgery. Upon completion of her surgical residency in June of 2001, Loretta began a clinical instructorship at the Virginia-Maryland Regional College of Veterinary Medicine.