Radiographic studies on the carpal joints in some small animals

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eingereicht von

Madeh A.A. Sadan

Tierarzt aus
South Valley University
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Gießen 2010

Mit Genehmigung des Fachbereichs Veterinärmedizin
der Justus-Liebig-Universität Gießen

Dekan: Prof. Dr. Dr. habil. G. Baljer

Gutachter: Prof. Dr. M. Kramer

Prof. Dr. Dr. S. Arnhold

Tag der Disputation: 27.04.2010

To my family

Contents

List of Abbreviations

IRC	Intermedioradial carpal bone
UC	Ulnar carpal bone
AC	Accessory carpal bone
1st C. B	First carpal bone
2nd C. B	Second carpal bone
3rd C. B	Third carpal bone
4th C. B	Fourth carpal bone
D. P	Dorsopalmar
M. L	Mediolateral
P. D	Proximodistal
Mm	Millimeter
PCA	Castless pancarpal arthrodesis plate
DCP	Dynamic Compression Plate
Sp No	Specimen’s number
MRI	Magnetic Resonance Imaging
CT	Computed Tomography

Introduction

Veterinary Diagnostic Imaging (radiography, ultrasonography, CT, MRI and scintigraphy) has made great developments in the last twenty years and was considered to be a separate specialty in veterinary medicine. Radiography is a fascinating aspect of veterinary medicine, which offers views into internal hidden structures of the animal's body specially the skeletal system.

The carpal region is a clinical important area in different animals (e.g. dogs and cats) that is frequently examined radiographically. The carpal joint is a compound joint that contains several bones which articulate with each other and articulate with the distal part of the radius and ulna and proximal part of the metacarpal bones. The great variations in shape, size, density, and weight of different carpal bones in different animals lead to several confusions during radiographic interpretation of several diseases affecting the carpal joints.

The etiology of carpal joint affections is trauma, congenital deformities, osteoarthritis, and degenerative changes. Carpal joint injuries may consist of fractures, ligamentous impairments, and various conformations. Chips or slaps on the articular surfaces of the radial carpal bone are most often seen after injuries resulting from jumps or falls, in those dogs, who undergo heavy exertions like sled dogs and field trial dogs. Diagnosis requires a high index of suspicion because radiographs (non screen film or high- detailed screens) must be made in special projections (eg. oblique planes, flexion and extension) to verify the insult **(Brinker et al., 1983).**

Accurate interpretation and objective evaluation of carpus radiographs require detailed knowledge of normal radiographic anatomy of the carpus **(Thrall,**

2002). Standard reference of normal radiographic anatomy of the carpus to which radiographs with suspected lesions or traumas should be compared is very helpful to interpretate the radiological findings.

The aim of the present study is to describe

1- The normal anatomy of the carpal joints in small and medium sized dogs and cats.
2- Radiographic examination of the affected carpal joints in dogs and cats and full interpretation of these radiographs with additional stress views.
3- Different surgical possibilities to treat different carpal joint diseases in dogs and cats.

Review of literature

I- Anatomy of the carpal joint in dogs and cats:

The carpal joint consists of several articulations including the radiocarpal joint, the intercarpal joint which is found between the two rows of the carpal bones, the interosseous articulation between the members of the same row of bones and the carpometacarpal joint (Fig. 1). The four members of the distal row of carpal bones join the bases of the five metacarpal bones by dorsal and palmar ligaments. The distal radioulnar joints share a common joint cavity, the midcarpal and carpometacarpal joint cavities are interconnected (**Bradley, 1959; Dyce et al., 1987; Farrow et al., 1994).**

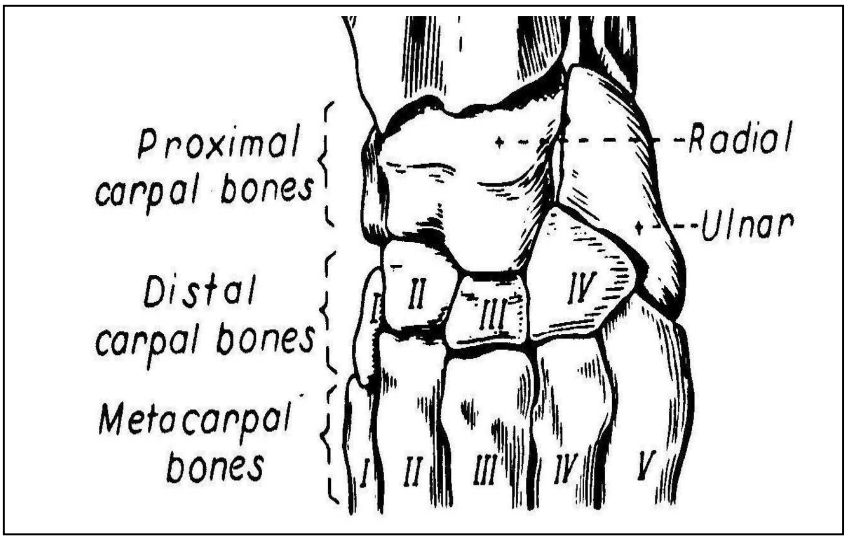


Fig. 1: Left carpus, articulated, dorsal aspect. (Evans H E, Christenson GC: Miller's Anatomy of the Dog. Philadelphia, WB Saunders, 1979).

The antebrachiocarpal joint in the dog is located between the distal ends of the radius and ulna proximally and the proximal row of the carpal bones distally **(Mikic et al., 1992; Farrow et al., 1994).** The feline carpal joint encompasses a complex series of the sub - division formed by the carpal bones and the adjacent long bones. It includes antebrachiocarpal joint, intercarpal joint, middle carpal joint, joint of the accessory carpal bone, and carpometacarpal joints. The antebrachiocarpal joint is located between the radius and ulna proximally and the proximal row of the carpal bones distally. Although this joint is supported by collateral ligaments, additional stability is achieved by the radial and ulnar styloid process, which extends distally on each side of the proximal row of carpal bones. The antebrachiocarpal joint has the greatest amount of movement. The middle carpal joint is the collective proximal - to - distal intercarpal joints that are located between the proximal and distal rows of the carpal bones. Very little motion occurs in the carpometacarpal and intercarpal joints (**Farrow et al., 1994; Fossum, 2002; Guilliard, 2006).** The carpus of carnivores comprises seven bones, three in the proximal row: the radial carpal bone, the ulnar carpal bone, the accessory carpal bone. Four bones create the distal row: the first, second, third and the fourth carpal bone (Fig. 2). The numerical reduction in the proximal row is apparently due to the fusion of the radial and intermediate carpal bone constituting a large bone, the intermedioradial carpal bone. In addition there is a small sesamoid bone in the tendon insertion of the abductor pollicis longus muscle, situated medial to the distal aspect of the radial carpal bone. These seven bones form a very complex set of joints. Essential three major articulations are present. The carpometacarpal joint is formed between the carpal bones I, II, III and IV and the base of metacarpal bones I, II, III, IV and V. This joint is supported by numerous ligaments, as the middle carpal joint (**Sisson and Grossman, 1963; Getty, 1975; Newton, 1985; Guilliard and Mayo, 2001; Guilliard, 2006).** Distal to the radius, the terms cranial and caudal are replaced by dorsal and palmar (**Brinker et al., 1983).**

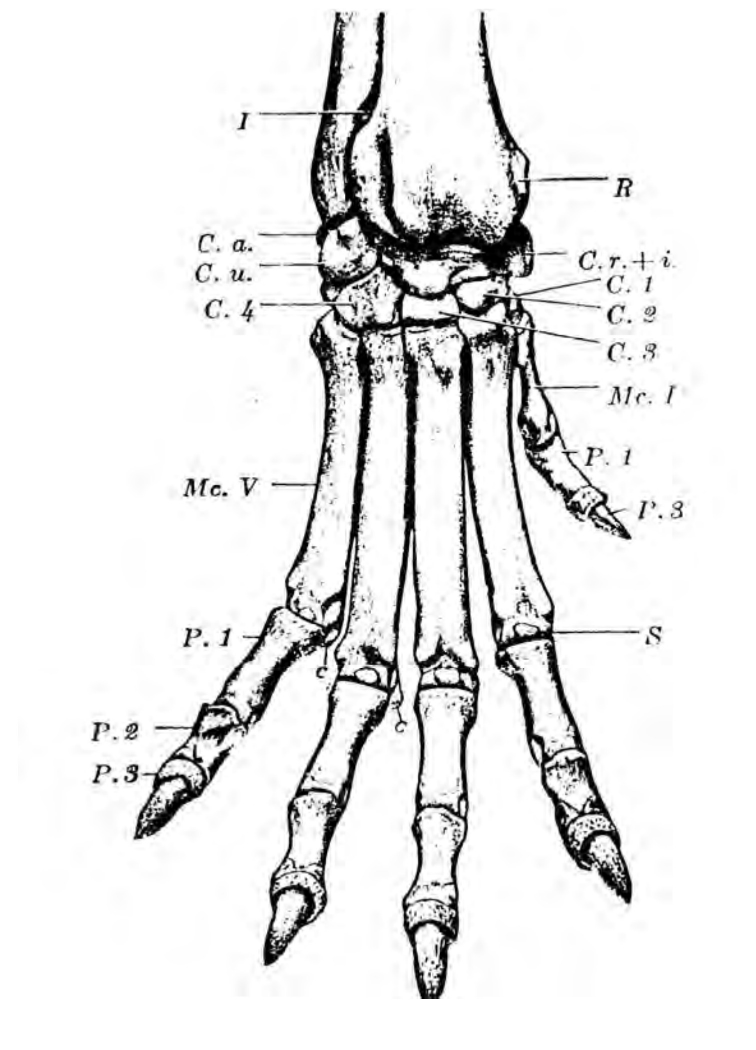


Fig. 2: Skeleton of distal part of right thoracic limb of dog; dorsal view. (Getty, R. The anatomy of the domestic animals. Fifth edition, 1448, W. B. Saunders Company, 1975), the digits are spread C. palmar (proximal sesamoids. C. A. accessory carpal (very small part visible): C.R. I., intermedioradial carpal bone: C.U. ulnar carpal; C.1.C.2.C.3.C.4, First to fourth carpal bone, I. distal end of the interosseous space, MC1 First metacarpal bone; MC.V. Fifth Metacarpal bone; P.1, P.2, P.3, proximal, middle and distal phalanges of fifth digits, P1 , P3, proximal and distal phalanges of the first digits. R, (trochlea) distal end of radius; S. dorsal sesamoid

The five metacarpal bones that are located close to each other are enclosed of a common integument, which articulates with the distal row of carpal bones. Each of the lateral four metacarpal bones bears three phalanges that, associated by sesamoid bones, form the skeleton of the four main digits. The first metacarpal bone medially located bears only two phalanges, which form the skeleton of the rudimentary first digit (**Evans, 1993; Fossum 2002).**

I.I. <u>Distal extremity of the forearm:</u>

The distal extremity of the radius is somewhat expanded. The articular surface is concave in its cranial part and convex in its caudal part; it has a slightly concave ovoid form, in which some abduction, adduction, and rotation are allowed to the antebrachiocarpal joint in addition to the major movements of flexion and extension. Its medial border projects downward, forming the styloid process of the radius. Lateral there is a concave facet for articulation with the ulna. The dorsal surface presents three distinct grooves for the extensor tendon.

The pointed enlarged distal end of the ulna is the styloid process (processus styloideus ulnae). It articulates with the ulnar carpal bone distally, and shows a convex facet dorso-medially with the radius (**Sisson and Grossman, 1963; Getty, 1975; Dyce et al., 1987).**

The lower end of the radius is a rather massive quadrangle of bone, 16-22 mm wide in the transverse aspect and 12-16 mm at the thickest part in the anteroposterior direction. Its concave carpal articular facet forms three-fifths of the antebrachial articular surface. On its dorso-medial side, there is a groove 5-10 mm wide for the extensor tendons and its ulnar part is significantly narrower in the anteroposterior plane than its medial part. The distal end of the ulna is an elongated, cylindrical, and rather thin bone, 5-8 mm in diameter, and much thinner than the corresponding part of the radius. Its convex joint facet forms three-tenths of the antebrachial articular surface. The distal end of the ulna in dogs directly articulates with the ulnar and accessory carpal bone forming specialized antebrachiocarpal arrangement more adapted to running (**Mikic et al., 1992).**

The distal region of the radius is the most massive part of the bone. Its distal part articulates with the radial carpal bone and to a lesser extent with the ulnar carpal bone. This surface is concave, both transversely and longitudinally, except for a caudomedial projection that lies in the groove of the radial carpal bone. The lateral surface of the distal extremity is slightly concave and lipped, forming the ulnar notch, which articulates with a facet near the distal end of the ulna. The distal extremity of the ulna is separated from the body of the bone by a notch in its cranial border. An oval slightly raised facet is located in the distal part of the notch for articulation with the ulnar notch of the radius. The ulna of the dog possesses no head (**Evans, 1993).**

I.2. Radial and intermediate carpal bones:

The intermedioradial carpal bone is a large bone that articulates with almost the entire distal surface of the radius and with the bones of the distal row. It projects prominently on the palmar aspect of the carpus (**Sisson and Grossman, 1963; Getty, 1975; Fossum, 2002).** The radial carpal bone (scaphoid) is located on the medial aspect of the proximal row; it represents a fusion of the primitive radial carpal bone with the central and intermediate carpal bones. The proximal surface of the bone is largely articular for the distal end of the radius. The distal surface of the radial carpal bone articulates with all of the four distal carpal bones. Laterally it articulates extensively with the ulnar carpal (Fig. 3). Its transverse dimension is about twice its width (**Dyce et al., 1987; Mikic et al., 1992; Evans, 1993).**

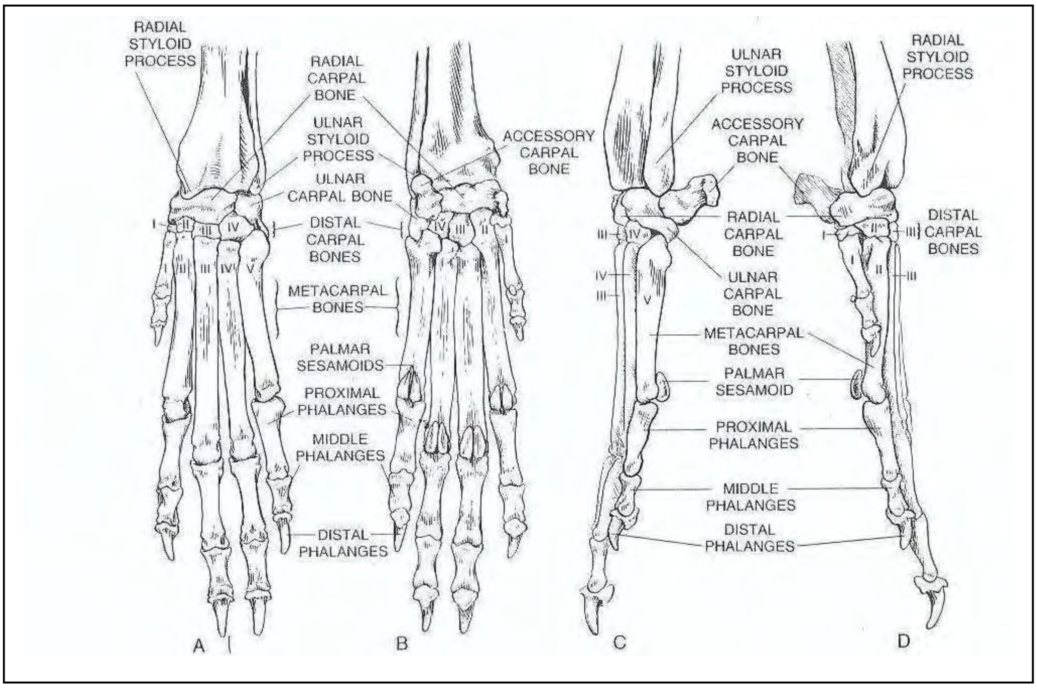


Fig. 3: Bones of the carpus, metacarpus, and phalanges of a dog. (A) Dorsal view. (B) Palmar view (C) Lateral view (D) Medial view. (Brinker et al., Handbook of small animal orthopedics and fracture treatment, 167 – 175, W. B. Saunders Company, 1983)

1.3. Ulnar carpal bone:

The ulnar carpal bone (triquetrum) is the lateral bone of the proximal row. It is shaped somewhat like the radial carpal, but is smaller. It articulates proximally with the radius and ulna, distally with the fourth carpal and the fifth metacarpal, medially with the radial carpal bone, and on the palmar side with the accessory carpal bone. It possesses a small lateral process and a larger palmar one for articulation with the accessory carpal and metacarpal V **(Sisson and Grossman, 1963; Getty, 1975; Mikic et al., 1992; Evans, 1993).**

1.4. Accessory carpal bone:

The accessory carpal bone is cylindrical, and is constricted in its middle and enlarged at each end; the anterior extremity articulates with the ulna and the ulnar carpal bone (**Sisson and Grossman, 1963; Getty, 1975).** The accessory carpal bone in dogs is a massive, long bone. The joint between the accessory and ulnar bones, is always connected with the antebrachiocarpal joint (**Mikic et al., 1992).** Accessory carpal bone (pisiforme) is a truncated rod of bone located on the palmar side of the ulnar carpal bone. Both ends of this bone are enlarged. The basal enlargement bears a slightly saddle shaped articular surface for the ulnar carpal bone, which is separated by an acute angle from a smaller, transversely concave, proximally directed articular area for the styloid process of the ulna. The flexor carpi ulnaris muscle inserts on it (**Evans, 1993).**

1.5. <u>First carpal bone:</u>

The first carpal bone (trapezium) is the smallest bone of the distal row; it articulates proximally with the radial carpal bone. It is somewhat flattened as it articulates with the palmaromedial surfaces of the second carpal bone and the base of the second metacarpal bone and distally with the first metacarpal bone (**Sisson and Grossman, 1963; Getty, 1975; Evans, 1993).**

1.6. <u>Second carpal bone:</u>

The second carpal bone is wedge-shaped, the base being palmar; its proximal surface is convex, and its distal is concave and rests on the metacarpal bone (**Sisson and Grossman, 1963; Getty, 1975).** The second carpal bone (trapezoideum) is a small and proximodistally a compressed bone that articulates proximally with the radial carpal bone, distally with the second metacarpal bone, laterally with the third carpal bone, and medially with first carpal bone (**Evans, 1993; Guilliard and Mayo, 2001).**

1.7. Third carpal bone:

The third carpal bone is somewhat like the second carpal bone (**Sisson and Grossman, 1963; Getty, 1975).** The third carpal bone (capitatum) is larger than the second carpal bone. It has a large palmar projection, which articulates with the three middle metacarpal bones. It articulates medially with the second carpal, laterally with the fourth carpal, proximally with the radial carpal, and distally with the third metacarpal bone (**Evans, 1993).**

1.8. Fourth carpal bone:

The fourth carpal bone is the largest bone of the distal row (**Sisson and Grossman, 1963; Getty, 1975).** The fourth carpal bone (hamatum) presents a caudal enlargement and is a wedge-shaped in both cranial and proximal views. It articulates distally with metacarpal IV and V, medially with the third carpal bone and proximomedially with the radial carpal (**Evans, 1993).**

1.9. The proximal extremity of the metacarpal bone:

There are five metacarpal bones in dogs and cats. The first is the shortest, the third and fourth are the longest and the second and fifth are similar in size. The proximal ends (bases) articulate with each other and with the corresponding carpal bones. The carpal articular surface formed by them is concave from side to side and dorsopalmar convex (**Sisson and Grossman, 1963; Getty, 1975; Newton, 1985).** The individual metacarpal bones of the dog are relatively weaker. The third and fourth metacarpal bones are square in section but the second and fifth are triangular. The proximal extremity (base) has a flattish articular surface for the distal row of carpal bones **(Dyce et al., 1987).** The metacarpal bones are numbered from the medial to the lateral. The five metacarpal bones are each cylindrically shaped and enlarged at each end, proximally to form the base, and distally to form the head. The middle portion is the body (**Evans, 1993**).

I.10. <u>Ligaments of the carpal joint (Figg. 4, 5, 6):</u>

The antebrachiocarpal joint is stabilized primarily by radial (medial) collateral ligament and an ulnar (lateral) collateral ligament. This joint has the capacity for the greatest amount of carpal motion. Approximately 80 to 90% of carpal motion occurs through this joint and less movement take place in the intercarpal and carpometacarpal joints. Numerous short ligaments reinforce the middle carpal joint by passing between the rows of bones as well as between the bones of each row. This joint is responsible for approximately 10 to 15% of carpal motion. Short ligaments to the ulnar carpal bone and long ligaments to the base of metacarpal bones IV and V hold the accessory carpal bone on the caudal lateral surface of the joint (**Newton, 1985; Evans, 1993; Fossum, 2002)**. Medial and lateral collateral ligaments are well developed in ungulates but are necessarily much weaker in the dog and cat allowing for some adduction and abduction. On the dorsal aspect, a number of short ligaments join neighboring bones in the same row, and those of the distal row to the metacarpus. More robust ligaments are found on the palmar aspect where a deep ligament covers the entire palmar surface of the skeleton. A second superficial transverse ligament passes obliquely from the free extremity of the accessory carpal bone to the medial aspect. Additional small ligaments join the accessory bone to the adjacent carpal and metacarpal bones. These palmar ligaments do not interfere with flexion but assist in preventing overextension **(Dyce et al., 1987).** There are no continuous collateral ligaments for the three main joints of the carpus. Long collateral ligaments are lacking. Two superimposed sleeves of collagenous tissue, with tendons located between them, ensure the integrity of the carpus. The superficial sleeve is modification of the deep carpal fascia, and the deep sleeve is the fibrous layer of the joint capsule. Laterally and medially, the two sleeves fuse and become specialized in part to form the short collateral ligaments. In the dorsal aspect of the carpal joint there are radioulnar ligament, dorsal radiocarpal ligament, short radial collateral ligament and short ulnar collateral ligament. In addition to palmar radiocarpal ligament, palmar ulnocarpal ligament and transverse palmar carpal ligament (flexor retinaculum) present on the palmar aspect of the carpal joint **(Evans, 1993).** The radioulnar and ulnocarpal ligaments, the ulnocarpal meniscus, the tendon sheath of the extensor carpi ulnaris muscle, the ulnar collateral ligament, and accessory fiber strands lead to complex guides movements such as pronation and supination and stabilize the proximal and distal carpal joint (**Schmidt, 1998).** The short radial collateral ligament consists of straight and oblique parts. The straight part runs from a tubercle above the styloid process to the most medial part of the radial carpal bone. The oblique part, after leaving the styloid process, runs obliquely to the palmaromedial surface of the radial carpal. The tendon of the M. abductor pollicis longus lies between the two parts as it crosses the medial surface of the carpus **(Mikic et al., 1992; Evans, 1993).** Dorsally the joint capsule of the carpal joint is slightly thickened by the dorsal radiocarpal ligament, which lies obliquely between the dorsal margin of the radius and the dorsal surface of the ulnar carpal bone, and by the dorsal radioulnar ligament (Figg. 4, 5). There are two distinct intra-articular ligaments. The strong palmar ulnocarpal ligament runs obliquely through the capsule-synovial recess from the radial side of the distal ulna, just behind the articular disc, to the Palmar capsule; then join with the reinforced capsule which attaches to the palmar surface of the radial and ulnar carpal bones to the radial side of the accessory carpal bone **(Mikic et al., 1992).**

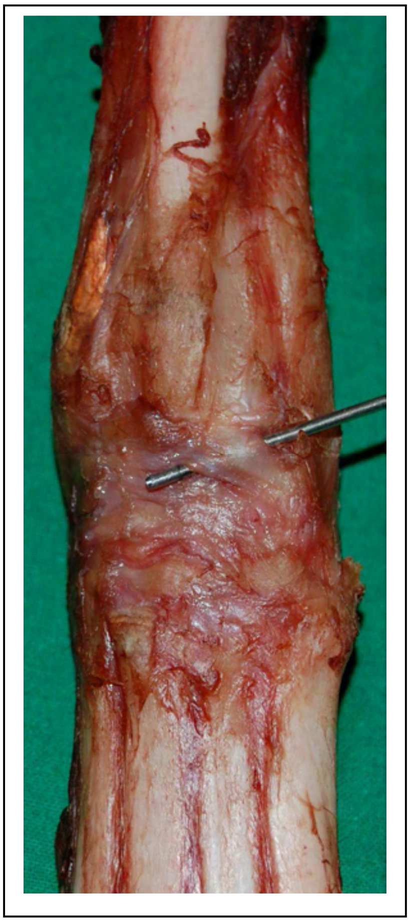


Fig. 4: Dorsal radiocarpal ligament in a dog.

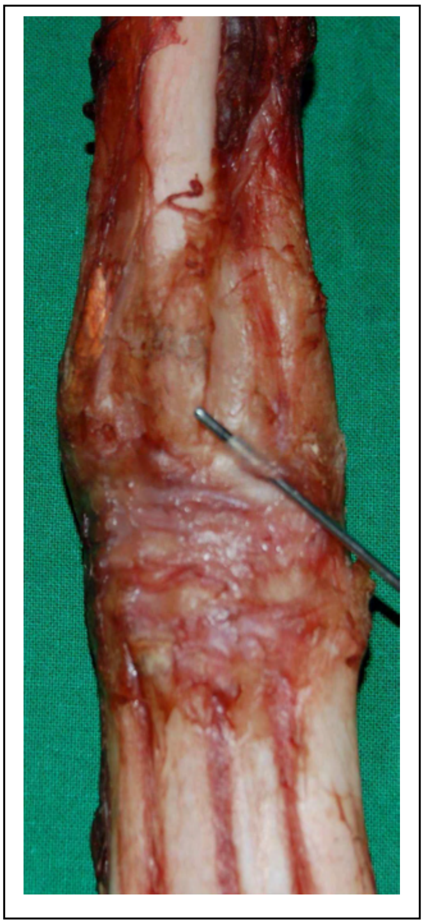


Fig. 5: Dorsal radioulnar ligament in a dog.

(Institute for Anatomy and Histology, JLU University, Giessen, Germany, 2009)

Collateral ligamentous support of the carpal joint arises from the short radial collateral ligament medially and from the short ulnar collateral ligament laterally. Also sleeves of collagenous tissue, that house tendons, provide medial and lateral support. Palmar support is from flexor retinaculum proximally and palmar fibrocartilage distally. Multiple small ligaments cross

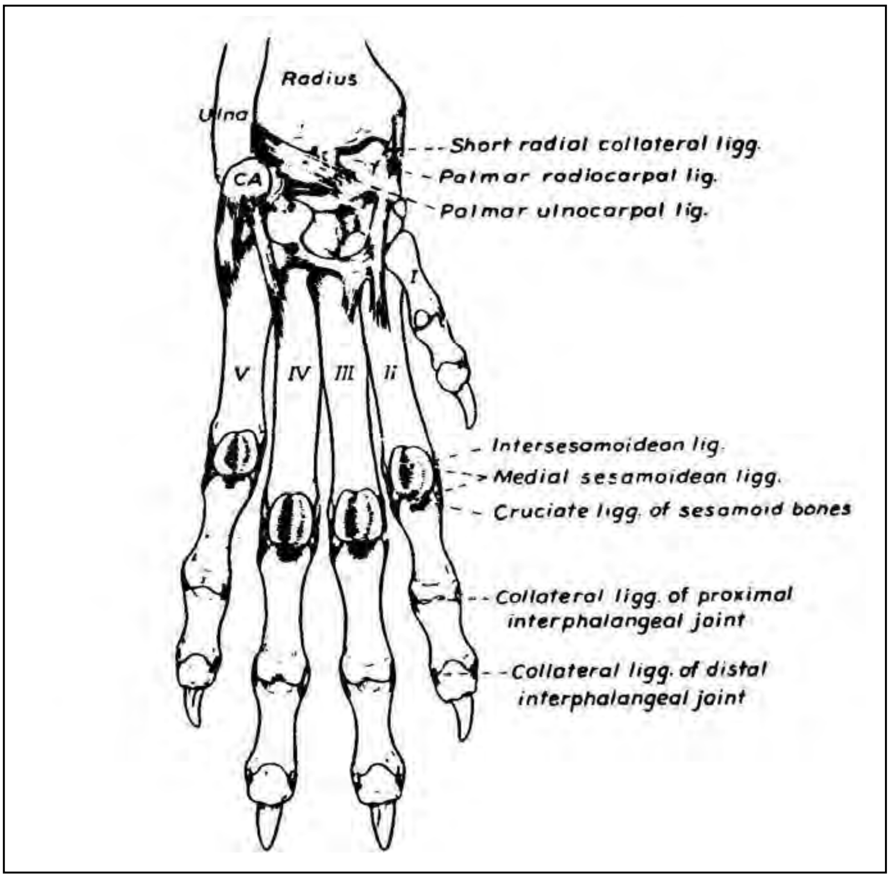


Fig. 6: Deep ligaments of the left fore paw, (CA, Accessory carpal, I to V metacarpals) (Evans H E, Christenson GC: Miller's Anatomy of the Dog. Philadelphia. WB Saunders, 1979).

the intercarpal articulations between carpal bones to provide additional collateral and palmar support (Fig. 6). Two accessory ligaments originate from the free end of the accessory carpal bone, in conjunction with the accessory carpal ligaments, act as a moment arm to balance the vertical force produced when the paw strikes the ground (**Evans, 1993; Farrow et al., 1994; Mckee, 1994; Fossum, 2002; Johnson and Hulse, 2002).** The distal radioulnar ligament can be divided into two parts, a proximal interosseous and a distal articular. The distal part of the distal radioulnar ligament fills the space between the radius and ulna and contributes to the articular surface. From a distal view, the ligament has a triangular shape with its base dorsally and its third angle reaching palmar. An additional part of the ligament extends dorsally over the dorsal rim of the distal radial articular surface, thus forming a labrum for the antebrachiocarpal joint **(Kaiser et al., 2007).**

2. <u>Affections of the carpal joint in dogs and cats:</u>

The carpal injuries in dogs and cats are divided into fractures, ligamentous impairments, luxation, subluxation, dislocations, growth plate defects, radial exostosis, growing faults, shearing injuries, osteoarthritis or neoplasia and various conformations. Osteoarthrosis arises secondarily, due to some previous accidental damage to joint margins or surfaces, following an instability caused by ligament ruptures or as a consequence of other infectious or non infectious joint disease. Chips or slabs of the articular surfaces of the radial carpal bone are most often seen after injuries resulting from jumps or falls and in dogs undergoing heavy exertion such as sled dogs and field trial dogs. Slab fractures of the distal surface of the accessory carpal bone, extending into the carpal joint through the base of the bone, occur mainly in the right forefoot of racing Greyhounds. This fracture has been considered to be an avulsion of the origin of the abductor digiti quinti muscle **(Brinker et al., 1983**; **Vaughan, 1985).** Fractures of the ulnar carpal bone and fractures of carpal bones I, II, III, or IV are manifested mostly as small chips or slaps in the dorsal surface. These fractures are associated with a hyperextension injury and are most often seen in racing or working dogs **(Brinker et al., 1983; Newton, 1985).** The carpal luxation and subluxation (Fig. 7) occurs commonly by car accident, by jumping from a height or over a barrier. Most of the animals with such a trauma are healthy prior to the injury, but it must be also remembered that animals with underlying different disease processes, such as rheumatoid arthritis or systemic lupus erythematosis, may require less trauma to cause an injury than normal dogs **(Newton, 1985; Leighton, 1994).**

Fig. 7: Dorsopalmar (DP) view of the left carpus in a cat demonstrates luxation of the antebrachiocarpal joint (arrow) with soft tissue swelling surrounding the carpal joint (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

Injuries in the carpal joint are common in racing Greyhounds and large hunting breed dogs. The complexity of the carpal articulations and the multiple bones and ligaments, that form and stabilize the joint, creates often a difficult diagnostic problem for the veterinarians. Most carpal injuries, and particularly those which are undiagnosed or untreated, increase the risk of osteoarthritis and have a potential for long-term lameness. Carpal injuries can lead to an ending career in most dogs. Carpal injuries are often seen as hyperextension ± torsional injuries in large dogs. They result in a loss of collateral and/ or palmar ligamentous support of the antebrachial, middle carpal, and or carpometacarpal joints (**Fossum**, **2002**; **Roush, 2003).**

3. Clinical Examination:

3.1. Luxation and subluxation of the carpal joint in dogs and cats:

Of great importance for the veterinarian is the direct physical orthopedic examination of the patient. Few diagnostic procedures offer the wealth of information that can be gleaned by performing a thorough physical examination. An examination may be defined as an inspection or investigation used as a means of diagnosing disease. The clinician must temper the depth of the examination with consideration for both the needs of the patient and the economic capabilities of the owner. The physical examination should be performed with attention to the following:

1- A review and assessment of patient's signalment. 2- The patient's chief complaint. 3- The history as obtained and recorded by the clinician in charge of the case. 4- The problem list. 5- The tentative / final diagnosis **(Whittick, 1990).** Traumatically induced subluxation of the accessory carpal bone in a dog results in chronic lameness with weight-bearing instability (**Lenehan and Tarvin, 1989).** Luxation of the radial carpal bone is characterized by its palmar position and an inducible hyperextension of the antebrachiocarpal joint. The bone is orientated so that the medial aspect is farthest proximal, with the convex proximal articular surface facing dorsally, resulting from rotation in two planes. This is accompanied by a rupture of the short radial collateral ligament and the dorsal joint capsule **(Pitcher, 1996).** Diagnosis of luxation of the accessory carpal bone in a racing greyhound, and subluxation of the same bone in a lurcher are described by **Guilliard (2001).** The injury in the lurcher occurs in both carpi, but on different occasions. Two dogs show severe thoracic limb lameness with marked carpal swelling. The subluxation is difficult to detect by palpation, but is suspected and confirmed on exploratory surgery, which shows an avulsion of the lateral support structures of the accessory carpal bone from the distal ulna. Clinical signs of the subluxation of the second carpal bone are subtle, with local soft tissue swelling and pain reaction on digital pressure over the dorsal aspect of the second carpal bone. In contrast to these findings, a dog with a complete luxation is high grade lame, having marked soft tissue swelling with carpal hyperextension and valgus **(Guilliard and Mayo, 2001).** Hyperextension, falling or other impact traumas that had hyperextended the carpus can cause severe injury to the numerous small palmar carpal ligaments that support the 3 levels of carpal joints. Patients present with varying severities of lameness, swelling, and pain, depending on the time that has elapsed since the injury **(Harasen, 2002)**. Damage to the palmar carpal ligaments results in varying degrees of hyperextension with or without lateral deviation. The involved ligaments are palmar accessory carpometacarpal, palmar radial carpometacarpal, and palmar fibrocartilage. Clinically, the animal may vary from being slightly lame to exhibiting gross hyperextension **(Whittick, 1990; Leighton, 1994)**.

3.2. <u>Fractures of carpal bones in dogs and cats:</u>

Usually clinical signs of slab fractures of the distal surface of the accessory carpal bone are not noted until the day following the injury, when a slight lameness and swelling are observed in the region of the accessory carpal bone. Chronic low-grade lameness persists when exercise is resumed**.** In case of fractures of the ulnar carpal bone and of the distal row of one of these bones clinical signs of intermittent mild lameness and joint effusion are mostly noted **(Brinker et al., 1983).** In 15 dogs with radial carpal bone fractures, soft tissue swelling can be detected. This varies from gross synovial distention of the carpus to minor thickening on the dorsomedial aspect of the joint. Pain can be elicited on manipulation of the antebrachial joint, particularly in flexion of the carpus. In those cases in which lameness is marked, a reduced range of movement is noted **(Bennett et al., 2000).** Chronic lameness is reported in nine dogs with radial carpal bone fractures. Reduced range of motion and soft-tissue swelling of the carpal joints are the most visible clinical signs. Three common fracture patterns are identified: oblique fracture with a large medial fragment, sagittal fracture with a small medial fragment, and comminuted fracture. Radial carpal bone sclerosis and carpal osteoarthritis are identified in nine dogs (**Tomlin et al., 2001).** Patients with fractures of the carpus usually have non weight bearing lameness. Attempts to place weight on the limb cause the carpus to collapse in a plantigrade stance. Pain, swelling, and crepitus are present in the affected limb. Varus or valgus deviation of the foot is usually present **(Fossum, 2002).**

3.3. <u>Arthritis and osteoarthritis of the carpal joint in dogs and cats:</u>

In osteoarthrosis lameness local pain, enlargement, capsular distention and reduced motion are the main clinical features (**Vaughan, 1985).** Pseudogout is diagnosed in a dog by **Haan and Andreasen (1992)**. Clinical signs included non-weight bearing lameness, signs of pain on joint manipulation, and high rectal temperature. Arthrocentesis of carpal joints reveal extra- and intracellular crystals containing calcium. The suspected cause is polyarthritis secondary to chronic Ehrlichiosis. Results of joint tap performed after resolutions of the clinical signs are negative for calcium pyrophosphate dehydrate crystals**.** In a case of rheumatoid arthritis, crepitation and ligamentous laxity may be found on manipulation of the affected joints. These signs can relate to loss of articular cartilage, destruction or weakening of ligaments, tendons and capsular structures, and destruction of subchondral bone (**Heuser, 1980).**

4. <u>Radiographic Examinations and Findings in the canine and feline carpal joints:</u>

4.1. <u>Positioning of dogs and cats:</u>

For the dorsopalmar (DP) projection of the carpus, the patient has to be placed in sternal recumbency with the thoracic limb of interest extended (Fig. 8). The extension of the affected limb can be maintained by placing a piece of foam material under the elbow for support. The head should be hold at a comfortable height, but high enough to permit extension without rotation of the carpus. The central X – ray beam should be passed through the center of the distal row of the carpal bones. In the dorsopalmar view of the radius and ulna, the patient is placed in sternal recumbency with the affected limb pulled forward and the head rotated toward the contralateral side **(Ticer, 1975; Ryan, 1981; Douglas et al., 1987; Morgan and Silverman, 1987; Lisa, 1994).** To evaluate the whole carpal joint for pathologies, standard dorsopalmar and mediolateral radiographs have to be used **(Whittick, 1990; Fossum, 2002; Johnson et al., 2005).** In the mediolateral projection, the patient should be placed in lateral recumbency with the affected side downwards. Foam pad of the appropriate thickness should be placed under the humerus and cranial thoracic parts. The carpus should be centered over the unexposed half of the cassette. The mediolateral flexed view is helpful in evaluating the carpal articulations when abnormal laxity of the joint is suspected (Figg. 9, 10) **(Ryan, 1981; Ticer, 1984; Douglas, et al., 1987; Morgan and Silverman, 1987; Lisa, 1994).**

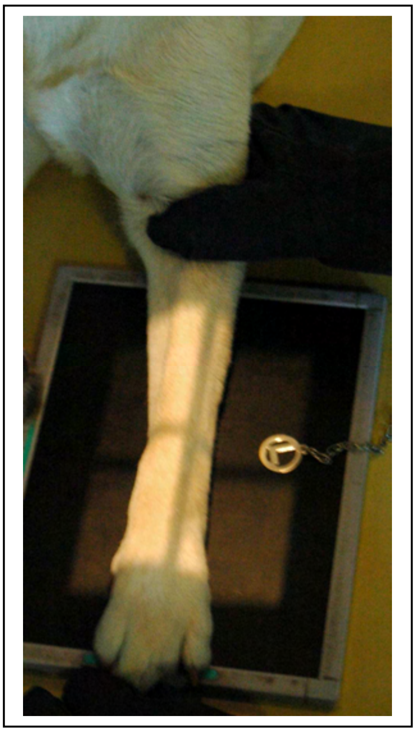


Fig. 8: Dorsopalmar view of the left carpus in a dog (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 9: Mediolateral projection of the Carpus in a dog, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 10: Mediolateral flexed projection of the carpus in a dog (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, 2009)

Dorsopalmar stressed views are useful for detection instabilities of the carpal joint and small avulsion fracture fragments. The affected carpus is placed in dorsopalmar position (Figg. 11, 12); the radius and ulna are held firmly in place. The paw is pushed medially or laterally with a ruler or wooden paddle. Care should be taken not to apply too much force on the joint to avoid further injury. Small carpal bones are not seldom fractured therefore radiography should include four views to evaluate these bones completely. Stress views may help in separating overlying bones so that fractures and sites of instability can be seen more easily. The radius is one of the more commonly fractured bones in the dog and cat, so fractures of any description can occur. The majority of radial fractures also have associated ulnar fractures. The majority of fractures occurs in midshaft and distal parts of the bone, and rarely includes an articular component. In addition to oblique views can be helpful for detection of carpal joint instability **(Ryan, 1981; Morgan and Silverman, 1987; Lisa, 1994; Morgan and Wolvekamp, 1994; Jerry and Darryl, 1999; Johnson and Hulse, 2002).**

Fig. 11: Lateral stress view of the right carpus in a dog (Department of Veterinary Clinic Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 12: Medial stress projection of the right carpus in a dog (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

In lateral oblique view of the carpus, the patient is placed in sternal recumbency. Next, a foam wedge is placed under the elbow to maintain extension of the thoracic limb in question, and a foam block of appropriate height is placed under the head so that the remaining body structures can be maintained in proper position and allows the affected limb to assume normal position. Approximately 35 degrees of lateral rotation from the straight anteroposterior projection is applied (Fig. 13). Visualization of the cranial lateral aspect of carpal metacarpal structures can be seen through this method of positioning **(Ryan, 1981; Ticer, 1984; Douglas et al., 1987).** In medial oblique view of the carpus, the patient is placed in sternal recumbency. Next, a foam wedge is placed under the elbow to maintain extension of the thoracic limb in question, a foam block of appropriate height is placed under the head so that the remaining body structures can be maintained in proper position. The affected limb is hold in normal position. Approximately 35 degrees of medial rotation from the straight anteroposterior projection is applied (Fig. 14). This permits visualization of the cranial medial aspect of carpal metacarpal structures **(Ryan, 1981; Douglas et al., 1987; Ticer, 1984).**

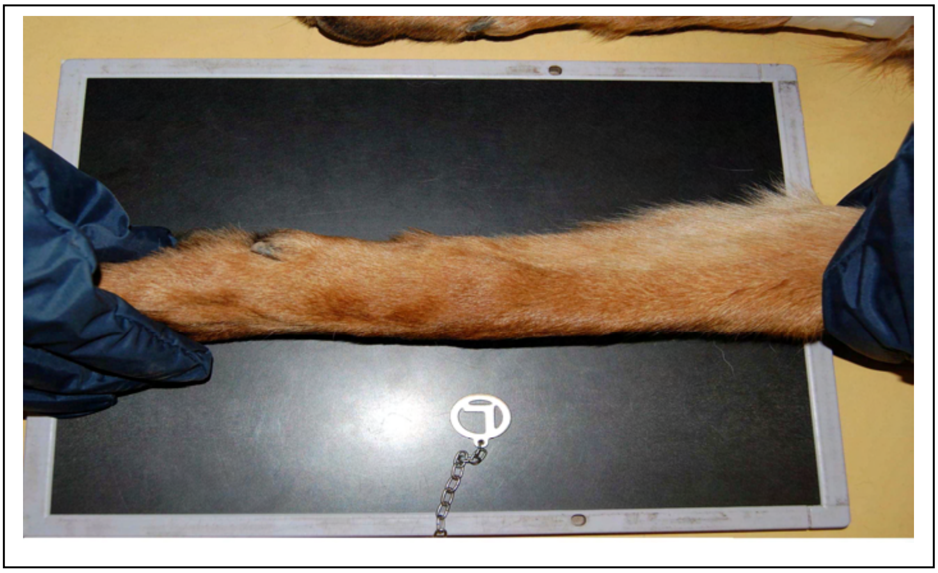


Fig. 13: Lateral oblique projection of the left carpus in a dog. (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009)

Fig. 14: Medial oblique view of the right carpus in a dog. (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009)

4.2. <u>Normal radiography of the carpal joint in dogs and cats:</u>

Radiographically the carpal joint in dogs and cats encompasses a complex of subdivisions formed by the carpal bones and the adjacent long bones. It includes five named entities as follow: antebrachiocarpal joint – the articulation between the radius and ulna proximally and the proximal row of carpal bones distally. Intercarpal joints are located between carpal bones (side to side as well as proximal to distal). The middle carpal joint is located between the proximal and distal rows of carpal bones. The joint of the accessory carpal bone is the articulation of the accessory carpal bone with the ulna and with the ulnar carpal bone. Carpometacarpal joints are the articulations between the distal row of carpal bones and the bases of the metacarpal bones. These are numbered one through five from medial to lateral to correspond to the involved metacarpal bone (Figg. 15, 16, 17, 18) (**Farrow et al., 1994).**

4.3. <u>Radiography of carpal joint affections in dogs and cats:</u>

Radiographic signs of joint disease are increased synovial volume, altered thickness of the joint space, increased or decreased subchondral bone opacity, perichondral bone proliferation, mineralization of joint soft tissues and intraarticular calcified bodies, joint malformation and intraarticular gas **(Morgan, 1999; Owens and Biery, 1999; Fossum, 2007; Thrall, 2007).**

4.3.1. <u>Luxation and subluxation of the carpal joint in dogs and cats:</u>

In case of luxation of the radial carpal bone, mediolateral and dorsopalmar radiographs are taken under sedation. The radial carpal bone is luxated and displaced in a palmaroproximal direction. The antebrachiocarpal joint is collapsed with palmar displacement of the distal limb and marked soft tissue swelling (Fig. 19) **(Pitcher, 1996).**

Fig. 15: Dorsopalmar view of normal right carpus in a dog. 1. Radius; 2. Ulna, 3. Intermedioradial carpal bone 4. Accessory carpal bone 5. Ulnar carpal bone 6. Sesamoid bone 7. First 8. second 9. Third 10. Fourth carpal bone 11. First 12. Second 13. Third 14. Fourth 15. Fifth metacarpal bones (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 16: Dorsopalmar view of normal right carpus in a cat 1. Radius, 2. Ulna 3. Intermedioradial carpal bone 4. Accessory carpal bone 5. Ulnar carpal bone, 6. Sesamoid bone 7. First. 8. Second. 9. Third, 10. Fourth carpal bone 11. First. 12. Second. 13. Third. 14. Fourth. 15. Fifth metacarpal bones. (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 17: Mediolateral view of normal right carpus in a dog 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, 12. Fourth + Fifth metacarpal bones. (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Fig. 18: Mediolateral view of normal left carpus in a cat 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, 12. Fourth + Fifth metacarpal bones, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Diagnosis of subluxation of the second carpal bone by radiographs is seen as an increase in the width of the joint space between the second and third carpal bone (Fig. 20). The mediolateral view shows a small radiodense mass on the dorsal aspect of the carpus between the proximal and distal rows of carpal bones **(Guilliard and Mayo, 2001).** Radiographic signs of isolated instability at the antebrachiocarpal joint level include an increase in carpal extension without alteration of the middle carpal joint. Radiographic signs of instability at the middle carpal joint with loss of integrity of the accessory carpal bone include widening of the space between the palmar process of the ulnar carpal bone and the base of the fifth metacarpal bone, and proximal deviation of the accessory carpal bone. The proximal carpal bones may appear to override the distal row of the carpal bones with instability of the carpometacarpal level **(Johnson and Hulse, 2002; Johnson et al., 2005).** Radiographic findings of the carpal joint luxation and subluxation include increased joint space, articular or periarticuar fractures may be present, periarticular osteophytes and periosteal reaction is usually present in chronic injury **(Owens and Biery, 1999).** Individual bones of the carpus may luxate partially or completely. The bones most commonly involved are the radial carpal bone or the first and the second carpal bones. Usually they are displaced dorsally **(Newton, 1985)**.

4.3.2. <u>Fractures of carpal bones in dogs and cats:</u>

In case of fractures of the ulnar carpal bone and (fractures) of the distal row of numbered bones, radiographic diagnosis is often difficult. Multiple oblique views (dorsolateral palmaromedial oblique and dorsomedial palmarolateral oblique) are often necessary for visualization **(Brinker et al., 1983).** In case of chips or slap fractures of the articular surface of the radial carpal bone, diagnosis requires a high index of suspicion because radiographs (non screen film or high-detailed screens) must be taken in oblique planes, in flexion and extension to verify the fracture (Fig. 21) **(Brinker et al., 1983).** Radial carpal bone fractures are categorized in four main types. The first three types have fracture lines that extend to the proximal or distal articular surfaces of this bone or both. Initially the fracture line may be incomplete and difficult to diagnose until there has bone resorption and widening of the fracture gap, or complete propagation of the fracture line. Comminuted T- shaped fractures (Fig. 22) that apparently develop without obvious trauma may result from incomplete fusion of the three ossification centers of this bone. Dorsal margin chip fractures result from compression and impingement by the distal radius during limb loading or avulsion by the dorsal radiocarpal ligament or hyperextension of the carpal joint. Palmar process fractures are sprain avulsion fractures of the bone at the proximal attachment of palmar radialcarpal ligament or the palmar attachment of the oblique part of the short radial collateral ligament, transverse fractures with a major medial and lateral fragment can occur, however, they are uncommon **(Newton, 1985; Johnson et al., 2005).** Accessory carpal bone fractures are classified into five main types (Fig. 23). Type I, II and III are avulsion fractures, but only the first two are intraarticular. Type I fractures at the proximal attachment of the accessoro-ulnar ligament are further defined as being palmarolateral (type IA) or palmaromedial (type IB). Type IV fractures are avulsion fractures of the attachment of the flexor carpi ulnaris muscle. Type V fractures are comminuted fractures. Fractures of the numbered carpal bones, (first, second, third and fourth carpal bones) can be small dorsal chips or larger slab fractures of the dorsomedial side of the second carpal bone or dorsal margin of the third carpal bone **(Johnson et al., 2005).** Slab fractures of the distal surface of the accessory carpal bone, extending into the carpal joint through the base of the bone. This fracture considered as avulsion fracture of the origin of the abductor digiti quinti muscle **(Brinker et al., 1983).** Avulsion fractures of the carpal bones are common and often associated with subluxation. Instability is often apparent and readily demonstrable with stress radiographs (**Farrow, 1977).** Diagnosis of fractures of radial carpal bones in 15 dogs is confirmed by radiography at the time of presentation. The fractures show similar configurations, consisting of a virtually undisplaced, slightly oblique fissure in a near sagittal plane, combined with a longitudinal fracture running mediolaterally through the medial fragment of the bone accompanied by varying degrees of dorsal displacement of the dorsal fragment. In three cases there appeared to be two longitudinal fracture lines producing two separate dorsal fragments, although interpretation of these films is difficult. Secondary periarticular osteophyte formation, indicative of degenerative joint disease, is present in most cases, but the severity of these changes does not directly reflect the duration of the clinical signs **(Bennett et al., 2000).** Fractures of carpal bones I, II, III, or IV are generally chip fractures associated with the hyperextension injuries and most often seen in racing or working dogs (**Newton, 1985)**.

4.3.3. Arthritis and osteoarthritis of the carpal joint in dogs and cats:

In osteoarthrosis radiography reveals osteophyte formations, loss of joint space, and soft tissue swellings are present (Fig. 24) (**Vaughan, 1985).** In a case of rheumatoid arthritis, radiographs of the carpal joint indicate some narrowing of joint spaces and subchondral lucencies (**Heuser, 1980).** Radiographic signs of a mild (1st degree) carpus sprain injury in dogs are minimal regional soft tissue swellings. No bony lesions are seen, no apparent instability in stress radiographs. In a moderate (2nd degree) of carpal sprain injury there are prominent regional soft tissue swellings usually seen in both intra and extra capsular regions. In stress radiographs, it may be possible to demonstrate spatial deviations or displacements. In the marked (3rd degree) of the sprain injury gross regional soft tissue swellings and bony lesions are present **(Farrow, 1977).** Early radiographic signs of infectious arthritis include soft tissue swelling of articular and periarticular structures, the joint space may appear widened because of increased joint fluids, later subchondral bone destruction or erosion may occurs. Chronically the affected joint has subchondral bone sclerosis. The joint space is collapsed and often there is marked proliferative degenerative joint disease. Radiographic signs of osteoarthritis are increased periarticular soft tissue swelling as a result of joint effusion and or thickening of the articular or periarticular soft tissues, narrowing or ablation of joint space due to loss of water from the articular cartilage is principle radiographic changes seen in early stage of osteoarthritis in addition to increase density within the subchondral bone and new bone deposition, osteophyte formation (bone spurs) often form at the margin of the articular surface and mineralization of the intraarticular and periarticular soft tissues may occur **(Owens and Biery, 1999; Morgan, 1999; Fossum, 2007; Thrall, 2007; Franklin et al., 2009).** The primary injury in a primary arthrosis is not identified radiographically because it affects the soft tissues. Chronic irritation to the synovial lining stimulates inflammatory components causing congestion, edema and the accumulation of the chronic inflammatory cells within the synovial lining. This causes joint capsule distension that may be recognized radiographically and can be referred to as serious arthrosis (**Morgan, 1999).**

Fig. 19: Dorsopalmar view of the left carpus in a dog demonstrates antebrachiocarpal joint subluxation (medial arrow), soft tissue swelling surrounding the carpal joint (lateral arrow) (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University Giessen, Germany 2008).

Fig. 20: Dorsopalmar view of the left carpal joint in a dog demonstrates subluxation of carpometacarpal joint (arrow), (Department of Veterinary Clinical Science, Clinic for Small animals, JLU University, Giessen, Germany, 2008).

Fig. 21: Dorsopalmar projection of fracture of intermedioradial carpal bone (arrow) with soft tissue swelling surrounding the right carpal joint in a dog, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany 2008).

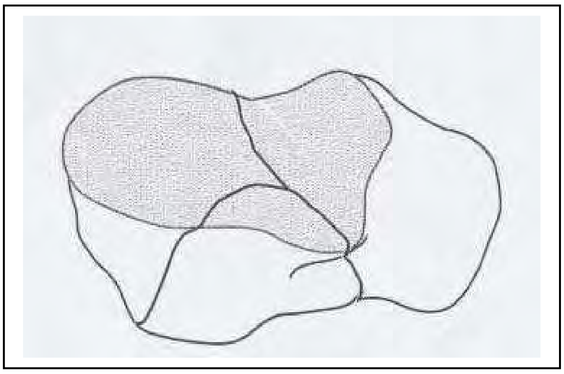


Fig. 22: Comminuted T shape fracture of the right radial carpal bone viewed from dorsal aspect. AO principles of fracture management in the dog and cat, Johnson et al. (2005).

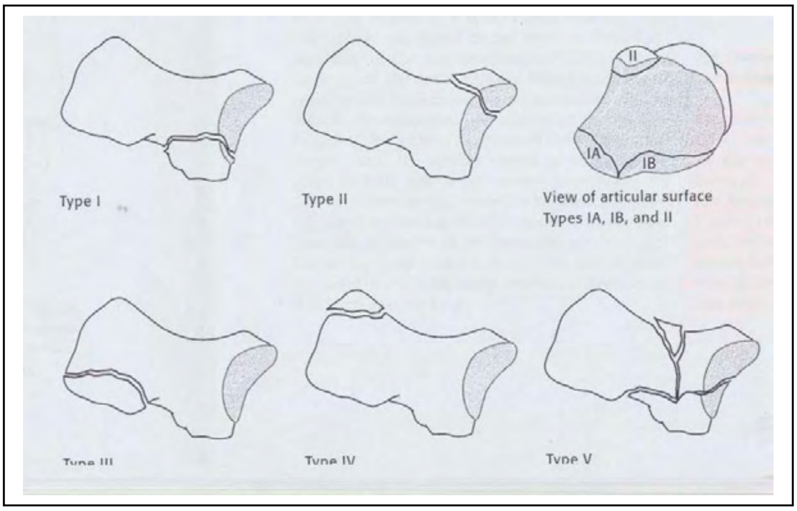


Fig. 23: Classification scheme of accessory carpal bone fractures, depicted on the right bone. AO principles of fracture management in the dog and cat, Johnson et al. (2005).

Fig. 24: Dorsopalmar view demonstrates osteoarthritis of left carpal joint in a dog, osteophytes formation (short white arrow), soft tissue swelling surrounding the carpal joint (long white arrow) and collapse of the joint space (black arrow), (Department of Veterinary Clinical Science, Clinic for Small animals, JLU University, Giessen, Germany, 2008).

4.4. <u>Radiography after treatment of carpus affections in dogs and cats:</u>

Indications for radiography range from subsequent progression of either a disease or healing process, recognition of specially identifiable pathology (e.g., palpable abdominal mass), to the evaluation for spread of disease (e.g., evaluation of the lungs for metastasis from a tumor) **(Burk and Feeny, 2003).** Medical records of 17 dogs that have undergone dorsal pancarpal arthrodesis with complication-free dynamic compression plate fixation are reviewed by **Michal et al. (2003).** Postoperative healing is evaluated radiographically. It starts five weeks after surgery and progressed for six to 12 weeks in all dogs. After this time, no further progression of healing is observed. Between 6 and 8 weeks, bony fusion progress is significantly more rapid in the intercarpal joint than in the radiocarpal joint. The following criteria have no influence on the healing time: gender, age, body weight, and immediate versus delayed surgery after trauma. The major difficulties noted with respect to the interpretation of postoperative radiographs are irregular bony bridging, mainly caused by inadequate palmar curettage, and oblique projection of articular surfaces resulting in superimposition of joint spaces and solid bone **(Michal et al., 2003).** After pancarpal arthrodesis of hyperextended carpal joints in nine dogs, radiographic evidence of incorporation of the corticocancellous bone strips is observed between two and three months by **Guerrero and Montavon (2005).** Post operative radiographs in subluxation of the second carpal bone in three dogs show a small joint space between the second and third carpal bone and an absence of the joint opacity between the proximal and distal carpal bones on the mediolateral projection **(Guilliard and Mayo, 2001).** After partial arthrodesis for treatment of carpal hyperextension injury in a dog, radiography reveals bony healing of arthrodesed joints, reactive bone formation over the dorsal aspect of the plate, and periarticular osteophyte formation **(Smith and Spagnola, 1991).**

5. Magnetic Resonance Imaging (MRI) of the carpal joint in dogs and cats:

For MRI examination of the carpal joint, slight flexion of the joint is recommended for better exploration of the joint spaces. Transverse scans of the antebrachium demonstrate best the joint space of the antebrachiocarpal joint, and transverse scans of the metacarpal bones are indicated for the two more distal joints, the mediocarpal and carpometacarpal joints (Figg. 25, 26). The grid for sagittal scans should be oriented to the longitudinal axis of the different metacarpal bones. For dorsal scans, the metacarpal bones could be used also as reference, or as an alternative and the carpal joint for joint changes **(Assheuer and Sager, 1997).** Current use of MRI in clinical practice is limited due to cost and accessibility; Magnetic Resonance

Imaging (MRI) provides exquisite details of the soft tissues supporting the carpus and distal limbs. The identification and characterization of tendon and ligament injuries are possible using this modality. Similarly, early detection of chondral lesions and non deforming bone injuries (bone bruises and non displaced fractures) are possible with MRI **(Kirberger and Barr, 2006).**

6. Computed Tomography (CT) of the carpal joint in dogs and cats:

For computed tomography examination, the dog is placed in ventral or dorsal recumbency. Positioning of the thoracic limb examination is possible in either pronation or supination position. For transverse slices, slight flexion of the carpal joint of the extended leg is helpful **(Assheuer and Sager, 1997).** Computed tomography (CT) does provide advantages over radiography in evaluation of the carpus. Fractures and osteochondral defects which are not evident in radiographs may be diagnosed with CT examinations. In addition, software manipulation of the data acquired during CT examination allows three dimensional reconstruction of complex fractures and virtual disarticulation to evaluate individual bones (Figg. 27, 28) **(Kirberger and Barr, 2006).**

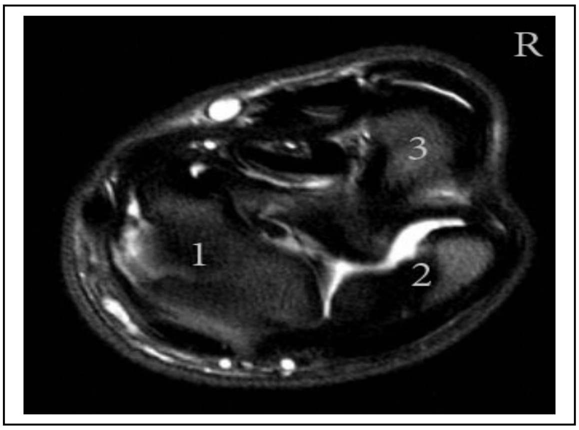


Fig. 25: Transverse (T1WTSE) T1 weighted Turbo Spin Echo MRI image demonstrates normal proximal row of carpal bones in a dog, 1. Intermedioradial carpal bone, 2. Ulnar carpal bone, 3. Accessory carpal bone, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

Fig. 26: Transverse (T1WTSE) T1 weighted Turbo Spin Echo MRI image demonstrates normal distal row of carpal bones in a dog, 1. First, 2. Second, 3. Third, 4. Fourth carpal bone. 5. Acessory carpal bone, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

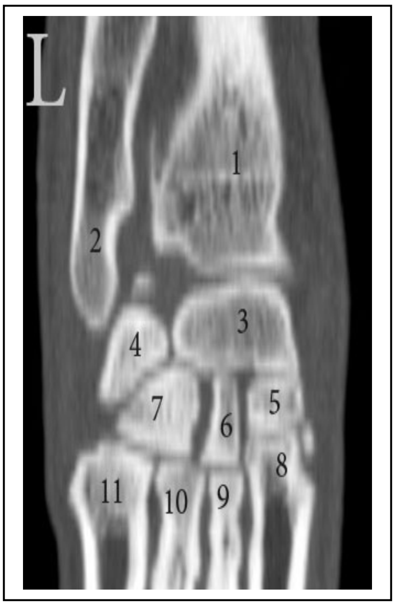


Fig. 27: Computed Tomography dorsal view (bone window) of the left normal carpus in a dog, 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Second, 6. Third, 7. Fourth carpal bone, 8. Second, 9. Third, 10. Fourth, 11. Fifth metacarpal bone, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

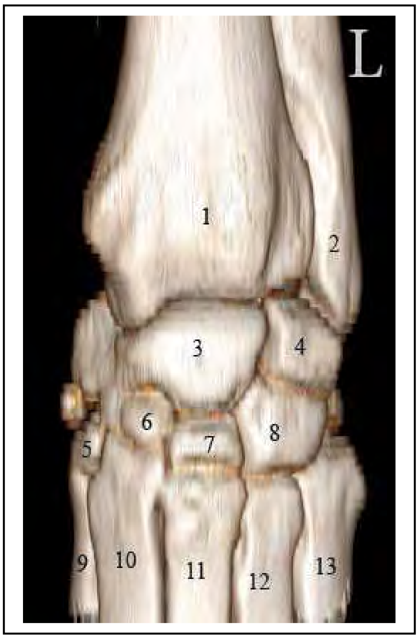


Fig. 28: Computed Tomography three dimensional reconstruction of the normal left carpus in a dog, 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. First, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First 10. Second, 11. Third, 12. Fourth, 13. Fifth metacarpal bone, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

7. Scintigraphy of the carpal joint in dogs and cats:

In very few cases where localization of lameness can not be made, scintigraphic examination may be utilized. Differentiations between significant radiological lesions and lesions seen by chance it may be possible to use angiography to study more accurate the soft tissue and bone phases. Appendicular degloving, crushing or shearing injuries may result in complete or segmental loss of vascular supply, with the distal limb being more vulnerable. Scintigraphy may be used to determine the viability of bone and soft tissues in these injuries **(Kirberger and Barr, 2006)**. Bone scintigraphy is an extreme tool for detecting changes in bone metabolism associated with skeletal diseases, injuries and arthropathies **(Lamb, 1991; Webbon and Mcevoy, 1995; Balogh et al., 1999).** Single phase bone scintigraphy is valuable and a relative simple tool for investigation of occult lameness in dogs. Careful positioning and multiple standard views will help to localize areas of increased uptake (Fig. 29) **(Schwarz et al., 2004)**.

Fig. 29: Ventrodorsal scintigraphy of the normal left carpus and in the right carpus there is increased accumulation of technetium 99 m – hydroxyl diphosphonat in a dog (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

8. Therapy:

Carpal arthrodesis is primarily used to treat animals with carpal hyperextension injuries causing severe palmar ligamentous and fibrocartilaginous damage.

These injuries do not generally respond satisfactorily to external coaptation. Additionally, shearing injuries, carpal luxation, irreparable articular fractures, severe degenerative joint disease, and immune mediated arthritis are treated with pancarpal arthrodesis (**Johnson et al., 2005).**

8.1. <u>Surgical approach to the carpus in dogs and cats:</u>

Surgical approach to the carpus usually necessitates complete dorsal exposure of one or more bones or joints (Fig. 30). This is best accomplished by using a dorsal skin incision over the carpus extending from the distal radius to the metacarpal bones. Deeper dissection of this incision will expose and allow retraction of the tendon of the common digital extensor muscle. Transverse arthrotomy of the antebrachial carpal joint will allow the exposure of the radial and ulnar carpal bones. Transverse arthrotomy of the middle carpal joint allows visualization of carpal bones I, II, III, IV (**Newton, 1985; Vaughan, 1985; Leighton, 1994; Fossum, 2002; Harasen, 2002; Guilliard, 2006).**

Fig. 30: Dorsal surgical approach of the carpal joint for panarthrodesis in dog, 10 cm skin incision, dissection of the subcutaneous tissue. Retraction of the tendon of extensor carpi radialis muscle, severing of the carpal ligaments and exposure of the carpal joints (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Most fractures of radial carpal bone can be exposed from cranial approach. Considerable synovial proliferation and inflammation may complicate the exposure. For fractures of the accessory carpal bones, a palmar approach can be done, skin incision extends from the base of the metacarpus to the distal part of the radius, incision of the antebrachial fascia reveals a tendentious slip from the tendon ulnaris lateralis to the free end of the accessory carpal bone, which is incised. The ligament from the accessory carpal bone to fourth metacarpal is detached close to the free end of the accessory carpal bone. To expose the fracture the deep branch of the ulnar nerve must be avoided **(Brinker et al., 1983).** Putting a plate on the medial aspect for pancarpal arthrodesis of hyperextended carpal joint in nine dogs, a medial approach is made to the carpus, beginning over the distal third of the radius, extending to the distal third of the second metacarpal bone (MC2). In most of the nine dogs in the study of **Turner and Lipowitz (1998)** the tendon of the abductor pollicis longus muscle is transected and the first digit is amputated to facilitate plate placement. The joint capsule and short carpal ligaments are incised to expose the joints leaving the short radial collateral ligament intact. A small Hohmann retractor is used to observe the joint surfaces **(Turner and Lipowitz, 1998; Guerrero and Montavon, 2005).** For pancarpal arthrodesis the limb is prepared circumferentially from the shoulder to the digits. The animal may be positioned in lateral recumbency with the affected limb upper most, in dorsal recumbency with the affected limb pulled caudally or in sternal recumbency with the limb pulled forwards. The ipsilateral proximal shoulder should be prepared for harvesting cancellous bone to autogenous graft. A tourniquet is used to control bleeding, but its application should be limited to sixty minutes. A dorsal incision is made over the midline of the carpus, extending proximally to the distal epiphysis of the radius and distally to the distal end of the metacarpal bones. The tendon of the extensor carpi radialis muscle to the metacarpals II and III are severed and the remaining extensor tendon is reflected laterally. The subcutaneous tissue, proliferative fibrous tissue and joint capsule are incised to expose the antebrachial, middle carpal and carpometacarpal joints. The joint capsule may be restricted for better exposure **(McKee, 1994; Johnson, 1995; Johnson and Hulse, 2002).** By subluxation of the second carpal bone in three dogs, surgical approach is made by a longitudinal incision over the dorsal aspect of the second carpal bone. Its dorsomedial surfaces are exposed by blunt dissection **(Guilliard and Mayo, 2001).** Palmarolateral approach of the carpal joint is used to expose the accessory carpal bone; skin incision follows the caudal border of the distal end of the ulna and extends distally to the palmar surface of the fifth metacarpal bone. Deep fascia and the flexor retinaculum are incised over the lateral aspect of the accessory carpal bone. Then limited elevation and reflection of the origin of abductor digiti quinti muscle from the accessory carpal is applied. Plamaromedial exposure of the carpal joint is used for exposure of the radial carpal bone; longitudinal skin incision is made on the palmaromedial aspect of the carpus, midway between the radial styloid process and the carpal pad. The cephalic vein is ligated and transected, and the incision carried deeper through the flexor retinaculur fascia. The digital flexor tendons and the median artery and nerve are retracted medially. The flexor retinaculum is incised lateral to the tendon of the flexor carpi radialis muscle to expose the palmar process of the radial carpal bone **(Johnson et al., 2005).** Surgical exposure of the radial carpal bone requires craniomedial incision beginning 3 to 4 cm proximal to the radiocarpal joint. Extend the incision distally to the midmetacarpus, and incise the subcutaneous tissues along the same line. The deep dissection is continued medial to extensor carpi radialis tendon to expose the joint capsule. Incise the joint capsule and identify the radial carpal bone **(Fossum, 2002).**

8.2. <u>Therapy of the different carpus affections in dogs and cats:</u>

8.2.1. <u>Luxation and subluxation of the carpal joint in dogs and cats:</u>

Pancarpal arthrodesis includes the fusion of the antebrachial, middle carpal and carpometacarpal joints, whereas partial arthrodesis is a selective fusion of one or more of the carpal joints. Indications for pancarpal arthrodesis can be listed as: luxation and subluxation of the carpal joint, shearing injuries, osteoarthritis, painful and unstable conditions unresponsive to reconstruction, incurable tendon, ligament injuries and multiple fractures (**Vaughan, 1985; Fossum, 2002; Slatter, 2003; Oszoy and Altunatmaz, 2004; Théoret and Moens, 2007).** Arthrodesis of the carpus is most commonly indicated after an injury caused by hyperextension, falling or other impact traumas that hyperextend the carpus. It can cause severe injury to the numerous small palmar carpal ligaments that support the 3 levels of carpal joints. These ligaments, along with the palmar carpal fibrocartilage, located on the palmar aspect of the carpometacarpal joint space, are the major supports that permit 10 to 12 degrees of extension at the antebrachiocarpal joint in an average standing animal. If a standard bone plate is used, contouring will be required to provide for 10 – 12 degrees of extension. The central hole of the carpal arthrodesis plate (CAP) should be centered over the radiocarpal bone. Application of diagnostic and surgical principles to carpal arthrodesis in the cat behooves the surgeon to bear two points in mind. First, even the smallest carpal arthrodesis plate (CAP) is too large for the cat's carpus. 7 – 8 holes length of 2.0/2.7 mm cuttable plate works well for most adult cats. Second, pancarpal arthrodesis eliminates the ability to supinate the manus, which affects the grooming behavior with that paw in the cat **(Parker et al., 1981; Harasen, 2002)**. In subluxation of the radiocarpal joint, a coaptation splint does not adequately stabilize the carpus, and arthrodesis of the radiocarpal joint is undertaken (Figg. 31, 32), utilizing a wedge graft and bone plate. Despite successful fusion of the joint, lameness persist in the affected limb. The lameness is attributed to subsequent carpometacarpal subluxation, which is presumed to the result of the added stress of weight bearing on the carpometacarpal joint following the arthrodesis. Arthrodesis of the intercarpal and carpometacarpal joint, utilizing cortical bone grafts and bone plate, restored normal gait **(Sexton and Hurvor, 1978).** The carpometacarpal joint is the most frequently injured joint. Jumping or falling from heights was the main cause of injuries in 39 dogs by the study of **Willer et al. (1990).** Of the 25 owners, who responded to a mailed questionnaire (mean follow-up, 32 months), all of them stated that their animal has improved or greatly improved after partial carpal arthrodesis. Hyperextension persists in 11% of the cases and degenerative joint disease of the antebrachiocarpal joint is present in 15.5% of the cases. No dogs with partial carpal arthrodesis required panarthrodesis at a later date **(Willer et al., 1990).**

Complete antebrachiocarpal luxation in dogs is a devastating injury associated with ruptures of multiple ligaments, including the medial and lateral collateral ligaments, the radiocarpal and ulnocarpal ligaments, and the joint capsule. Pancarpal arthrodesis is normally the therapeutic choice in dogs **(Voss et al., 2003).** Repair of antebrachiocarpal joint luxation usually requires reconstruction of the collateral ligaments and appropriate external fixation. Failure of the latter procedures is an indication for arthrodesis of the antebrachiocarpal joint **(Whittick, 1990).** Partial arthrodesis is performed for carpal hyperextension injury in a dog. T-plate application for middle carpal and carpometacarpal arthrodesis was associated with low patient morbidity and allows normal pet activity without clinical lameness. A guarded prognosis is advised for degenerative joint disease that may lead to decreased range of motion of the antebrachiocarpal joint **(Smith and Spagnola, 1991)**. For treatment of luxation of the accessory carpal bone in two dogs, a racing greyhound and subluxation of the same bone in a lurcher, Pancarpal arthrodesis with accessory carpal bone excision undertaken in the greyhound is successful. Following repair of the torn ligaments, the lurcher returned to full activity without lameness before sustaining the same injury to the other carpus **(Guilliard, 2001)**.

Fig. 31: Dorsopalmar view of the left carpus in a dog demonstrates pancarpal arthrodesis as a treatment of a subluxation of the antebrachiocarpal joint. The pancarpal arthrodesis plate (PCA) is 120 mm length with screws sizes of 2.7/ 3.5 mm (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

Fig. 32: Pancarpal arthrodesis for treatment of a subluxation of antebrachiocarpal joint in a dog. The pancarpal arthrodesis plate (PCA) is 120 mm length with screws sizes of 2.7/ 3.5 mm (Department of Veterinary Clinical Science, Clinical for Small Animals, JLU University, Giessen, Germany, 2008).

Subluxation or luxation of the antebrachiocarpal joint should be treated with pancarpal arthrodesis. Subluxation of the middle carpal and carpometacarpal joints with associated disruption of the accessory carpal ligaments, palmar fibrocartilage, and palmar ligaments of those joints should also be treated with pancarpal arthrodesis. Disruption of the accessory carpal ligaments, carpometacarpal ligaments, and palmar fibrocartilage, resulting in subluxation of the carpometacarpal joint without disruption and displacement of the accessory carpal and ulnar carpal bones, may be treated with a partial carpal arthrodesis **(Parker et al., 1981; Slocum and Devine, 1982).** Conservative treatment of sever hyperextended carpus is mostly unsuccessful. Application of the cast or splints alone normally does not resolve the problem. Reconstruction of some palmar ligament is reported, and may be successful if hyperextension is recognized early or in light weight dogs. Many small palmar ligaments are usually injured, making reconstruction difficult or impossible (**Guerrero and Montavon, 2005).** Post pancarpal arthrodesis as a treatment of carpal luxation and subluxation, soft padded bandage with a coaptation splint should be applied to reduce swelling and support the internal fixation. Healing of arthrodesis takes 12 to 16 weeks. An external splint should be worn for 6 to 8 weeks. When the splint is removed, the internal fixation should support the arthrodesis. Activity should be strictly controlled until union of the bones has occurred **(Fossum, 2002).** During carpal arthrodesis it can be advantageous to apply tourniquet avoiding hemorrhage to shorten the operating time. With careful dissection hemorrhage is not a major problem **(Vaughan, 1985).**

8.2.2. <u>Fracture of carpal bones in dogs and cats:</u>

In slab fractures of the distal surface of the accessory carpal bone there is inadequate tendency for complete healing with conservative treatment such as external splinting or casting of the limb **(Brinker et al., 1983).** Fractures of carpal bones I, II, III, or IV are generally chip fractures (Fig. 33) associated with the hyperextension injuries and most often seen in racing or working dogs. External fixation usually allows for union without the necessity of intra-articular surgery (**Newton, 1985)**.

Fig. 33: Mediolateral hyperextended view of the left carpus in a dog demonstrates fracture of the third carpal bone (arrow), accompanied by hyperextension and widening of the intercarpal joint space (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009).

Open reduction and internal fixation is made for severe metacarpal fractures in 37 dogs in the study of **Muir and Norris (1997).** The displacement of the fracture or axial malalignement is significantly associated with fractures of the mid or distal regions of the metacarpus or metatarsus. Pancarpal arthrodesis is performed in 54 dogs with metacarpal fractures using 2.7 or 3.5 mm bone plates dorsally applied. Medical records are retrospectively evaluated to identify those dogs with metacarpal bone fractures after pancarpal arthrodesis and to determine the angle of arthrodesis, the percentage of the third metacarpal bone covered by the bone plate, and the percentage width of the bone occupied by a screw. The length of the metacarpal bone covered by a bone plate affects the frequency of metacarpal fracture. Fewer fractures occurred when more than 53% of the bone length is covered by a dynamic compression plate. Performing pancarpal arthrodesis with a dorsally applied bone plate, it is recommended that at least 50% of the length of the third metacarpal bone should be covered by a plate **(Whitelock et al., 1999).** Conservative treatment of carpal bones fractures with a cast or a splint is not effective. After stabilization of the radial carpal bone with one or more lag screws (Figg. 34, 35), short lash walks should be used initially to help maintain strength and joint mobility **(Fossum, 2002).**

Veterinary cuttable plates are used for internal fixation of long bone fractures in fifteen small dogs and cats and also for small bone fractures in large breeds. They are variable in two sizes, both with a width of 7.0 mm and in a 50-hole length measuring 300 mm (**Théoret and Moens, 2007).**

8.2.3. <u>Sprain and injuries of the carpal joint in dogs and cats:</u>

Sever carpal sprain may require surgical restoration of one or more torn ligaments. In chronic cases in which the damaged ligaments have become frayed so badly, reattachment is impossible for the most part. It may be necessary to make an arthrodesis with a compression plate. This is sometimes erroneously termed fusing the joint **(Farrow, 2003).** For the carpal laxity syndrome in young dogs exercise and commercially available balanced diets and physiotherapy without any other treatment are usually sufficient to achieve physical and functional recovery (**Cetinkaya et al., 2007)**. Severe shearing injuries of the carpus may be associated with massive soft tissue loss and instability of the carpus. The external fixator may be used to stabilize the carpus while the soft tissue injuries are treated simultaneously. In many cases, the carpus will be functionally stable after the wound has healed **(Beardsley and Schrader, 1995).**

Fig. 34: Fracture of intermedioradial carpal bone (arrow) in a dog, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

Fig. 35: Dorsopalmar view of the right carpus of a dog demonstrates pancarpal arthrodesis as a treatment of fracture of an intermedioradial carpal bone. The pancarpal arthrodesis plate (PCA) is 130 mm length with screws sizes of 2.7/ 3.5 mm (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2008).

8.2.4. Arthritis and osteoarthritis of the carpal joint in dogs and cats:

The clinical application of corticosteroids is widespread. They are used to suppress inflammation, allergy and immune responses in many diseases, e.g. rheumatoid arthritis **(Hougardy et al., 2000).** Anti-inflammatory medications have long been prescribed for relief of pain and discomfort associated with osteoarthritis in canine. This occurs despite of the recognized side effects associated with use of NSAIDs and corticosteroids. On the available reports, one suggests that NSAIDs provide this relief through a combination of central and peripheral actions. Recent discovery of two isoforms of cyclooxygenase has increased our understanding of NSAID activity and may result in identification of drugs that potentially will have fewer side effects. A review of NSAIDs used in veterinary medicine indicates that relatively little is known regarding their role in treating osteoarthritis **(Johnston and Budsberg, 1997).** NSAIDs are used to treat osteoarthritis; however, it is imperative to remember that dogs are especially sensitive to these drugs, and reports of serious, and occasional fatal complications are numerous. Carprofen is a propionic acid-derived NSAID that has anti-inflammatory, analgesic, and antipyretic activity. In animals, carprofen is as potent as indomethacine and more potent than aspirin or phenylbutazone, but carprofen appears to be safer than most other NSAIDs (**Fox and Johnston, 1997).** The pain-relieving effect of carprofen (Rimadyl) and the tolerance to the drug are investigated in 805 dogs suffering from lameness as a result of osteoarthritis. 194 of the dogs (26.7 %) are no longer lame and 357 (49.2 %) have improved **(Mansa et al., 2007).** Osteoarthritis is a chronic, painful condition that is known to affect a large proportion of cats. Non-steroidal anti-inflammatory drugs (NSAIDs) proven to have efficacy in dogs but in cats there are limited published data on the use of NSAIDs in the long-term management of this condition. In long-term treatment for osteoarthritis in cats meloxicam given orally is safe and palatable when given with food at a dose of 0.01- 0.03 mg/kg.BW (**Gunew et al., 2008).**

8.3. <u>Results and complications after surgical therapy of the carpal joint in dogs and cats:</u>

In nine dogs there are complications after arthrodesis of hyperextended carpus. Four dogs of them show lick dermatitis developed over the surgical site likely because of superficially placed plate, and resolved after implant removed. Using of short plate results in screw loosening or bone fracture. One of the important out comes of this operation that, group of these dogs has healing of the operated joints at four to six weeks (**Vaughan, 1985).** After carpal arthrodesis as treatment of severe carpal sprain injuries in nine dogs, following complications occurred: Fracture of the compression plate in one case and loosening of the implants in two cases **(Johnson, 2008).**

Failure of carpal arthrodesis may be caused by infection, incomplete cartilage removal, or technical error in size or placement of the implants. Occasionally the plate may cause irritation of the extensor tendons or minimal soft tissue covering. External temperature changes (e.g. walking in snow) can affect the plate and cause lameness **(Slatter, 2003).** Dressing complications of pancarpal arthrodesis can be avoided with good bandaging technique and appropriate dressing aftercare. Fracture and pain associated with implant on the third metacarpal bone can be controlled by using a hybrid pancarpal arthrodesis plate with reduced screw diameter for the metacarpal fixation holes and appropriate exercise control in postoperative period. Failure of pancarpal arthrodesis is usually a result of poor cartilage debridement or surgical immobilization or inadequate post operative exercise management. Complications of partial carpal arthrodesis are interferences of implants on the antebrachiocarpal joint. Failure to identify early or mild instability in the antebrachiocarpal joint may lead to subsequent degenerative changes and hyperextension, necessitating pancarpal arthrodesis (**Guilliard, 2006).** Reasons for unsuccessful results of arthrodesis may be due to the degenerative joint diseases developing because of the changing biomechanical stress in the joints proximal to arthrodesis region and fractures in the arthrodesis site **(Gorse et al., 1991).** Pancarpal and partial arthrodesis result in excellent limb function in 80% of 50 patients treated for hyperextension injuries**.** The remaining 20% substantially improve after surgery, but they show varying degrees of limb dysfunction (lameness) after exercise. A small percentage still has continued, slight, weight – bearing lameness. Occasionally soft tissue irritations or screw loosenings are an indication for implant removal **(Denny and Barr, 1991).** Metacarpal bone fractures may occure in a small percentage of patients with pancarpal arthrodesis, especially if the plate extends only a short distance on the metacarpal bone **(Whitelock et al., 1999).** Medical records of seven dogs with severe, (grade three), open shearing wounds of the carpus or tarsus are reviewed. These dogs are treated with an immediate arthrodesis. Six dogs have got a transarticular external skeletal fixator (ESF), and one dog is treated with plate fixation. The soft tissues are managed simultaneously along with definitive joint stabilization in all cases. Minor complications occurred in four dogs: In one dog a skin graft is required, in one dog a skin graft is recommended but not performed, in another dog a secondary skin closure is performed, and in one dog a delayed cancellous bone graft is placed. Major complications occurred in three dogs: In two dogs restabilization of the arthrodesis is necessary and in one dog implant (i.e. plate) is removed due to infection **(Benson and Boudrieau, 2002).**

Materials and Methods

The present study is carried out on affected carpal joints of fifty adult living dogs and eleven adult living cats. The anatomy of the carpal bones and carpal ligaments in the examined animals (dogs and cats) is described. The carpal ligaments are dissected in 20 cadaveric carpal joints of dogs and 6 cadaveric joints of cats, these joints are macerated and the carpal bones are extracted. The carpal bones are measured in all directions (dorsopalmar, mediolateral and proximodistal) by aid of a caliber.

Radiographic examinations of the carpus are carried out with the animal in recumbent position by using of X- ray apparatus• with maximum output of 125 KV and 500 MAs as shown in Table (1), Fig. (36). Radiographic exposures include dorsopalmar, straight mediolateral, flexed mediolateral, craniolateral caudomedial oblique and craniomedial caudolateral oblique views in addition to stress views when needed **(Butler et al., 2000).**

Radiographic examinations in dogs are performed under anesthesia with a combination of Xylazine HCL 2% and Ketamine* 10% in range of 2:1 and in cats with Medetomidine 0.08 ml/ kg. BW and Ketamine 0.7 mg/kg. BW **(Hall and Taylor, 1994).**

Table 1: Radiographic exposure factors for the affected carpal joints in dogs and cats:

Animal	**KV**	**MAs**
Dog	**48**	**44**
Cat	**3.6**	**3.6**

All radiographs are interpretated for the following points:

1- Description of the radiographic appearance of the different affections, which can be demonstrated radiographically in carpal joints in dogs and cats.

2- Different surgical possibilities to treat different carpal joint diseases in dogs and cats are described.

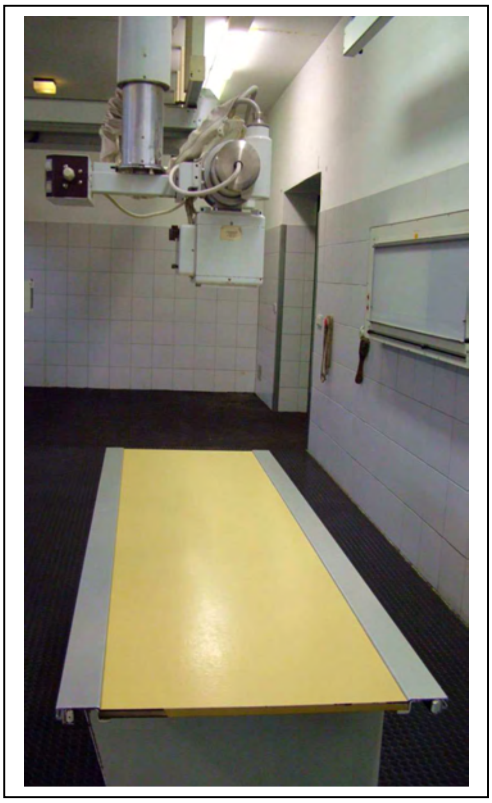


Fig. 36: X- ray apparatus, (Department of Veterinary Clinical Science, Clinic for Small Animals, JLU University, Giessen, Germany, 2009)

• Hoffman Company/ Germany
* Medistar Company / Germany

Results

I – Anatomy of the carpal bones in dogs and cats (Figg. 37 - 44):

The carpal joint in dogs and cats includes the antebrachiocarpal, middle carpal, intercarpal, and carpometacarpal articulations. The bones enter in the formation of these various articulations including the distal extremities of the radius and ulna (forearm), the carpal bones and the proximal extremities of the metacarpal bones. The carpus consists of seven carpal bones in dogs and cats. The carpal bones are arranged in two rows; proximal (antebrachial) and distal (metacarpal). The proximal row comprises three bones: the intermedioradial, ulnar and accessory carpal bones. The distal row consists of four bones: the first, second, third and fourth carpal bones.

1.1. Carpal bones in dogs and cats:

1.1.1. Distal extremity of the forearm in dogs and cats:

The distal extremity of the radius is wide and quadrangular in shape and has a concave articular surface for the intermedioradial and ulnar carpal bones. Its medial border projects downward to form the styloid process of the radius. Laterally it has a concave facet for the articulation with the ulna. Dorsally there are three grooves for the extensor tendons. The distal end of the ulna is small and reduced to a blunt point forming styloid process of the ulna. It articulates distally with the ulnar carpal bone and has a convex surface for the articulation with the radius.

1.1.2. The intermedioradial carpal bone in dogs and cats:

The intermedioradial carpal bone is the largest one of the carpal bones (see Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). It is a combination of the radial and intermediate carpal bone in other species. It is situated medially and proximally, it has a craniocaudal convexo-concave articular surface (Figg. 37, 41), and it articulates with the distal articular surface of the radius. Laterally it has a semicircular convex articular facet (Figg. 40, 44) for articulation with the ulnar carpal bone. Distally, there are three concave articular facets (Figg. 38, 42) for articulation with the distal row of the carpal bones; in cats the end of this third medial articular facet projects dorsomedially (Fig. 42). Medially it projects palmarly and there is a small round rough fossa.

1.1.3. The sesamoid bone of abductor pollicis longus muscle in dogs and cats:

It is a small round bone (Figg. 39, 43) in dogs and cats on the medial aspect of the intermedioradial carpal bone.

1.1.4. The ulnar carpal bone in dogs and cats:

The ulnar carpal bone is a triangular bone (Figg. 37, 41) situated on the lateral aspect of the carpal joint, it articulates proximally with the distal radius and ulna. Medially, it has a proximal concave facet and distally a convex one for articulation with the intermedioradial carpal bone, this medial distal facet is more convex in cats (Fig. 41). Laterally, there is a small and round fossa (Figg. 40, 44). On the palmar aspect there is a small oval facet and a distal large round one for articulation with the accessory carpal bone. Distally the ulnar carpal bone articulates with the fourth carpal bone and the fifth metacarpal bone.

1.1.5. The accessory carpal bone in dogs and cats:

The accessory carpal bone is rod in shape constricted in its middle and enlarged at its both ends (Figg. 38, 42), its dorsal border has saddle-shaped articular surface distally for the articulation with the ulnar carpal bone and another concave articular facet proximally for the articulation with the styloid process of the ulna. In cats these two facets are separated with a small shallow groove (Figg. 43, 44).

1.1.6. <u>First carpal bone in dogs and cats:</u>

The first carpal bone is the smallest one of the carpal bones (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). It is situated on the medial aspect of the carpal joint. The shape is convex-concave in a proximodistal orientation (Figg. 37, 41). The proximal convex articular surface for the articulation with the intermedioradial carpal bone and the distal concave one articulates with the first metacarpal bone. Laterally there is a concave facet, which articulates with a palmaromedial convex facet of the second carpal bone.

1.1.7. <u>Second carpal bone in dogs and cats:</u>

The second carpal bone is a wedge shaped bone compressed proximodistally. It has a proximal convex facet (Figg. 37, 41) to articulate with the intermedioradial carpal bone. The distal concave articular surface articulates with the second metacarpal bone. Medially there is convex articular surface, which articulates with the first carpal bone, and laterally it has a small concave articular facet for the third carpal bone.

1.1.8. <u>Third carpal bone in dogs and cats:</u>

The third carpal bone is larger than the second carpal bone (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). It has a proximal convex articular surface, which articulates with the distal concave facet of the intermedioradial carpal bone. This proximal convex surface is more prominent in cats than in dogs and projects palmaromedially (Fig. 41). Medially, there is a slightly convex facet which articulates with the concave facet of the second carpal bone, the convexity of this facet is more prominent in cats than in dogs (Figg. 37, 41). Distally, it has a concave articular surface (Figg. 38, 42) for the articulation with the third metacarpal bone. Laterally, there is a concave facet, which articulates with the convex facet of the fourth carpal bone.

1.1.9. <u>Fourth carpal bone in dogs and cats:</u>

It is a wedge shaped bone, which is situated on the lateral aspect of the carpal joint and it is the largest bone of the distal row of the carpal joint (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). Proximally, it has a convex articular surface (Figg. 37, 41), it articulates medially with the intermedioradial carpal bone and laterally with the ulnar carpal bone. Medially, there is a slightly convex facet, which articulates with the concave facet of the third carpal bone. Distally, it has a concave articular surface which articulates with the third metacarpal bone medially and fourth and fifth metacarpal bone laterally.

1.1.10. <u>Proximal extremities of the metacarpal bones:</u>

There are five metacarpal bones arranged from first to fifth from the medial to the lateral aspect, each metacarpal bone articulates with the distal articular surface of the corresponding carpal bone, the fifth metacarpal bone articulates with the distal and lateral part of the articular surface of the fourth carpal bone. The second and fifth metacarpal bones are similar in shape to each other and also the third and fourth of the metacarpal bones.

II. <u>Size of the carpal bones in dogs and cats</u>

The dorsopalmar, mediolateral and proximodistal dimensions of the carpal bones in 20 carpal joints of dogs (weight ranges from 8 to 21 Kg BW (Ø = 13 kg)) (Table 2, 3) and in 6 carpal joints of cats (weight ranges from 4.5 to 5 Kg BW (Ø = 4.8 kg)) (Table 4, 5) are measured. The mean (= Ø) of these measurements are explained in (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4).

2.1. <u>Dimensions of carpal bones in dogs (N = 8) with weight ranging from 8 to 10 Kg BW (Ø = 8.8 Kg):</u>

The dorsopalmar diameter of the intermedioradial carpal bone in dogs with weight 8 to 10 Kg BW ranges from 0.7 to 1.2 cm (Ø = 0.8 cm), mediolateral from 1.1 to 1.4 cm (Ø = 1.2 cm) and proximodistal is from 0.6 to 0.9 cm (Ø = 0.7 cm).

The dorsopalmar diameter of the ulnar carpal bone in those dogs ranges from 0.7 to 1.0 cm (Ø = 0.8 cm), mediolateral from 0.5 to 0.7 cm (Ø = 0.6 cm) and proximodistal from 1.0 to 1.5 cm (Ø = 1.1 cm).

The dorsopalmar diameter of the accessory carpal bone ranges from 0.8 to 1.3 cm (Ø = 0.9 cm), mediolateral from 0.6 to 0.7 cm (Ø = 0.6 cm) and proximodistal from 0.7 to 0.9 cm (Ø = 0.8 cm).

The dorsopalmar diameter of the first carpal bone ranges from 0.4 to 0.6 cm (Ø = 0.5 cm), mediolateral from 0.4 to 0.5 cm (Ø = 0.4 cm) and proximodistal from 0.2 to 0.4 cm (Ø = 0.3 cm).

The dorsopalmar diameter of the second carpal bone ranges from 0.5 to 0.6 cm (Ø = 0.5 cm), mediolateral from 0.5 to 0.8 cm (Ø = 0.6 cm) and proximodistal from 0.2 to 0.4 cm (Ø = 0.3 cm).

The dorsopalmar diameter of the third carpal bone ranges from 0.8 to 1.2 cm (Ø = 0.9 cm), mediolateral from 0.4 to 0.7 cm (Ø = 0.5 cm) and proximodistal from 0.5 to 0.8 cm (Ø = 0.6 cm). The dorsopalmar diameter of the fourth carpal bone ranges from 0.8 to 1.1 cm (Ø = 0.9 cm), mediolateral from 0.6 to 0.9 cm (Ø = 0.7 cm) and proximodistal diameter from 0.6 to 0.9 cm (Ø = 0.7 cm).

2.2. <u>Dimensions of carpal bones in dogs (N = 7) with weight ranging from 12 to 15.5 Kg BW (Ø = 14 Kg):</u>

The dorsopalmar diameter of the intermedioradial carpal bone in dogs with weight 12 to 15.5 Kg BW ranging from 1.4 to 1.7 cm (Ø = 1.5 cm), mediolateral from 1.6 to 1.9 cm (Ø = 1.7 cm) and proximodistal from 0.9 to 1.1 cm (Ø = 1.0 cm).

The dorsopalmar diameter of the ulnar carpal bone in those dogs ranges from 0.9 to 1.2 cm (Ø = 1.1 cm), mediolateral from 0.7 to 0.9 cm (Ø = 0.8 cm) and proximodistal from 1.6 to 1.9 cm (Ø = 1.7 cm).

The dorsopalmar diameter of the accessory carpal bone ranges from 1.4 to 1.8 cm (Ø = 1.6 cm), mediolateral diameter from 0.7 to 0.9 cm (Ø = 0.8 cm) and proximodistal diameter from 1.0 to 1.1 cm (Ø = 1.0 cm).

The dorsopalmar diameter of the first carpal bone ranges from 0.6 to 0.7 cm (Ø = 0.7 cm), mediolateral from 0.6 to 0.7 cm (Ø = 0.7 cm) and proximodistal from 0.4 to 0.5 cm (Ø = 0.4 cm).

The dorsopalmar diameter of the second carpal bone ranges from 0.6 to 0.7 cm (Ø = 0.6 cm), mediolateral from 0.8 to 0.9 cm (Ø = 0.8 cm) and proximodistal from 0.4 to 0.5 cm (Ø = 0.4 cm). The dorsopalmar diameter of the third carpal bone ranges from 1.2 to 1.5 cm (Ø = 1.4 cm), mediolateral from 0.7 to 0.8 cm (Ø = 0.7 cm) and proximodistal from 0.8 to 1.0 cm (Ø = 0.9 cm). The dorsopalmar diameter of the fourth carpal bone ranges from 1.1 to 1.3 cm (Ø = 1.2 cm), mediolateral from 0.9 to 1.1 cm (Ø = 1.0 cm) and proximodistal from 0.9 to 1.0 cm (Ø = 0.9 cm).

2.3. Dimensions of carpal bones in dogs (N = 5) with weight ranging from 18 to 21 Kg BW (Ø = 19 Kg):

The dorsopalmar diameter of the intermedioradial carpal bone in dogs with weight 18 to 21 Kg BW ranging from 1.7 to 1.8 cm (Ø = 1.7 cm), mediolateral from 1.8 to 1.9 cm (Ø = 1.8 cm) and proximodistal from 1.0 to 1.1 cm (Ø = 1.0 cm).

The dorsopalmar diameter of the ulnar carpal bone in those dogs ranges from 1.2 to 1.3 cm (Ø = 1.3 cm), mediolateral 0.9 cm and proximodistal from 1.8 to 2.0 cm (Ø = 1.9 cm).

The dorsopalmar diameter of the accessory carpal bone ranges from 1.7 to 1.9 cm (Ø = 1.8 cm), mediolateral from 0.9 to 1.0 cm (Ø = 0.9 cm) and proximodistal from 1.1 to 1.2 cm (Ø = 1.1 cm).

The dorsopalmar diameter of the first carpal bone ranges from 0.7 to 0.8 cm (Ø = 0.8 cm), mediolateral ranges from 0.7 to 0.8 cm (Ø = 0.7 cm) and proximodistal from 0.4 to 0.5 cm (Ø = 0.5 cm).

The dorsopalmar diameter of the second carpal bone ranges from 0.7 to 0.8 cm (Ø = 0.8 cm), mediolateral from 0.9 to 1.0 cm (Ø = 0.9 cm) and proximodistal ranges from 0.5 to 0.6 cm (Ø = 0.5 cm).

The dorsopalmar diameter of the third carpal bone ranges from 1.5 to 1.6 cm (Ø = 1.5 cm), the mediolateral from 0.7 to 0.9 cm (Ø = 0.8 cm). The proximodistal from 0.9 to 1.0 cm (Ø = 1.0 cm). The dorsopalmar diameter of the fourth carpal bone ranges from 1.3 to 1.4 cm (Ø = 1.3 cm), mediolateral from 1.1 to 1.2 cm (Ø = 1.1 cm) and proximodistal from 1.0 to 1.1 cm (Ø = 1.0 cm).

2.4. Dimensions of carpal bones in cats (N = 6) with weight ranging from 4.5 to 5 Kg BW (Ø = 4.8 Kg):

The dorsopalmar diameter of the intermedioradial carpal bone in cats (body weight 4.5 to 5 Kg) ranges from 0.7 to 0.8 cm (Ø = 0.7 cm), mediolateral from 0.8 to 0.9 cm (Ø = 0.9 cm), and the proximodistal diameter is 0.6 cm.

The dorsopalmar diameter of the ulnar carpal bone in those cats is 0.5 cm and the mediolateral diameter is 0.5 cm. The proximodistal diameter ranges from 0.8 to 0.9 cm (Ø = 0.9 cm). The dorsopalmar diameter of the accessory carpal bone is 0.8 cm, the mediolateral diameter ranges from 0.3 to 0.4 cm (Ø = 0.4 cm) and the proximodistal from 0.4 to 0.5 cm (Ø = 0.5 cm).

The dorsopalmar diameter of the first carpal bone is 0.6 cm, the mediolateral diameter ranges from 0.3 to 0.4 cm (Ø = 0.4 cm). The proximodistal from 0.3 to 0.4 cm (Ø = 0.3 cm). The dorsopalmar and the mediolateral diameters of the second carpal bone are 0.5 cm. The proximodistal diameter is 0.3 cm.

The dorsopalmar diameter of the third carpal bone ranges from 0.7 to 0.8 cm (Ø = 0.8 cm). The mediolateral diameter is 0.4 cm, and the proximodistal diameter is 0.5 cm. The dorsopalmar diameter of the fourth carpal bone ranges from 0.6 to 0.7 cm (Ø = 0.6 cm), mediolateral from 0.4 to 0.5 cm (Ø = 0.5 cm). The proximodistal diameter is 0.6 cm.

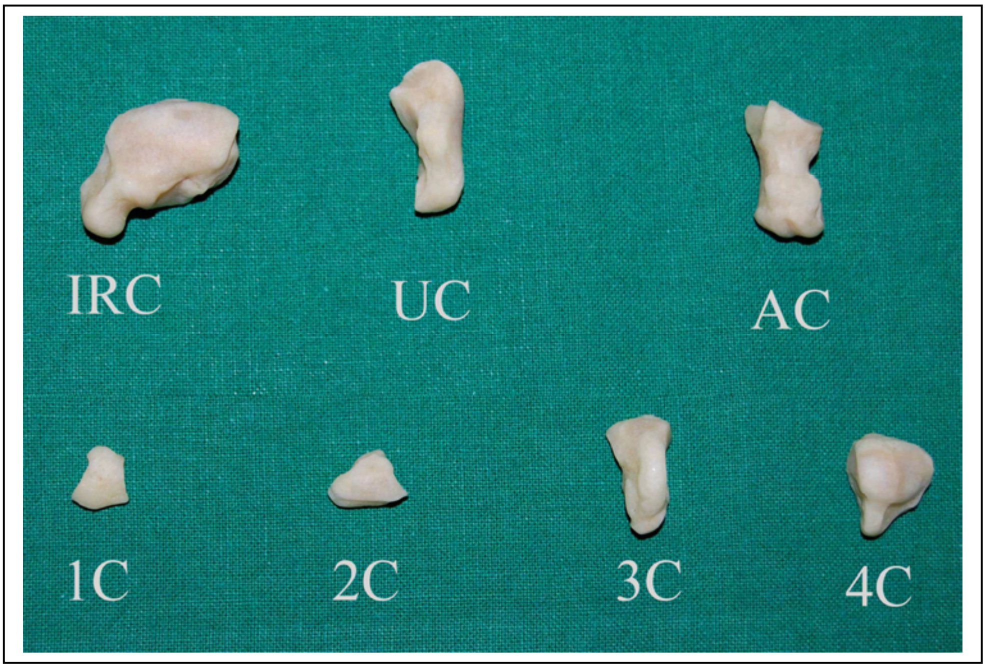


Fig. 37: Proximal anatomical view of the right carpal bones in a dog. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

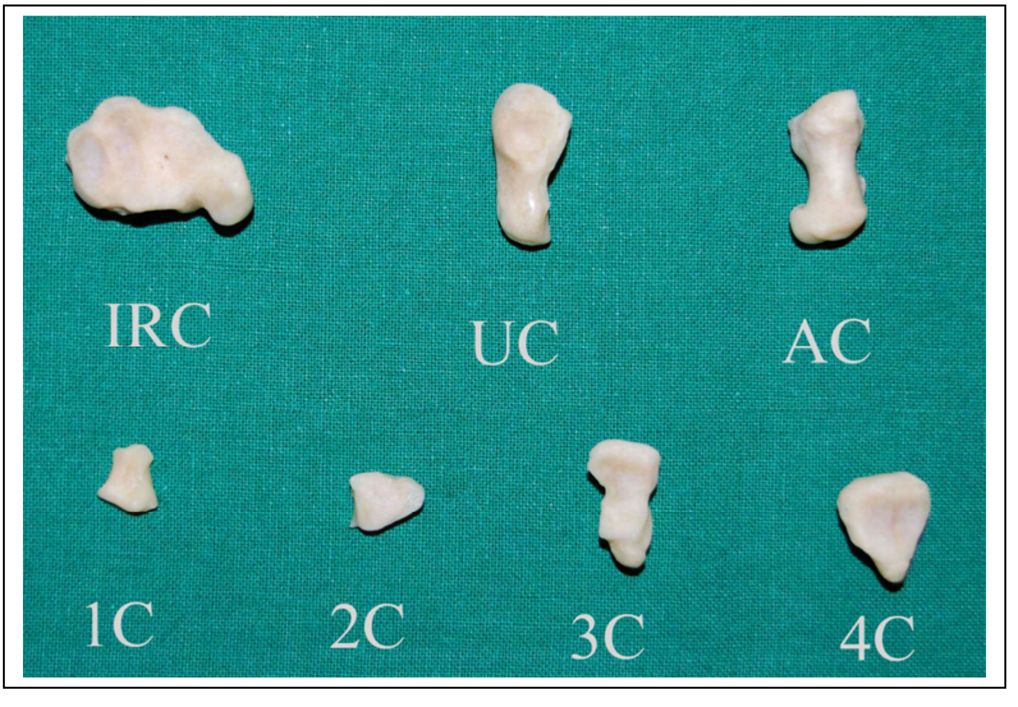


Fig. 38: Distal anatomical view of the right carpal bones in a dog. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

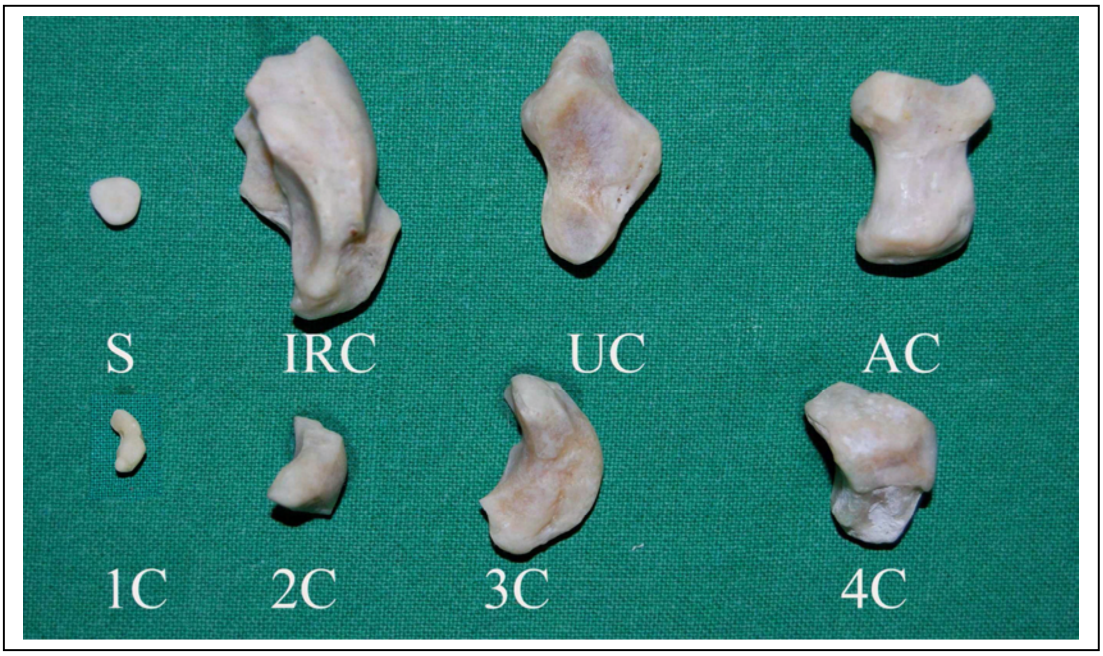


Fig. 39: Medial anatomical view of the right carpal bones in a dog. S (Sesamoid bone) IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C. 2C.3C. 4C (First to Fourth carpal bones).

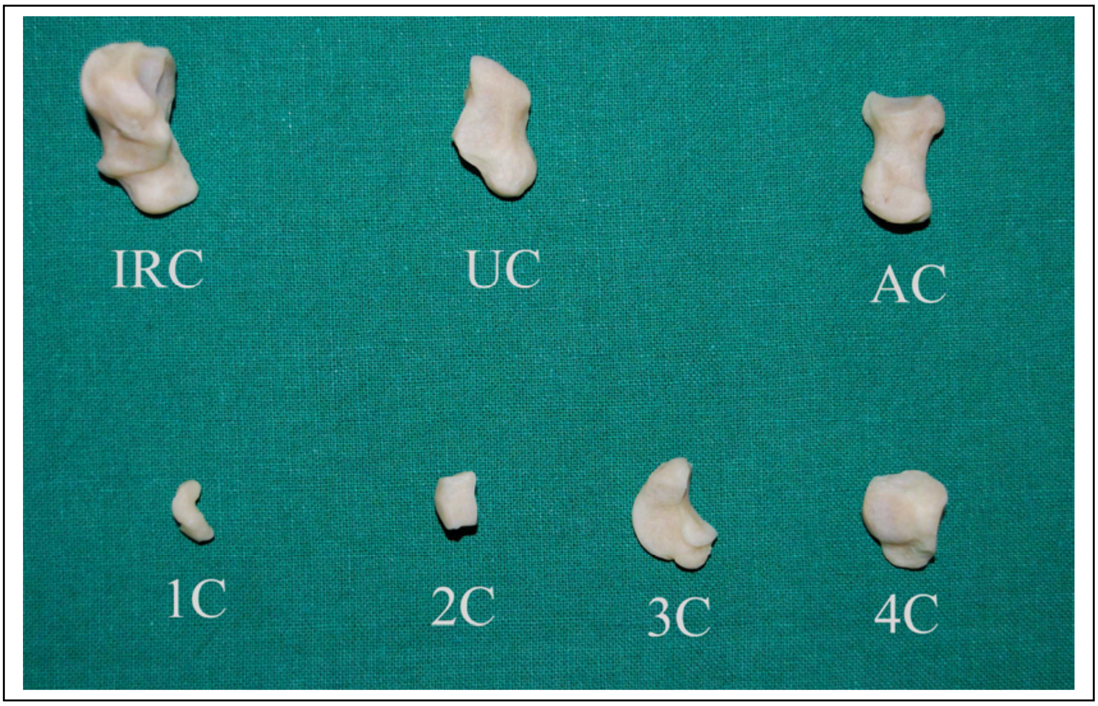


Fig. 40: Lateral anatomical view of the right carpal bones in a dog. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

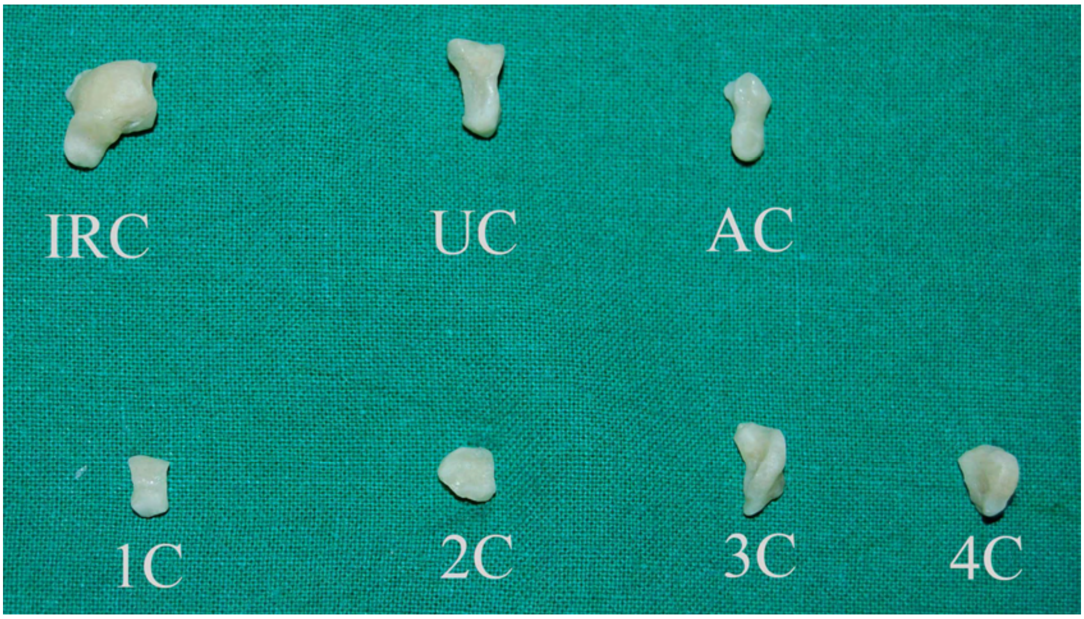


Fig. 41: Proximal anatomical view of the right carpal bones in a cat. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

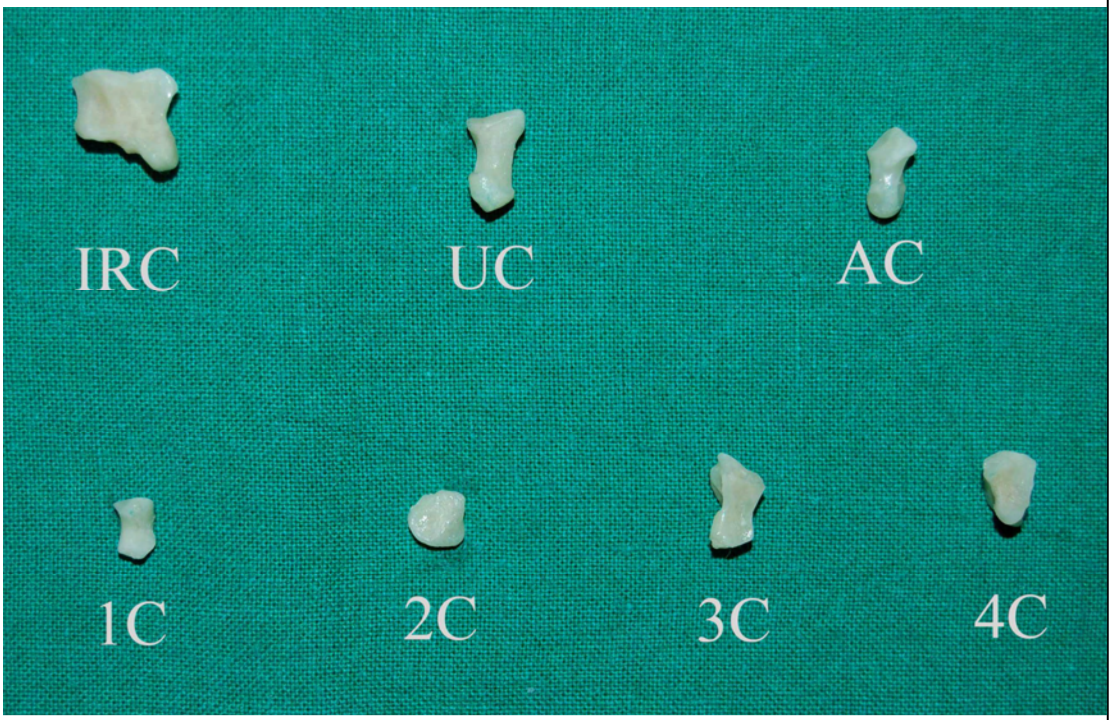


Fig. 42: Distal anatomical view of the right carpal bones in a cat. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

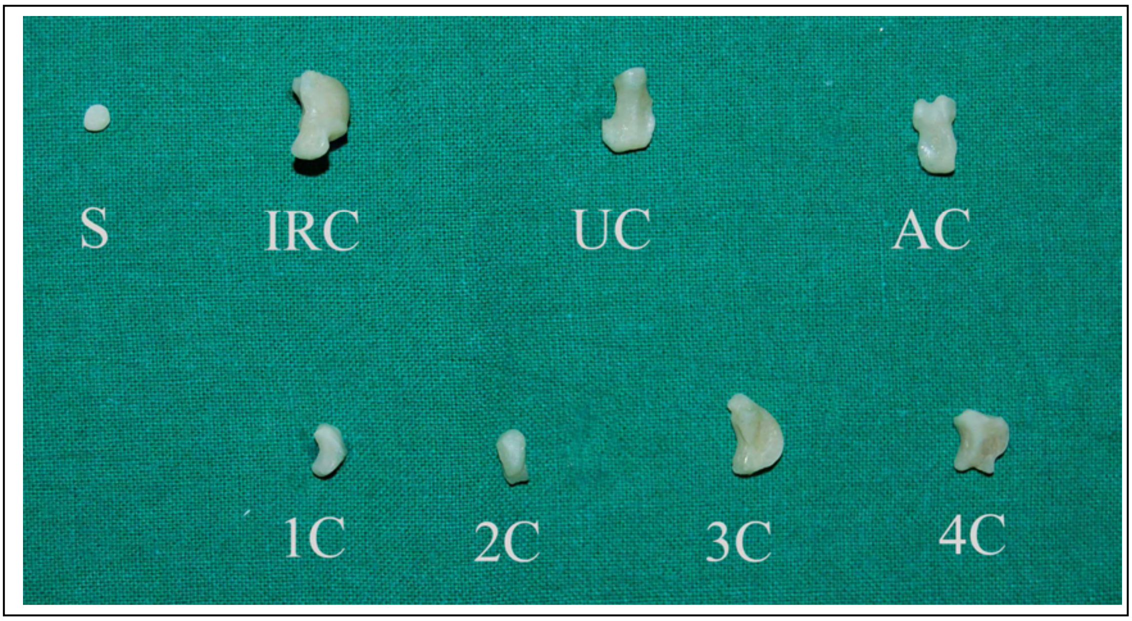


Fig. 43: Medial anatomical view of the right carpal bones in a cat. S (Sesamoid bone) IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

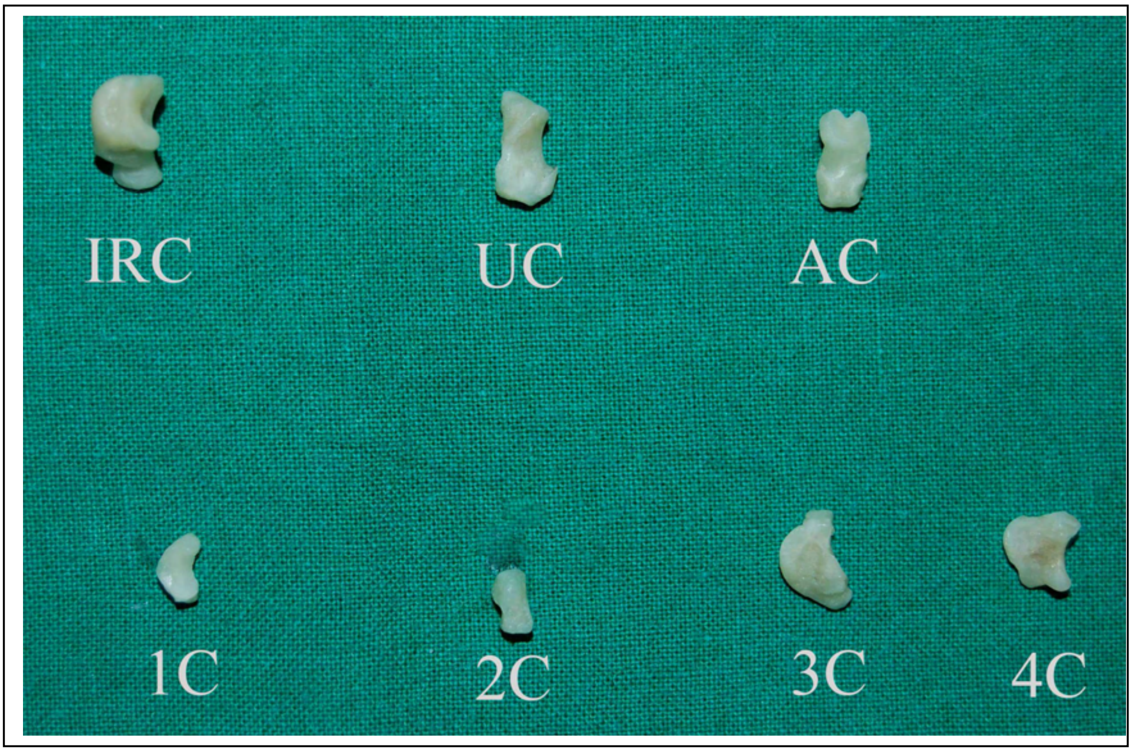


Fig. 44: Lateral anatomical view of the right carpal bones in a cat. IRC (Intermedioradial carpal bone) UC (Ulnar carpal bone) AC (Accessory carpal bone) 1C.2C.3C.4C (First to Fourth carpal bones).

Table 2: Dimensions (cm) of the proximal row of the carpal bones in 20 carpal joints of dogs:

Sp No	Body Weight (Kg)	I.R. C			U.C.B			A.C.B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
1	8	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
2	8	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
3	8	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
4	8	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
5	9	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
6	9	0.7	1.1	0.6	0.7	0.5	1.0	0.8	0.6	0.7
7	10	1.2	1.4	0.9	1.0	0.7	1.5	1.3	0.7	0.9
8	10	1.2	1.4	0.9	1.0	0.7	1.5	1.3	0.7	0.9
9	12	1.4	1.6	0.9	1.0	0.7	1.6	1.4	0.7	1.0
10	12	1.4	1.6	0.9	1.0	0.7	1.6	1.4	0.7	1.0
11	14	1.5	1.7	1.0	0.9	0.8	1.6	1.5	0.8	1.0
12	14	1.5	1.7	1.0	0.9	0.8	1.6	1.5	0.8	1.0
13	15	1.6	1.8	1.1	1.2	0.9	1.8	1.7	0.9	1.1

Sp No (specimen's number). I.R.C (Intermedioradial carpal), U.C.B (Ulnar carpal), A.C.B. (Accessory carpal), D. P. (Dorsopalmar), M. L. (Mediolateral), P. D. (Proximodistal)

Table 2: (Continued)

Sp No	Body Weight (Kg)	I.R. C			U.C.B			A.C.B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
14	15.5	1.7	1.9	1.0	1.2	0.9	1.9	1.8	0.9	1.0
15	15.5	1.7	1.9	1.0	1.2	0.9	1.9	1.8	0.9	1.1
16	18	1.7	1.8	1.0	1.2	0.9	1.9	1.7	0.9	1.1
17	18	1.7	1.8	1.0	1.3	0.9	1.9	1.7	0.9	1.1
18	18	1.7	1.8	1.0	1.2	0.9	1.8	1.7	0.9	1.1
19	21	1.7	1.9	1.1	1.3	0.9	2.0	1.9	1.0	1.2
20	21	1.8	1.9	1.0	1.3	0.9	2.0	1.9	1.0	1.2

Sp No (specimen's number). I.R.C (Intermedioradial carpal), U.C.B (Ulnar carpal), A.C.B. (Accessory carpal), D. P. (Dorsopalmar), M. L. (Mediolateral), P. D. (Proximodistal)

Table 3: Dimensions (cm) of the distal row of the carpal bones in 20 carpal joints of dogs:

Sp No	Body Weight (Kg)	1st C. B			2nd C. B			3rd C. B			4th C. B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
1	**8**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
2	**8**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
3	**8**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
4	**8**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
5	**9**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
6	**9**	**0.4**	**0.4**	**0.2**	**0.5**	**0.5**	**0.2**	**0.8**	**0.4**	**0.5**	**0.8**	**0.6**	**0.6**
7	**10**	**0.6**	**0.5**	**0.4**	**0.6**	**0.8**	**0.4**	**1.2**	**0.7**	**0.8**	**1.1**	**0.9**	**0.9**
8	**10**	**0.6**	**0.5**	**0.4**	**0.6**	**0.8**	**0.4**	**1.2**	**0.7**	**0.8**	**1.1**	**0.9**	**0.9**
9	**12**	**0.6**	**0.6**	**0.4**	**0.6**	**0.8**	**0.4**	**1.3**	**0.7**	**0.8**	**1.1**	**0.9**	**0.9**
10	**12**	**0.6**	**0.6**	**0.4**	**0.6**	**0.8**	**0.4**	**1.3**	**0.7**	**0.8**	**1.1**	**0.9**	**0.9**
11	**14**	**0.7**	**0.7**	**0.4**	**0.6**	**0.8**	**0.4**	**1.2**	**0.7**	**0.8**	**1.1**	**1.1**	**0.9**
12	**14**	**0.7**	**0.7**	**0.4**	**0.6**	**0.8**	**0.4**	**1.2**	**0.7**	**0.8**	**1.1**	**1.1**	**0.9**
13	**15**	**0.7**	**0.7**	**0.5**	**0.7**	**0.9**	**0.5**	**1.5**	**0.7**	**0.9**	**1.3**	**1.1**	**1.0**

Sp No (specimen's number). 1st C. B. (first carpal bone), 2nd C. B. (second carpal bone), 3rd C. B. (third carpal bone), 4th C. B. (fourth carpal bone), D. P. (Dorsopalmar), M. L. (Mediolateral), P. D. (Proximodistal)

Table 3: (Continued)

Sp No	Body Weight (Kg)	1st C. B			2nd C. B			3rd C. B			4th C. B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
14	**15.5**	**0.7**	**0.7**	**0.4**	**0.7**	**0.9**	**0.5**	**1.5**	**0.8**	**1.0**	**1.3**	**1.1**	**1.0**
15	**15.5**	**0.7**	**0.7**	**0.4**	**0.7**	**0.9**	**0.5**	**1.5**	**0.8**	**1.0**	**1.3**	**1.1**	**1.0**
16	**18**	**0.8**	**0.7**	**0.4**	**0.8**	**0.9**	**0.5**	**1.5**	**0.8**	**1.0**	**1.3**	**1.1**	**1.0**
17	**18**	**0.8**	**0.7**	**0.4**	**0.8**	**0.9**	**0.5**	**1.5**	**0.8**	**1.0**	**1.3**	**1.1**	**1.0**
18	**18**	**0.7**	**0.7**	**0.5**	**0.7**	**0.9**	**0.5**	**1.5**	**0.7**	**0.9**	**1.3**	**1.1**	**1.0**
19	**21**	**0.8**	**0.8**	**0.5**	**0.8**	**1.0**	**0.5**	**1.6**	**0.9**	**1.0**	**1.3**	**1.2**	**1.1**
20	**21**	**0.8**	**0.8**	**0.5**	**0.8**	**1.0**	**0.6**	**1.5**	**0.9**	**1.0**	**1.4**	**1.2**	**1.0**

Sp No (specimen's number). 1st C. B. (first carpal bone), 2nd C. B. (second carpal bone), 3rd C. B. (third carpal bone), 4th C. B. (fourth carpal bone), D. P. (Dorsopalmar), M. L. (Mediolateral), P. D. (Proximodistal)

Table 4: Dimensions (cm) of the proximal row of the carpal bones in 6 carpal joints of cats:

Sp No	Body Weight (Kg)	I.R. C			U.C.B			A.C.B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
1	4.5	0.7	0.8	0.6	0.5	0.5	0.8	0.8	0.3	0.4
2	4.5	0.7	0.8	0.6	0.5	0.5	0.8	0.8	0.3	0.4
3	4.8	0.7	0.9	0.6	0.5	0.5	0.9	0.8	0.4	0.4
4	4.8	0.7	0.9	0.6	0.5	0.5	0.9	0.8	0.4	0.4
5	5	0.7	0.9	0.6	0.5	0.5	0.9	0.8	0.4	0.5
6	5	0.8	0.9	0.6	0.5	0.5	0.9	0.8	0.4	0.5

Sp No (specimen's number). I.R.C (Intermedioradial carpal), U.C.B (Ulnar carpal), A.C.B. (Accessory carpal), D. P. (Dorsopalmar), M. L. (Mediolateral), P. D. (Proximodistal)

Table 5: Dimensions (cm) of the distal row of the carpal bones in 6 carpal joints of cats:

Sp No	Body Weight (Kg)	1st C. B			2nd C. B			3rd C. B			4th C. B		
		D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D	D.P	M.L	P.D
1	**4.5**	**0.6**	**0.3**	**0.3**	**0.5**	**0.5**	**0.3**	**0.7**	**0.4**	**0.5**	**0.6**	**0.4**	**0.6**
2	**4.5**	**0.6**	**0.3**	**0.3**	**0.5**	**0.5**	**0.3**	**0.7**	**0.4**	**0.5**	**0.6**	**0.4**	**0.6**
3	**4.8**	**0.6**	**0.4**	**0.3**	**0.5**	**0.5**	**0.3**	**0.8**	**0.4**	**0.5**	**0.6**	**0.5**	**0.6**
4	**4.8**	**0.6**	**0.4**	**0.3**	**0.5**	**0.5**	**0.3**	**0.8**	**0.4**	**0.5**	**0.6**	**0.5**	**0.6**
5	**5**	**0.6**	**0.4**	**0.4**	**0.5**	**0.5**	**0.3**	**0.8**	**0.4**	**0.5**	**0.7**	**0.5**	**0.6**
6	**5**	**0.6**	**0.4**	**0.4**	**0.5**	**0.5**	**0.3**	**0.8**	**0.4**	**0.5**	**0.7**	**0.5**	**0.6**

Sp No (specimen's number). 1st C. B. (first carpal bone), 2nd C. B. (second carpal bone), 3rd C. B. (third carpal bone), 4th C. B. (fourth carpal bone), D. P. (Dorsopalmar), M.L. (Mediolateral), P.D. (Proximodistal)

Table 6: Mean of dimensions (cm) of carpal bones in dogs with body weight of 8 - 10 Kg BW:

Bones	**Dorsopalmar**	**Mediolateral**	**Proximodistal**
Intermedioradial carpal bone	0.8	1.2	0.7
Ulnar carpal bone	0.8	0.6	1.1
Accessory carpal bone	0.9	0.6	0.8
First carpal bone	0.5	0.4	0.3
Second carpal bone	0.5	0.6	0.4
Third carpal bone	0.9	0.5	0.6
Fourth carpal bone	0.9	0.7	0.7

Table 7: Mean of dimensions (cm) of carpal bones in dogs with body weight of 12 - 15.5 Kg BW:

Bones	Dorsopalmar	Mediolateral	Proximodistal
Intermedioradial carpal bone	1.5	1.7	1.0
Ulnar carpal bone	1.1	0.8	1.7
Accessory carpal bone	1.6	0.8	1.0
First carpal bone	0.7	0.7	0.4
Second carpal bone	0.6	0.8	0.4
Third carpal bone	1.4	0.7	0.9
Fourth carpal bone	1.2	1.0	1.0

Table 8: Mean of dimensions (cm) of carpal bones in dogs with body weight of 18 - 21 Kg BW:

Bones	Dorsopalmar	Mediolateral	Proximodistal
Intermedioradial carpal bone	1.7	1.8	1.0
Ulnar carpal bone	1.3	0.9	1.9
Accessory carpal bone	1.8	0.9	1.1
First carpal bone	0.8	0.7	0.5
Second carpal bone	0.8	0.9	0.5
Third carpal bone	1.5	0.8	1.0
Fourth carpal bone	1.3	1.1	1.1

Table 9: Mean of the dimensions (cm) of carpal bones in 6 cats with body weight 4.5 - 5 Kg BW:

Bones	Dorsopalmar	Mediolateral	Proximodistal
Intermedioradial carpal bone	0.7	0.9	0.6
Ulnar carpal bone	0.5	0.5	0.9
Accessory carpal bone	0.8	0.4	0.5
First carpal bone	0.6	0.4	0.3
Second carpal bone	0.5	0.5	0.3
Third carpal bone	0.8	0.4	0.5
Fourth carpal bone	0.6	0.5	0.6

Chart 1: Dimensions (cm) of the carpal bones in dogs with body weight ranging from 8 - 10 kg BW:

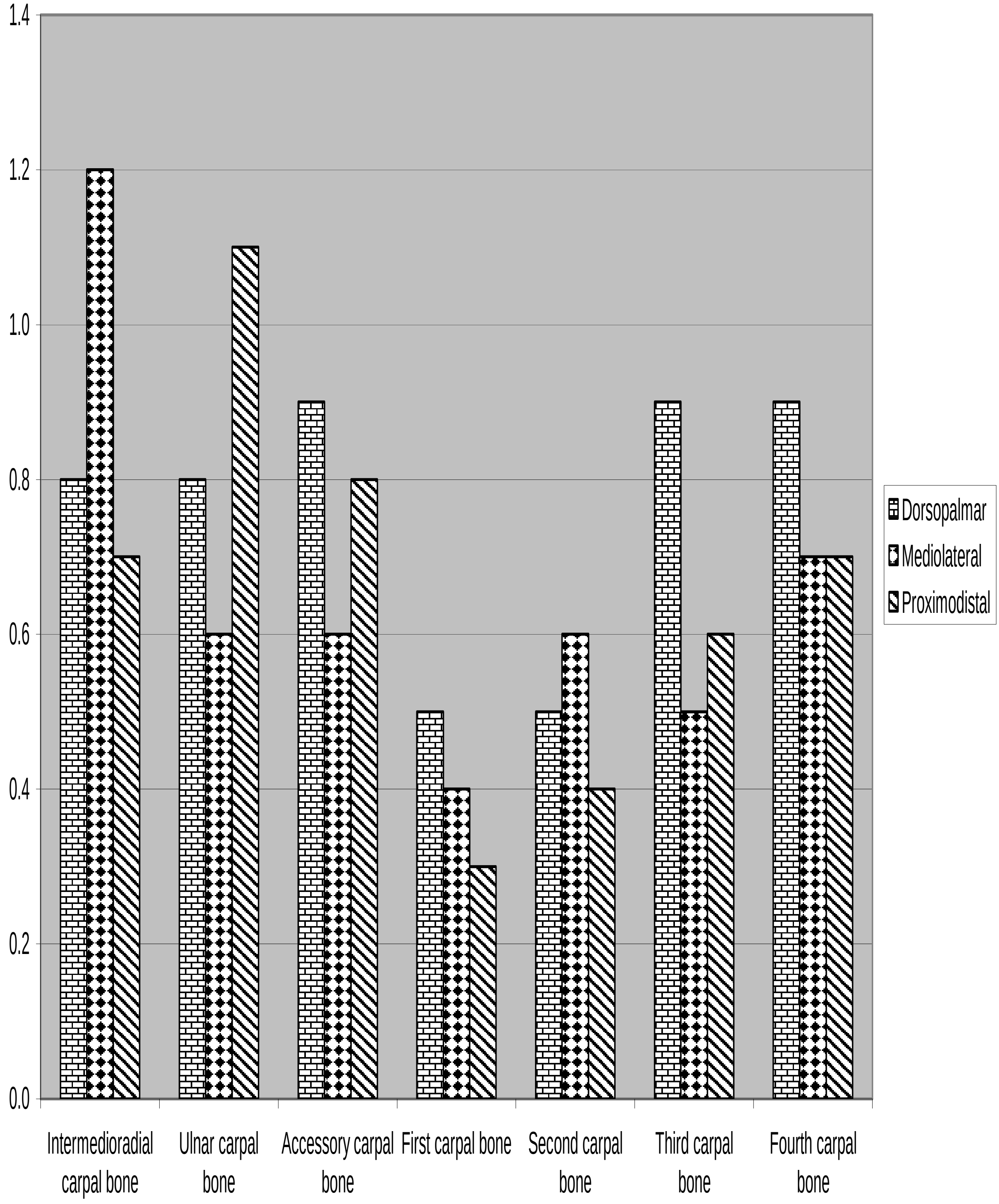


Chart 2: Dimensions (cm) of the carpal bones in dogs with body weight ranging from 12 - 15.5 kg BW:

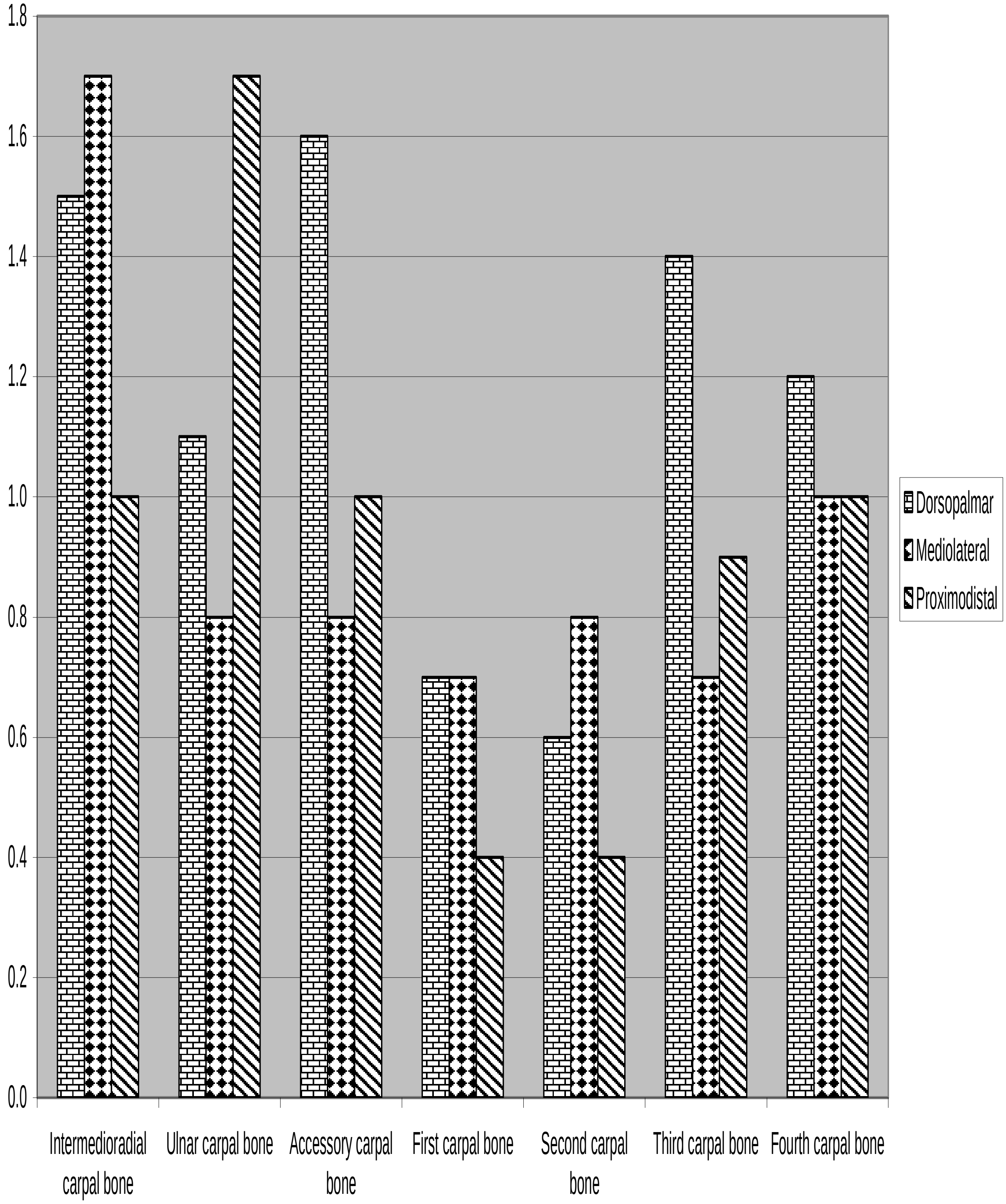


Chart 3: Dimensions (cm) of the carpal bones in dogs with body weight ranging from 18 - 21 kg BW:

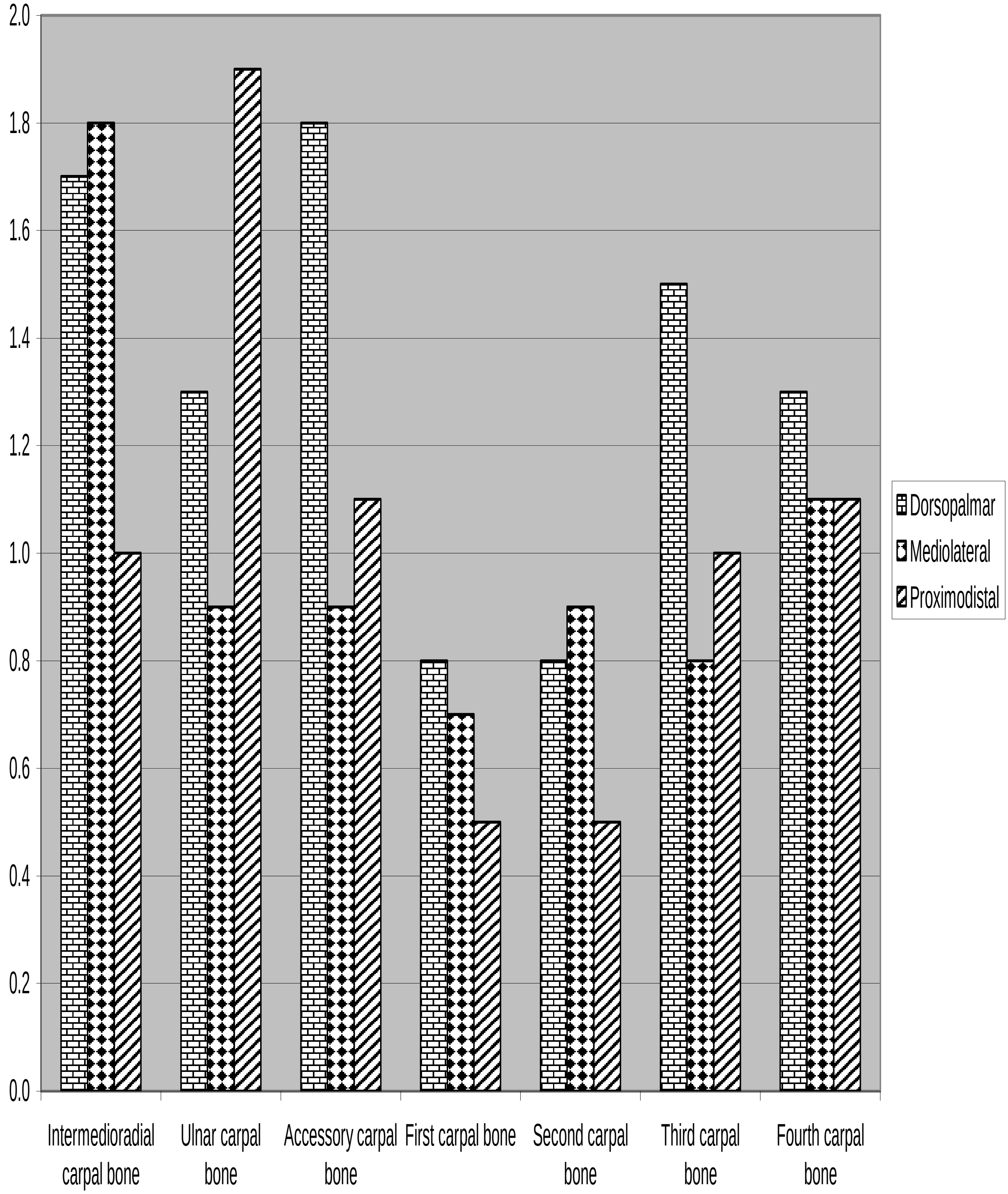
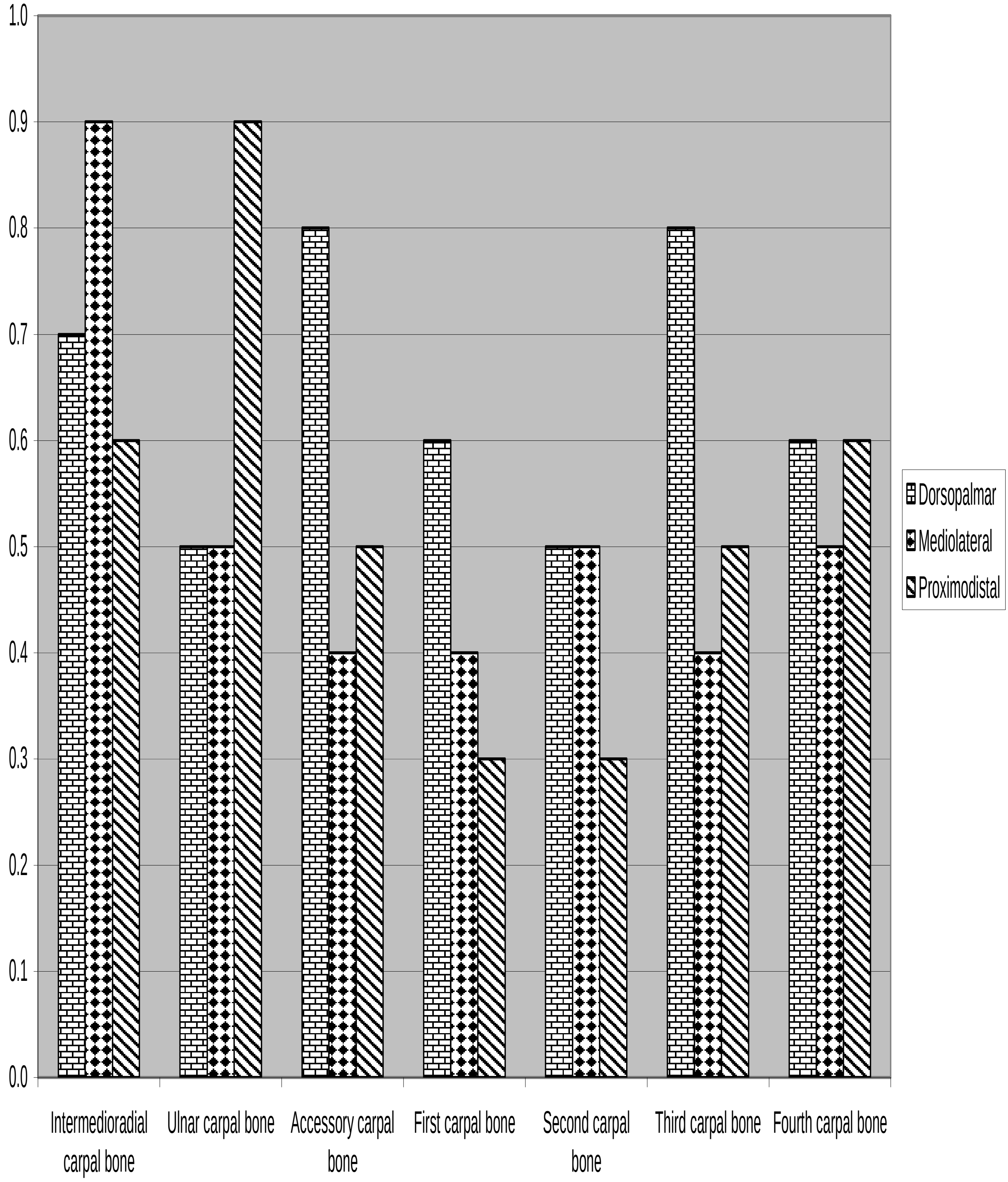


Chart 4: Dimensions (cm) of the carpal bones in cats with body weight ranging from 4.5 - 5 kg BW:



III. <u>Anatomy of the carpal ligaments in dogs and cats (Figg. 45 - 70):</u>

The three main joints of the carpus, (antebrachiocarpal, middle carpal and carpometacarpal joints) are supported by very short ligaments present on the dorsal and palmar aspect of the carpal joint. These ligaments support the joint capsule, in addition to the short radial and ulnar collateral carpal ligaments.

3.1. <u>Dorsal carpal ligaments in dogs and cats (Figg. 45 – 48 and 58 - 61):</u>

The dorsal aspect of the carpal joint in dogs and cats is supported by the following ligaments: dorsal radiocarpal, dorsal radioulnar, dorsal intercarpal, and dorsal carpometacarpal ligaments.

3.1.1. <u>Dorsal radiocarpal ligament in dogs and cats:</u>

The dorsal radiocarpal ligament is a short ligament, it originates from dorsal aspect of distal radius and inserts on the ulnar carpal bone (Figg. 45, 58).

3.1.2. <u>Dorsal radioulnar ligament in dogs and cats:</u>

The dorsal radioulnar ligament is a very short ligament that fills the space between the radius and ulna; it connects the ulna with the radius (Figg. 46, 59).

3.1.3. <u>Dorsal intercarpal ligament in dogs and cats:</u>

The dorsal intercarpal ligaments are very short ligaments spreaded on the dorsal aspect of proximal and distal rows of the carpal bones, the origin and insertion of these ligaments can not be identified clearly (Figg. 47, 60).

3.1.4. <u>Dorsal carpometacarpal ligament in dogs and cats:</u>

The dorsal carpometacarpal ligaments are very short ligaments present on the dorsal aspect of the carpal joint; they connect the dorsal aspect of the distal row of carpal bones and proximal dorsal aspect of metacarpal bones (Figg. 48, 61).

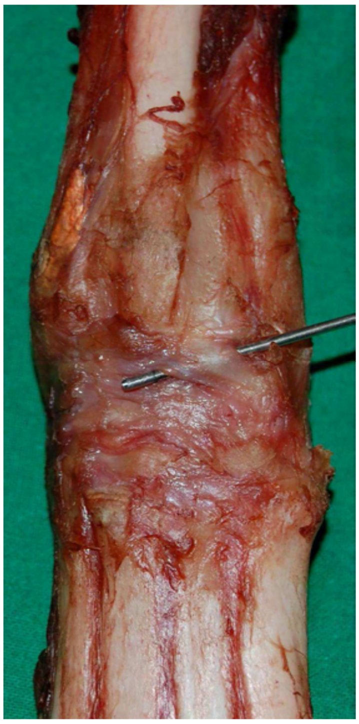


Fig. 45: Dorsal radiocarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, common digital extensor tendon, tendon of the extensor carpi radialis muscle and fascia are removed.

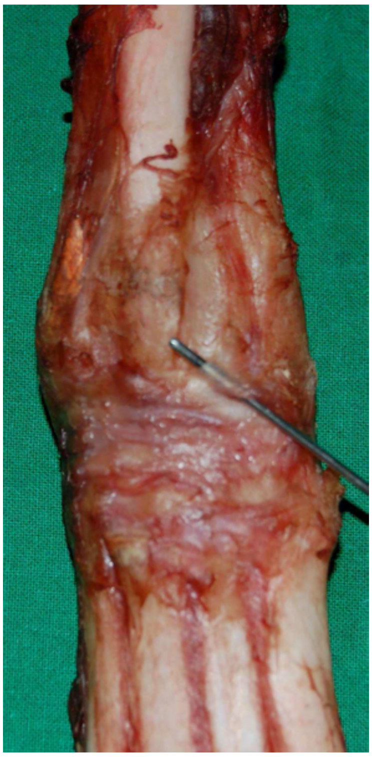


Fig. 46: Dorsal radioulnar ligament of the left carpus in a dog. Skin, subcutaneous tissue, common digital extensor tendon, tendon of the extensor carpi radialis muscle and fascia are removed.

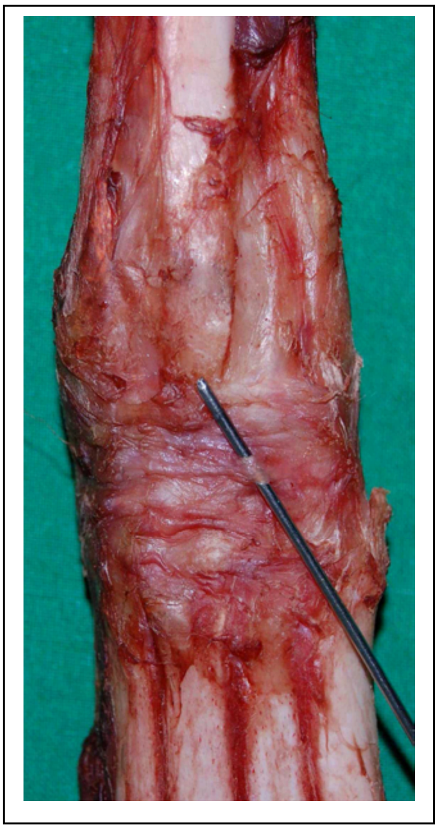


Fig. 47: Dorsal intercarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, common digital extensor tendon and fascia are removed.

Fig. 48: Dorsal carpometacarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, common digital extensor tendon and fascia are removed.

3.2. Palmar carpal ligaments in dogs and cats (Figg. 49 - 55 and 62 - 68):

The palmar aspect of the carpal joint in dogs and cats is supported by the following ligaments: palmar radiocarpal, palmar ulnocarpal, palmar intercarpal and palmar carpometacarpal ligaments. In addition, there are the palmar accessory metacarpal, palmar medial accessory metacarpal and palmar accessorioulnar ligaments, which support the accessory carpal bone in its position.

3.2.1. Palmar accessorioulnar ligament in dogs and cats:

It is a short ligament that originates from the dorsodistal aspect of the accessory carpal bone and it inserts on ulnar carpal bone (Figg. 49, 62). It supports the accessory carpal bone in its position.

3.2.2. Palmar medial accessory metacarpal ligament in dogs and cats:

The palmar medial accessory metacarpal is one of the ligaments, which holds the accessory carpal bone in its place. It originates from the medial aspect of the accessory carpal bone and it inserts on the proximal palmar aspect of the fourth metacarpal bone (Figg. 50, 63).

3.2.3. Palmar accessory metacarpal ligament in dogs and cats:

The palmar accessory metacarpal ligament holds the accessory carpal bone in its position, it supports the accessory medial metacarpal and the accessorioulnar carpal ligament in this function, it originates from the palmar aspect of the accessory carpal bone and it inserts on the palmar proximal aspect of the fifth metacarpal bone (Figg. 51, 64).

3.2.4. Palmar intercarpal ligaments in dogs and cats:

The palmar intercarpal ligaments are very short ligaments spreaded on the palmar aspect of proximal and distal rows of the carpal bones, the origin and insertion of these ligaments can not be identified clearly in our study (Figg. 52, 65).

3.2.5. <u>Palmar carpometacarpal ligaments in dogs and cats:</u>

The palmar carpometacarpal ligaments are very short ligaments present on the palmar aspect of the carpal joint. They connect the palmar aspect of the distal row of carpal bones and palmar proximal aspect of metacarpal bones; they also can not be identified clearly in this study (Figg. 53, 66).

3.2.6. <u>Palmar radiocarpal ligament in dogs and cats:</u>

It is a short ligament that originates from the palmar aspect of the radius and inserts on the palmar aspect of the intermedioradial carpal bone (Figg. 54, 67).

3.2.7. <u>Palmar ulnocarpal ligament in dogs and cats:</u>

The ulnocarpal ligament is a short ligament on the palmar aspect of the carpal joint, it originates from the distal radial aspect of the ulna and inserts on the palmar surface of the intermedioradial bone (Figg. 55, 68).

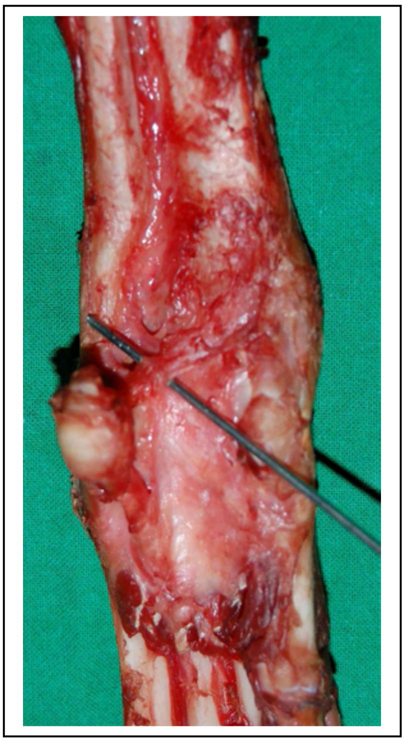


Fig. 49: Palmar accessorioulnar ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and the fascia are removed.

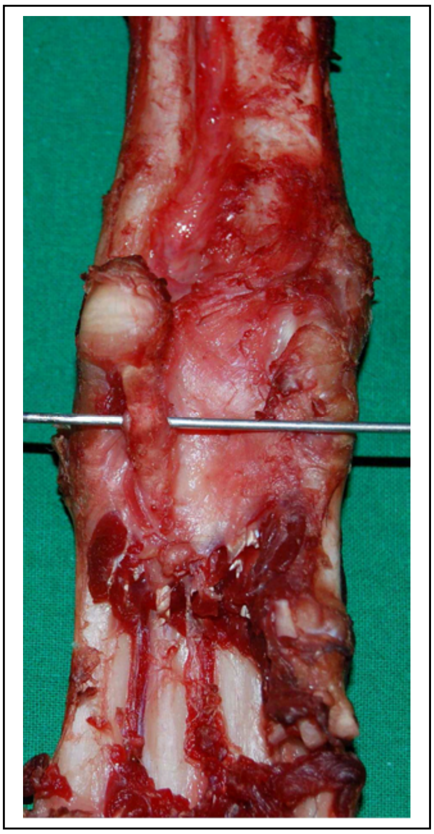


Fig. 50: Palmar medial accessory metacarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons, tendon of extensor carpi ulnaris and fascia are removed.

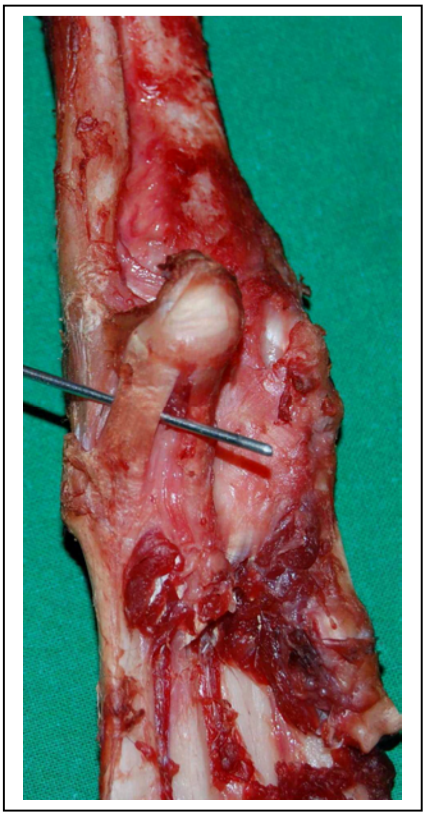


Fig. 51: Palmar accessory metacarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons, tendon of extensor carpi ulnaris and fascia are removed.

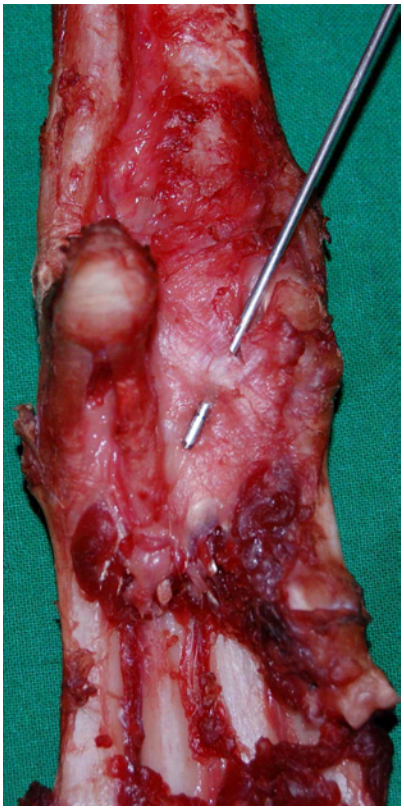


Fig. 52: Palmar intercarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

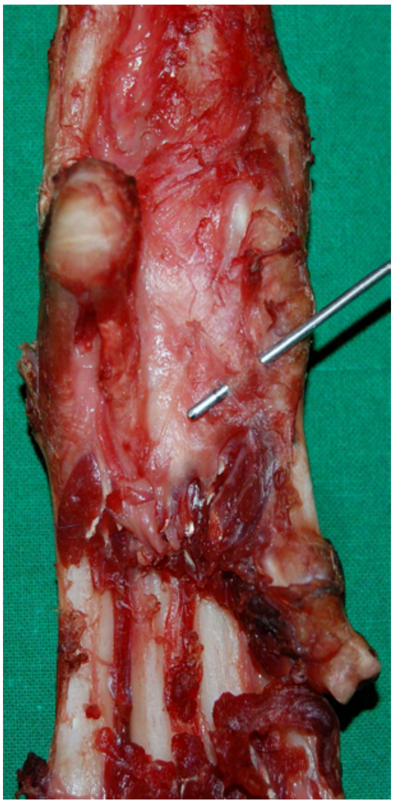


Fig. 53: Palmar carpometacarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

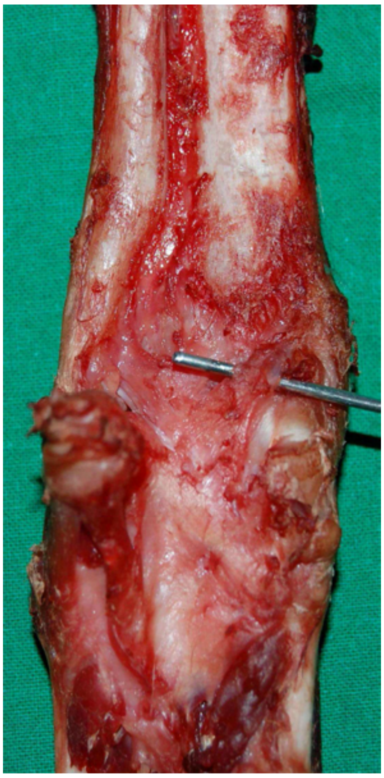


Fig. 54: Palmar radiocarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

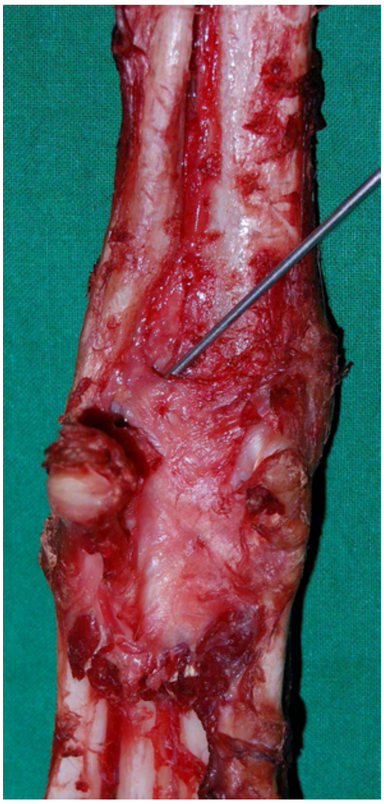


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Fig. 55: Palmar ulnocarpal ligament of the left carpus in a dog. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

3.3. <u>Short collateral ligaments in dogs and cats (Figg. 56 - 57 and 69 - 70):</u>

There are two very short collateral ligaments (radial collateral and ulnar collateral ligaments), which support the carpal joint medially and laterally.

3.3.1. <u>Short radial (medial) collateral ligaments in dogs and cats:</u>

The radial medial collateral ligament is a short ligament that supports the medial aspect of the carpal joint. It originates from the styloid process of the radius and inserts distally on the intermedioradial carpal bone (Figg. 56, 69).

3.3.2. <u>Short ulnar (lateral) collateral ligaments in dogs and cats:</u>

The ulnar lateral collateral ligament is a short ligament that is situated on the lateral aspect of the carpal joint. It originates from the styloid process of the ulna and inserts on the ulnar carpal bone (Figg. 57, 70).

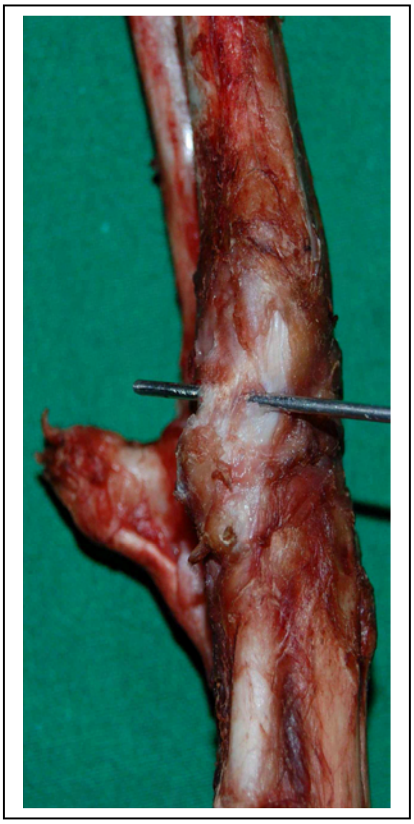

Fig. 56: Short radial (medial) collateral ligament of the left carpus in a dog. Skin, subcutaneous tissue, tendon of the flexor carpi radialis muscle and fascia are removed.

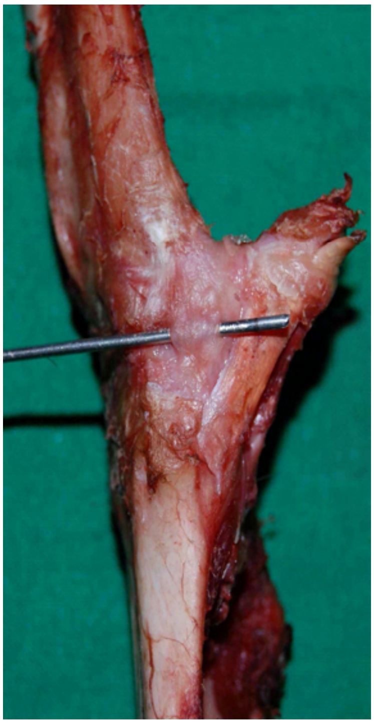

Fig. 57: Short ulnar (lateral) collateral ligament of the left carpus in a dog. Skin, subcutaneous tissue, tendon of the extensor carpi ulnaris muscle and fascia are removed.

Carpal ligaments in cats

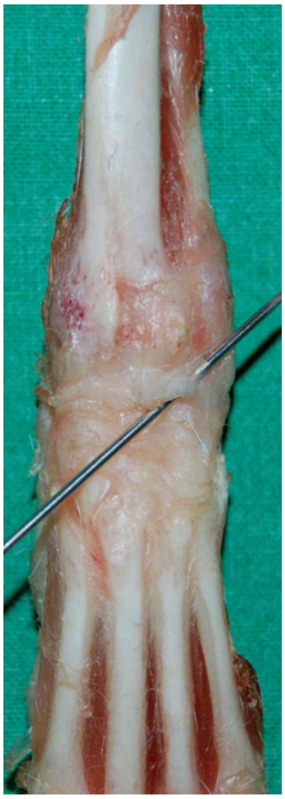

Fig. 58: Dorsal radiocarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, common digital extensor tendon, tendon of the extensor carpi radialis muscle and fascia are removed.

Fig. 59: Dorsal radioulnar ligament of the left carpus in a cat. Skin, subcutaneous tissue, common digital extensor tendon, tendon of the extensor carpi radialis muscle and fascia are removed.

Fig. 60: Dorsal intercarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, common digital extensor tendon and fascia are removed.

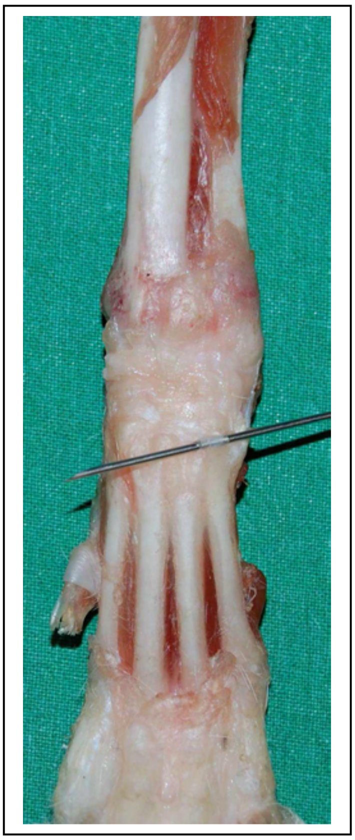

Fig. 61: Dorsal carpometacarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, common digital extensor tendon and fascia are removed.

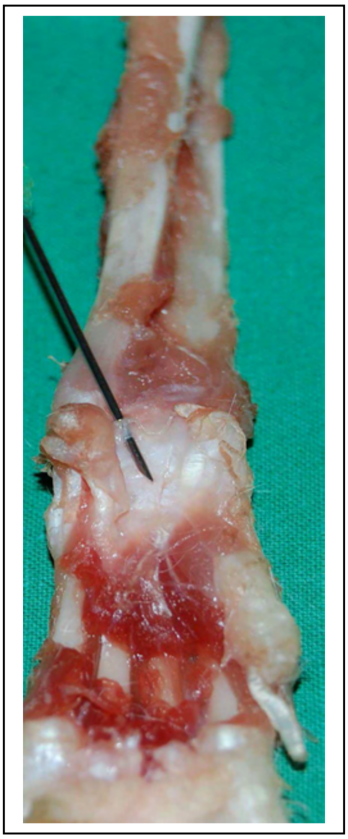

Fig. 62: Palmar accessorioulnar ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons, fascia are removed.

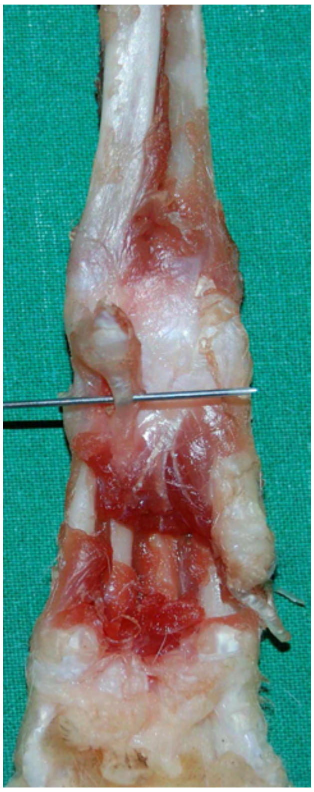

Fig. 63: Palmar medial accessory metacarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons, tendon of extensor carpi ulnaris and fascia are removed.

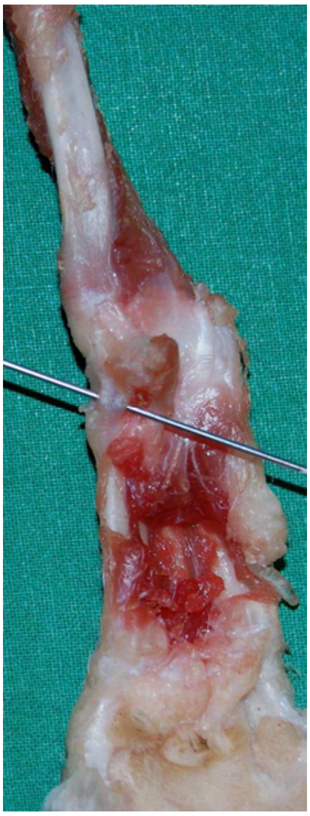

Fig. 64: Palmar accessory metacarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons, tendon of extensor carpi ulnaris and fascia are removed.

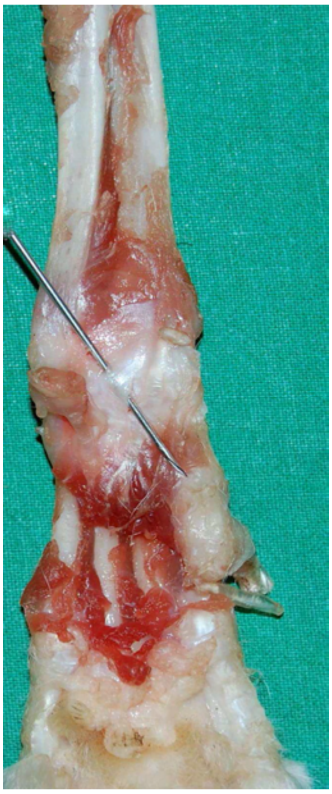

Fig. 65: Palmar intercarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

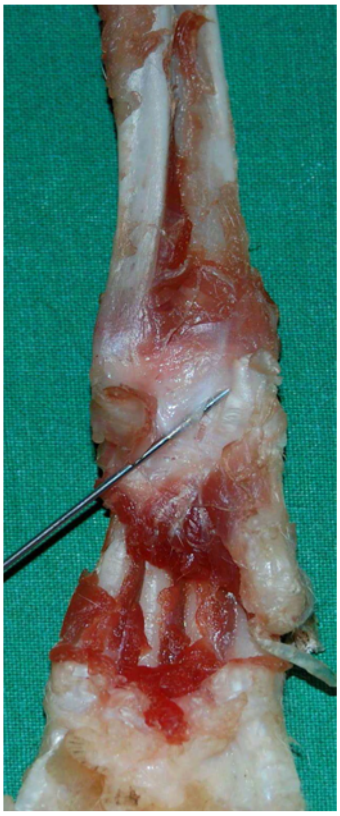

Fig. 66: Palmar carpometacarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

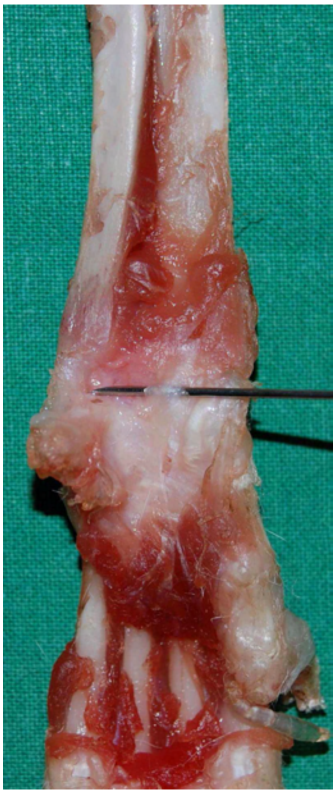

Fig. 67: Palmar radiocarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

Fig. 68: Palmar ulnocarpal ligament of the left carpus in a cat. Skin, subcutaneous tissue, flexor retinaculum, superficial and deep flexor tendons and fascia are removed.

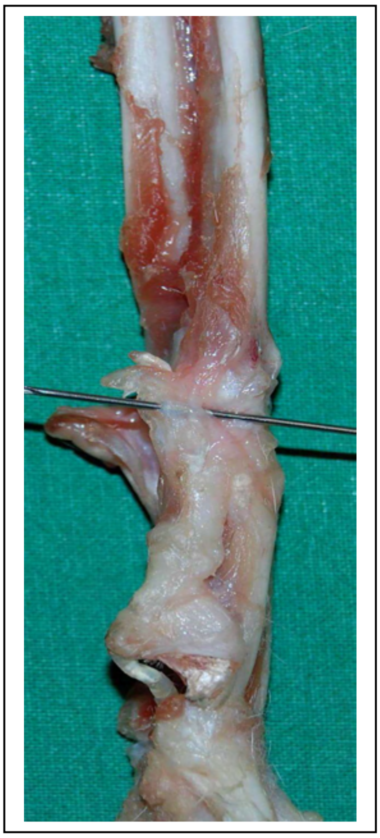

Fig. 69: Short radial (medial) collateral ligament of the left carpus in a cat. Skin, subcutaneous tissue, tendon of the flexor carpi radialis muscle and fascia are removed.

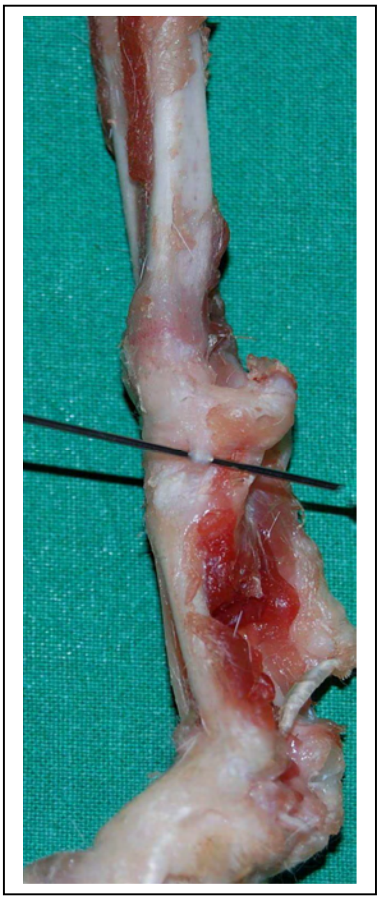

Fig. 70: Short ulnar (lateral) collateral ligament of the left carpus in a cat. Skin, subcutaneous tissue, tendon of the extensor carpi ulnaris muscle and fascia are removed.

III. Normal radiography of carpal joint in dogs and cats:

Radiographically the carpal joint in dogs and cats consists of a set of articulations. It includes antebrachiocarpal joint, the articulation between the radius and ulna proximally and the proximal row of carpal bones distally. Intercarpal joints are located between carpal bones (side to side as well as proximal to distal). The middle carpal joint is located between the proximal and distal rows of carpal bones. Carpometacarpal joints are the articulations between the distal row of carpal bones and the bases of the metacarpal bones.

3.1. Normal radiography of carpal joint in dogs and cats on the dorsopalmar view:

The intermedioradial carpal bone is quadriangular in shape articulated proximally with distal surface of the radius. It articulates laterally with the ulnar carpal bone and distally with the distal row of the carpus (including the first, second, third and fourth carpal bones) (Figg. 71, 3; 72, 3).

The sesamoid bone of abductor pollicis longus muscle is a small round bone present and superimposed on the medial aspect of the intermedioradial carpal bone (Figg. 71, 6; 72, 6).

The ulnar carpal bone is triangular in shape, it articulates proximally with the distal ulna, medially with the intermedioradial carpal bone and distally with the fourth carpal bone. The ulnar carpal bone is superimposed partially on the distal ulna and accessory carpal bone proximally, medially on the intermedioradial carpal bone and on the fourth carpal bone distally (Figg. 71, 5; 72, 5).

The accessory carpal bone is rod in shape superimposed partially on the distal radius proximally and with the intermedioradial and ulnar carpal bones distally. This differs some what in the cat where it is superimposed only on the ulnar carpal bone and on the distal ulna (Figg. 71, 4; 72, 4).

The first carpal bone is oblong in shape. It is situated in the medial aspect of the joint; it is superimposed laterally on the second carpal bone and distally on the first metacarpal bone (Figg. 71, 7; 72, 7).

The second carpal bone is small quadrilateral in shape. It articulates with the first carpal bone medially, with the third carpal bone laterally and with the second metacarpal bone distally (Figg. 71, 8; 72, 8).

The third carpal bone appears oblong in shape, it articulates proximally with the intermedioradial carpal bone, distally with the third metacarpal bone, medially with the second carpal bone and with the fourth carpal bone laterally (Figg. 71, 9; 72, 9).

The fourth carpal bone is wedge shaped superimposed proximolaterally on the ulnar carpal bone, it articulates proximomedially with the intermedioradial carpal bone, medially with the third carpal bone and distally with the fourth and fifth metacarpal bones (Figg. 71, 10; 72, 10).

Fig. 71: Radiographical dorsopalmar view of normal right carpus in a dog 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Accessory carpal bone, 5. Ulnar carpal bone, 6. Sesamoid bone 7. First, 8. Second, 9. Third, 10. Fourth carpal bone, 11. First, 12. Second, 13. Third, 14. Fourth, 15. Fifth metacarpal bones.

Fig. 72: Radiographical dorsopalmar view of normal right carpus in a cat 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Accessory carpal bone, 5. Ulnar carpal bone, 6. Sesamoid bone 7. First, 8. Second, 9. Third, 10. Fourth carpal bone, 11. First, 12. Second, 13. Third, 14. Fourth, 15. Fifth metacarpal bones.

3.2. <u>Normal radiography of carpal joint in dogs and cats on the mediolateral view:</u>

The intermedioradial carpal bone appears triangular in shape superimposed palmarly on the cranial aspect of the ulnar carpal bone, it articulates proximally with the radius and distally with the distal row of the carpal bones (Figg.73, 3; 74, 3).

The ulnar carpal bone is oblong in shape superimposed cranially on the intermedioradial carpal bone, and it articulates caudally with the accessory carpal bone and proximally with the distal ulna (Figg. 73, 4; 74, 4).

The accessory carpal bone appears clear in this view, it is oblong in shape, articulates with the ulnar carpal bone cranially and with the distal ulna proximally (Figg. 73, 5; 74, 5).

The distal row of the carpal bones appears superimposed over each other arranged from cranially to caudally as follow, second, third and fourth carpal bones (Figg. 73, 6-8; 74, 6-8).

3.3. <u>Normal radiography of carpal joint in dogs and cats on the lateral flexed view:</u>

The intermedioradial carpal bone appears triangular in shape superimposed on the ulnar carpal bone caudally and it articulates proximally with the distal radius, and distally with the distal row of the carpal bones (Figg. 75, 3; 76, 3).

The ulnar carpal bone superimposed cranially on the intermedioradial carpal bone, caudally on the accessory carpal bone and on the distal radius and ulna proximally (Figg. 75, 4; 76, 4).

The accessory carpal bone is situated caudally and it is superimposed cranially on the ulnar carpal bone, proximally on the ulna and distally on the first metacarpal bone (Figg. 75, 5; 76, 5).

The distal row of the carpal bones are superimposed over each other and arranged from the cranial surface to caudally as follow; second, third and fourth carpal bones respectively (Figg. 75, 6-8; 76, 6-8).

Fig. 73: Radiographical mediolateral view of normal right carpus in a dog 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, 12. Fourth + Fifth metacarpal bones.

Fig. 74: Radiographical mediolateral view of normal left carpus in a cat 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, 12. Fourth + Fifth metacarpal bones.

Fig. 75: Radiographical mediolateral flexed view of normal right carpus in a dog 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, Fourth and Fifth metacarpal bones.

Fig. 76: Radiographical mediolateral flexed view of normal left carpus in a cat 1. Radius, 2. Ulna, 3. Intermedioradial carpal bone, 4. Ulnar carpal bone, 5. Accessory carpal bone, 6. Second, 7. Third, 8. Fourth carpal bone, 9. First, 10. Second, 11. Third, Fourth and Fifth metacarpal bones.

IV. <u>Radiography of carpal joint affections in dogs and cats:</u>

The carpal joint is a compound joint that contains several bones which articulate with each other and articulate with the distal part of the radius and ulna and proximal part of the metacarpal bones. The great variations in shape, size, and density of different carpal bones in dogs and cats may lead to confusions during radiographic interpretation of diseases affecting the carpal joints such as arthritis, osteoarthritis, fractures, luxation, subluxation, and various malconformations. The causes of carpal joint affections are trauma, congenital diseases, infectious and degenerative changes.

4.1. <u>Arthritis and osteoarthritis of the carpal joint in dogs and cats:</u>

Osteoarthritis is the most common affections of the carpal joints in dogs and cats. From sixty one examined carpal joints in the present study, twenty six cases (43%) suffer from osteoarthritis. Arthritis is an inflammation of one or more joints of the carpus accompanied by different radiographical changes in bones, joint spaces, and soft tissues surrounding the carpal joint articulations. It is caused by trauma or infectious agents. Osteoarthritis is an inflammation of carpal bones and carpal joints accompanied by alterations of joint space and shape of carpal bones.

4.1.1. Osteoarthritis of the carpal joint in dogs and cats:

Osteoarthritis is a common form of arthritis. Radiographically the signs of osteoarthritis of carpal joints in dogs and cats are soft tissue swelling, osteophytes formations in the carpal bones and loss of joint spaces of the antebrachiocarpal, intercarpal and carpometacarpal joints. In the present study eleven dogs (18%) and two cats (3%) have soft tissue swelling surrounding the carpal joint, loss of the joint space and osteophyte deposition in the intermedioradial carpal bone (Figg. 77, 78). Nine dogs (15%) and two cats (3%) have osteoarthritis with osteophyte formations in the accessory carpal bone (Fig. 79). Two dogs (3%) have the same radiographic findings of the osteoarthritis with several osteophyte formations present on the distal radius, intermedioradial carpal, ulnar carpal, accessory carpal, first, second, third and fourth carpal bones (Fig. 80).

4.1.2 Ankylosis of the carpal joint in dogs and cats:

Ankylosis of the carpal joint in dogs and cats is the end stage of degenerative joint diseases or inflammatory diseases. Radiographically characterized by severe narrowing of the antebrachiocarpal, intercarpal, and carpometacarpal joints spaces, fusion of the joints, periosteal reaction and new bone formation, loss of the bone density due to atrophy and soft tissues swelling surrounding the carpal joint in the affected cases, from sixty one cases in the present study, four cases (one dog and three cats) 7% suffer from ankylosis of the carpal joints (Figg. 81, 82, 83, 84).

Fig. 77: Medial oblique view demonstrates osteoarthritis of the right carpal joint in a dog. Swelling of the soft tissues surrounding the carpal joint (long arrow), osteophyte formation in the intermedioradial carpal bone (short arrow).

Fig. 78: Mediolateral view shows osteoarthritis of the left carpal joint in a cat. Swelling of the soft tissues surrounding the carpal joint (short arrow), osteophyte formation in the intermedioradial carpal bone (long arrow).

Fig. 79: Mediolateral view demonstrates osteoarthritis of the left carpal joint in a dog. Swelling of the soft tissues surrounding the carpal joint, osteophyte formation in the accessory carpal bone (arrow), alteration of the joints space.

Fig. 80: Mediolateral view demonstrates osteoarthritis of the left carpal joint in a dog. Swelling of the soft tissues surrounding the carpal joint (grey arrow), osteophyte formation in the distal radius, intermedioradial carpal, ulnar carpal, accessory carpal bone, and the distal row of the carpal bones, alteration of the joint space (white arrows).

Fig. 81: Dorsopalmar view shows ankylosis of the left carpal joint in a dog, alteration of the joint space (long white arrow), osteophyte formation (grey arrows), atrophy and loss of the carpal bones density (short white arrows).

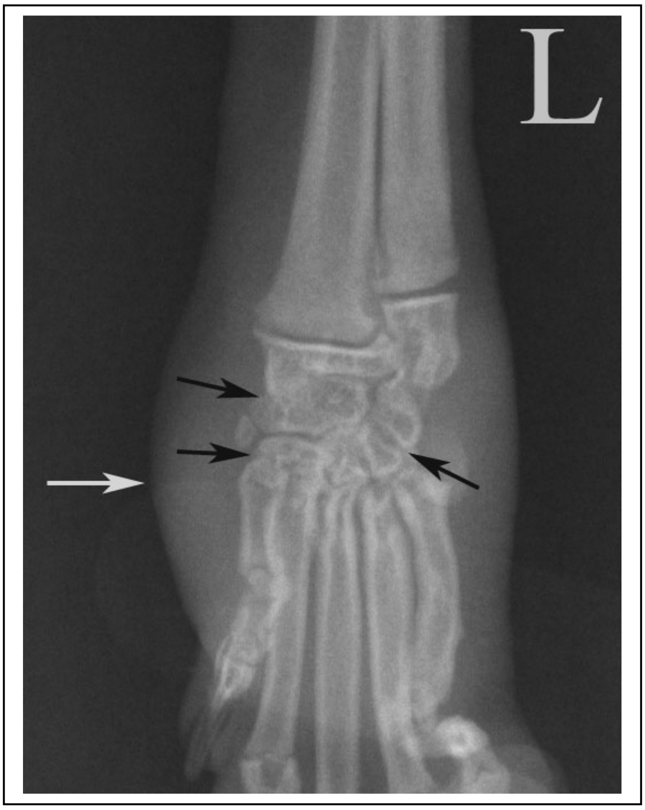

Fig. 82: Dorsopalmar view of the left carpus in a cat demonstrates ankylosis of antebrachiocarpal, intercarpal and carpometacarpal joints (black arrows), alteration of the joint space, swelling of the soft tissue surrounding the carpal joint (white arrow).

Fig. 83: Mediolateral view shows ankylosis of antebrachiocarpal, intercarpal and carpometacarpal joints (black arrows) in left carpus in a cat, alteration of the joint space, swelling of the soft tissue surrounding the carpal joint (white arrows).

Fig. 84: Mediolateral flexed view demonstrates ankylosis of antebrachiocarpal, intercarpal, and carpometacarpal joints, loss of the joint spaces (black arrows) in right carpus in a cat, swelling of the soft tissue surrounding the carpal joint (white arrow), Loss of bone density and atrophy of the carpal bones.

4.2. Traumatic injuries of the carpal joint in dogs and cats:

Traumatic injuries of the carpal joint in dogs and cats include car accident and hyperextension injuries resulting in severe injury and damage to the palmar or dorsal carpal ligaments and some times of the medial or lateral collateral ligaments. The carpal luxation, subluxation, and fractures of the proximal and distal row of the carpal bones occur commonly following this trauma. Carpal radiographs are essential for diagnosis of joint luxation, subluxation, and fractures of the carpal bones in dogs and cats.

4.2.1. Subluxation of the carpal joint in dogs and cats:

Subluxation of the carpal joint in dogs and cats means partial luxation of carpal articulations, (antebrachiocarpal, middle carpal, or carpometacarpal articulations) in different directions (either in cranial, caudal, medial or lateral direction). In this study there are thirteen cases (eleven dogs 18% and two cats 3%) suffering from subluxation from sixty one examined carpal joints. Antebrachiocarpal joint subluxation occurs in seven cases 11% (five dogs 8% and two cats 3%), two dogs 3%, and two cats 3% suffering from palmar subluxation of the antebrachiocarpal joint and three dogs 5% have subluxation of the antebrachiocarpal joint to the medial aspect. Subluxation of the carpometacarpal joint to the medial aspect occurs in five dogs 8% with widening of the carpal joints space, swelling of the soft tissues surrounding the carpal joint (Figg. 85, 86, 87). One dog 2% suffers from intercarpal joint subluxation to the caudomedial aspect.

Stress radiographs are diagnostic for subluxation of the carpal joint at different levels of the joint and in different directions in dogs and cats (Fig. 88). Subluxation of antebrachiocarpal and carpometacarpal joint may occur to the medial aspect with increase of the joint space and swelling of the soft tissues surrounding the carpal joint. It can be diagnosed by the lateral stress view (Figg. 89, 90, 91), or it may be subluxated to the lateral aspect and can be diagnosed by the medial stress view (Fig. 92).

From sixty one studied animals with affected carpal joints, there are ten dogs (16%) suffering from hyperextension of the carpal joint, nine dogs of them were characterized radiographically on the mediolateral hyperextended view by soft tissues swelling surrounding the carpal joint and increase of the joint space of the intercarpal and carpometacarpal joints (Figg. 93, 94, 95), one case has no radiographical signs but it appears clinically, that the carpal joint is hyperextended in the affected side more than the normal joint by clinical and physical examination.

Fig. 85: Mediolateral view shows palmar subluxation of the right antebrachiocarpal joint in a cat (long arrow), swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 86: Dorsopalmar view with lateral stress of the right carpal joint in a dog shows subluxation of the carpometacarpal joint, widening of the joint space (long arrow) and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 87: Mediolateral hyperextended view shows palmar subluxation of the antebrachiocarpal joint of the right side in a cat (long arrow), and swelling of the soft tissue surrounding the carpal joint (short arrow).

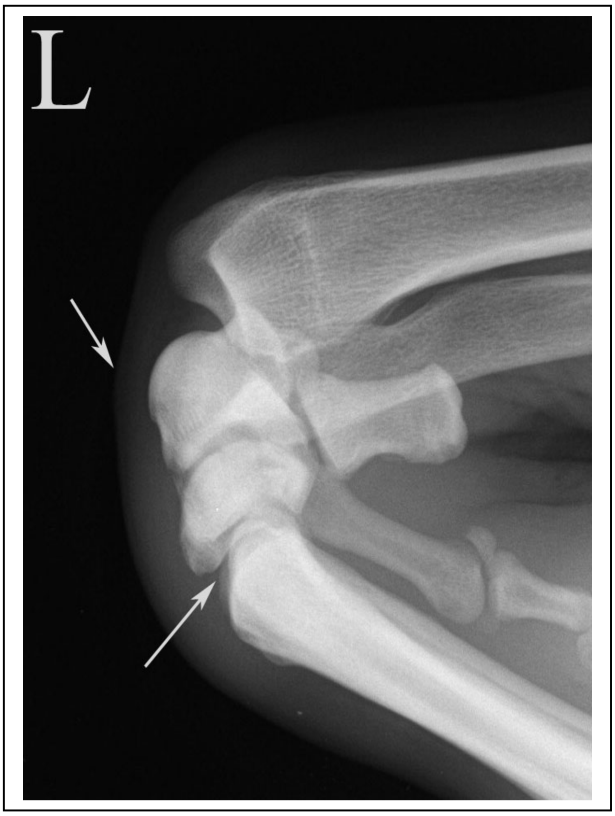

Fig. 88: Mediolateral flexed view demonstrates subluxation of the left carpometacarpal joint in a dog, widening of the joint space (long arrow), and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 89: Dorsopalmar view with lateral angulation of the left carpal joint in a dog shows subluxation of the carpometacarpal joint, widening of the carpometacarpal joint space (long arrow) and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 90: Dorsopalmar view with lateral stress of the left carpal joint in a dog demonstrates medial subluxation of the left carpometacarpal joint, proximal dislocation of the second metacarpal bone, widening of the joint space (long arrow) and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 91: Dorsopalmar view with lateral angulation of the right carpus in a dog shows medial subluxation of the antebrachiocarpal joint in a dog (long white arrow), presence of two small bone fragments of the distal radius (black arrows) and swelling of the soft tissue surrounding the carpal joint (short white arrow).

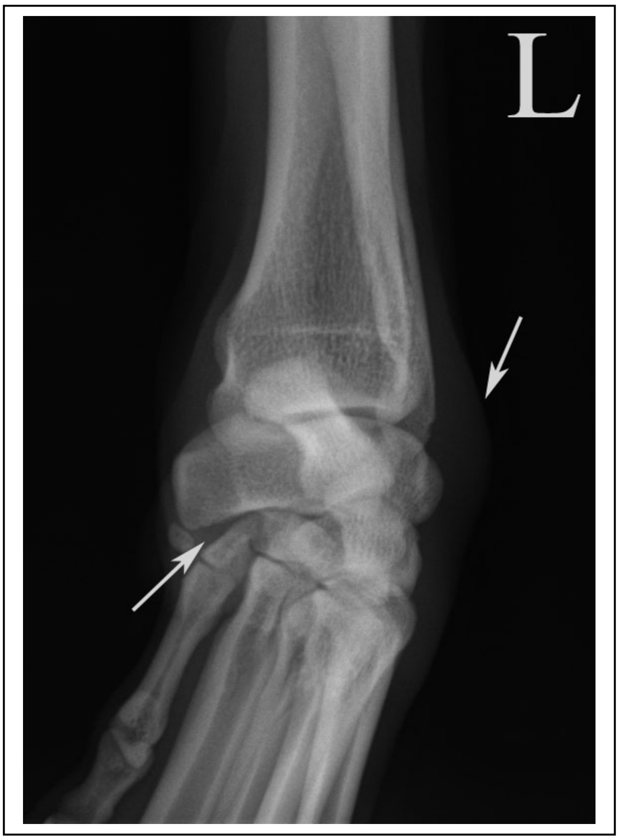

Fig. 92: Dorsopalmar view with medial stress of the left carpus in a dog demonstrates medial rotation of the carpal bones in the intercarpal joint to the caudolateral side, widening of the joint space (long arrow) and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 93: Mediolateral hyperextended view shows abnormal hyperextension of the right intercarpal joint in a dog, increase of the joint space (long arrow), and swelling of the soft tissue surrounding the carpal joint (short arrow).

Fig. 94: Mediolateral hyperextended view demonstrates normal other side of the left carpal joint in the same dog, for comparison with the previous affected side.

Fig. 95: Mediolateral hyperextended view demonstrates abnormal hyperextension of the right carpometacarpal joint in a dog (long arrow), and swelling of the soft tissue surrounding the carpal joint (short arrow).

4.2.2. **Luxation of the carpal joint in dogs and cats:**

Luxation of the carpal joint means complete separation and movement of the carpal joint articulations (antebrachiocarpal, middle carpal or carpometacarpal joints) in different directions and dislocations either cranially or caudally. The affected joints appear radiographically severely swollen, and it has severely increased joints spaces because there is alteration of the normal articulation and normal alignment of these joints. This occurs due to loss and damage of the dorsal and palmar ligamentous support of the carpal joints, either the dorsal or palmar carpal ligaments in addition to the short medial or lateral collateral ligaments.

From sixty one examined carpal joints of dogs and cats in this study, there are three cases; two affected cats (3%) suffering from complete luxation of the antebrachiocarpal joint. It is luxated to mediopalmar direction in one cat. The affected joint shows high degree of swelling of the soft tissues surrounding the carpal joint (Figg. 96, 97) and also severely increased joint space of the antebrachiocarpal joint. In the other cat the antebrachiocarpal joint is luxated to the dorsal aspect (Figg. 98, 99), in addition to swelling of the soft tissues surrounding the affected joint, there are multiple small bone fragments are present on the palmar aspect of the luxated joint. One dog shows luxation of the left antebrachiocarpal joint to the dorsal and medial aspect accompanied by swelling of the soft tissues surrounding the affected carpal joint (Fig. 100).

4.2.3. **Fractures of the carpal bones in dogs and cats:**

Fractures of the carpal bones in dogs and cats occur mainly due to severe trauma by car accident or falling from extreme height. In sixty one examined carpal joints of this study there are five cases (9%) suffering from carpal bones fractures, three dogs (5%) have intermedioradial carpal bone fractures, one dog

(2%) has a fracture of the third carpal bone and another dog (2%) has an old fracture of the ulnar carpal bone.

The fractured intermedioradial carpal bone in the dorsopalmar view (Fig. 101) shows a vertical fracture line that runs through the bone. The medial fragment is mildly displaced distally. In the mediolateral view and flexed mediolateral view, the fracture line of an old fractured intermedioradial carpal bone in one dog is proximally irregularly outlined and proximally it appears that the fracture gap is incompletely fused; also there is an osteophyte formation on the intermedioradial carpal bone, third carpal bone, and the distal aspect of the accessory carpal bone (Figg. 102, 103).

The fracture of the third carpal bones in one dog appears radiographically as a separated and displaced fragment in addition to swelling of the soft tissues surrounding the carpal joint. In the affected case there is also osteophyte formation present on the distal aspect of the accessory carpal bone (Fig. 104). The fracture of the ulnar carpal bone in one dog appears radiographically as an old fracture associated with osteophyte formation on the intermedioradial carpal bone and swelling of the soft tissues surrounding the carpal joint (Fig. 105).

Fig. 96: Dorsopalmar view of the left carpus demonstrates mediopalmar luxation of antebrachiocarpal joint in a cat, high degree of widening of antebrachiocarpal joint space (black arrow), and swelling of the soft tissue surrounding the carpal joint (white arrow).

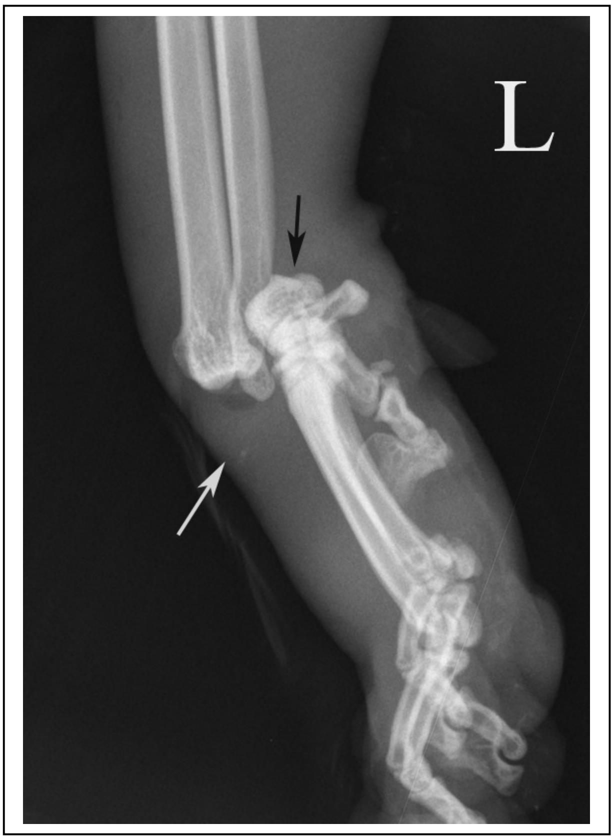

Fig. 97: Mediolateral view of the left carpus demonstrates palmar luxation of the antebrachiocarpal joint in a cat (black arrow), swelling of the soft tissue surrounding the carpal joint (white arrow).

Fig. 98: Mediolateral view of the left carpus in a cat demonstrates dorsal luxation of the antebrachiocarpal joint (white arrow), swelling of the soft tissue surrounding the carpal joint (grey arrows) and presence of small multiple bone fragments (black arrows).

Fig. 99: Dorsopalmar view of the left carpus in a cat demonstrates dorsolateral luxation of antebrachiocarpal joint (white arrow), swelling of the soft tissue surrounding the carpal joint (grey medial and lateral arrows).

Fig. 100: Dorsopalmar view of the left carpus in a dog demonstrates dorsal and medial luxation of antebrachiocarpal joint (white arrow), swelling of the soft tissue surrounding the affected carpal joint (grey arrow).

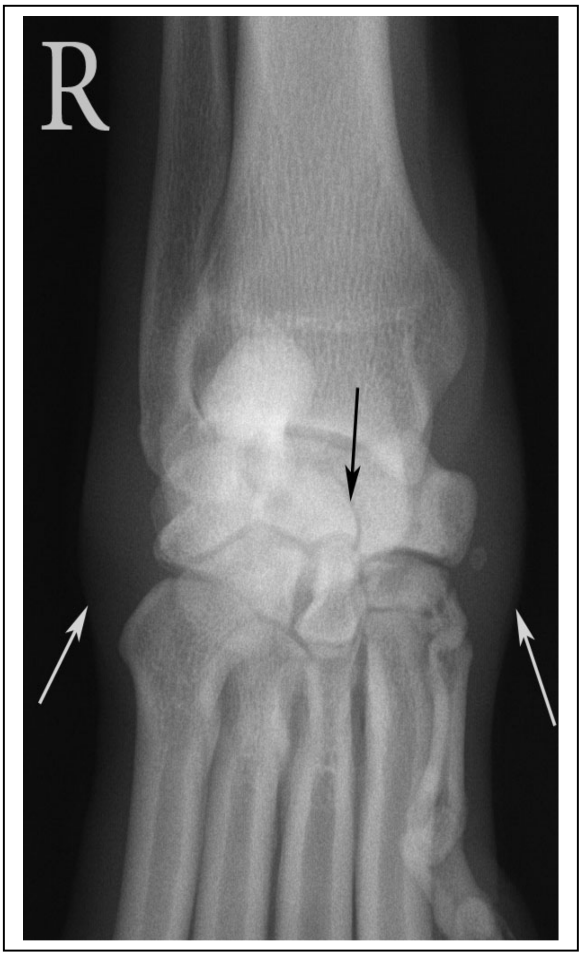

Fig. 101: Dorsopalmar view demonstrates fracture of the intermedioradial carpal bone in the right carpus in a dog (black arrow), swelling of the soft tissue surrounding the carpal joint (white medial and lateral arrows), vertical fracture line is running through the bone and the medial fragment is mildly distally displaced.

Fig. 102: Flexed mediolateral view demonstrates fracture of the intermedioradial carpal bone in the right carpus in a dog (long white arrow), swelling of the soft tissue surrounding the carpal joint (grey arrow), vertical fracture line is running through the bone, osteophyte formation on intermedioradial carpal bone and on third carpal bone (short white arrow).

Fig. 103: Mediolateral view demonstrates fracture of the intermedioradial carpal bone in the right carpus of a dog (black arrow), swelling of the soft tissue surrounding the carpal joint, vertical fracture line is running through the bone, new bone formation on intermedioradial carpal bone, third carpal bone (white arrow) and on the accessory carpal bone (grey arrow).

Fig. 104: Mediolateral hyperextended view shows chip fracture of the third carpal bone (short white arrow) in the left carpus of a dog, displaced fragment, swelling of the soft tissue surrounding the carpal joint (long white arrow), osteophyte formation at the distal aspect of the accessory carpal bone (grey arrow), hyperextension and widening of the intercarpal joint space (black arrow).

Fig. 105: Dorsopalmar view with medial stress of the left carpus in a dog demonstrates old fracture of the ulnar carpal bone (long white arrow), swelling of the soft tissue surrounding the carpal joint (short white arrow) and osteophyte formation in the intermedioradial carpal bone (grey arrow).

V. **Surgical procedures for treatment of the different carpus affections in dogs and cats:**

5.1. **Pancarpal arthrodesis:**

Pancarpal arthrodesis using Castless pancarpal arthrodesis plate (PCA-plate) is applied in this study for treatment of different carpal joint affections in eighteen cases (29%) such as luxation (two cats and one dog, Fig. 106), subluxation (six dogs and two cats), complicated fractures of the carpal bones (two dogs, Fig. 107), and hyperextension of carpal joint (five dogs) (Table 10). Pancarpal arthrodesis includes fusion of all carpal joint articulations (antebrachiocarpal, middle carpal and carpometacarpal joint).

Aanaesthesia: The dogs are going under anaesthesia using L- Methadone in a dose of 0.5 mg/kg BW and Diazepam in dose of 0.5 mg/kg BW, Ketamine 10 % in a dose of 2 mg/kg BW and Xylazine in a dose of 0.2 mg/kg BW intravenously. The cats are going under anaesthesia with Medetomidine 0.08 mg/kg BW and Ketamine 2 % in a dose of 5 mg/kg BW intravenously.

Then dogs and cats are positioned in sternal recumbency under effect of general anaesthesia (Isofluran 2 % + 98 % Oxygen), with both limbs extended cranially.

Clipping and shaving the hair of the affected limb from the elbow joint distally to the foot (Figg. 108 and 109), cleaning and soaking of the limb with antiseptic solution (Kodan)® is applied. Draping of the affected site and animal body with clean and sterile surgical drapes in addition to tourniquet application at the level of the elbow joint is applied. Skin incision at the level of the distal radius is applied and extended distally to the distal part of the metacarpal bones, blunt dissection of the subcutaneous tissues and retraction of the tendon of the extensor carpi radials muscle and cutting of the short carpal ligaments at the level of metacarpal bones to expose the carpal bones (Fig. 110). The intra articular cartilage is taken off with a high speed burr and flushes with sterile normal saline for proper fixation of the joints and to achieve fusion of the bones.

Several bone drilling is applied in the end of the distal radius (Fig. 111) and proximal metacarpal bones for proper blood flow and nourishment. Then autologus bone graft is positioned in the intercarpal joint spaces for providing proper and faster bone fusion.

Thorough removal of the intra articular cartilage and proper alignment of the carpal joint is applied. Castless pancarpal arthrodesis plate (PCA- plate) 110, 120, 130 and 140 mm in length according to the size of the operated dogs and eleven screws with sizes of 2.7 mm / 3.5 mm is positioned on the carpal joint (Fig. 112). Four 3.5 mm screws are positioned in the distal radius, one 2.7 or 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in fourth metacarpal bone (Table 11, 12). In a cat the castless pancarpal arthrodesis plate (PCA- plate) is smaller in size, it has 60 mm length and nine screw holes with sizes of 2.0 mm and 2.7 mm. Four 2.7 mm screws are positioned in the distal radius, one 2.7 or 2.0 mm screw in the intermedioradial carpal bone, each two 2.0 mm screws in the third metacarpal bone and fourth metacarpal bone.

Caused by the normal angle of carpal joint extension 12°, the plate is contoured to form this degree of extension of the joint. The plate is placed on the carpal joint and fixated by two needles or pins placed in the soft tissues in between the third and fourth metacarpal bones to be sure that the plate is correctly placed over the third and fourth metacarpal bones (Fig.

113). The first is the drilling of the intermedioradial carpal bone by using of 2.5 mm drill bit for screw size of 3.5 mm (Fig. 113), then the hole is tapped by a 3.5 mm tap and at last there is fixation of the screw using screw driver. The bone drilling and tapping differs according to the screw size (Table 13; Figg. 114, 115). After fixation of the intermedioradial carpal bone, the next proximal screw in the distal radius and next distal screws (one screw in the third metacarpal bone and one screw in the fourth metacarpal bone) have to inserted in a compression way. The remnant of the plate holes are filled with screws in a neutral way.

After proper fixation of the plate, subcutaneous tissues are sutured with monocryl 3-0 and the skin is closed with ethilon 3-0 (Figg. 116, 117). The limb is rapped in supportive bandage that has to be changed one day after surgery.

Radiographic images in two views (dorsopalmar and mediolateral views) of the operated carpal joint are obtained directly following the operation to make sure that the alignment and positioning of the plate and screws on the bones are correct (Figg. 118, 119).

In dogs and cats Cephalexin is given 25 mg/kg BW and 20 mg/kg respectively twice daily for 7 days and 4 mg/kg BW Rimadyl for dogs and Metacam 0.05 mg/kg for cats is administrated once daily for 4 weeks post operatively.

Pancarpal arthrodesis using Dynamic Compression Plate (DCP) plates was applied in two dogs. In one dog it was applied for treatment of an old fracture of the ulnar carpal bone associated with osteoarthritis by using of two plates; one is 134 mm plate with eleven holes and screw sizes of 3.5 mm was placed on the third metacarpal bone, the other one is 65 mm Buttress plate with eight holes and screws sizes of 2.0 mm was placed on the fourth metacarpal bone (Fig. 120 A, B). Postoperative radiographic images were taken (Fig. 121). In the other dog 78 mm (DCP) plate with ten holes with screws sizes of 1.5 and 2.0 mm for treatment of antebrachiocarpal joint luxation (Fig. 122).

5.2. <u>Partial carpal arthrodesis for the treatment of carpus affections in dogs and cats:</u>

Partial arthrodesis is a selective fusion of the middle carpal and carpometacarpal joints. It is indicated to repair subluxation of the middle carpal and carpometacarpal joints. In the present study partial carpal arthrodesis was applied only in one dog for the treatment of a medial subluxation of the carpometacarpal joint associated with displacement of the first and second metacarpal bones (Fig. 90).

For partial carpal arthrodesis in dogs and cats, the animal is surgically prepared and positioned in the same manner as for pancarpal arthrodesis. After surgical exposure of the carpal joint, the intraarticular cartilages of the middle carpal and carpometacarpal joint are removed by using high speed burr. This is applied to produce better and faster fusion of the middle carpal and carpometacarpal joints. After that, a 75 mm T- plate with eight holes and 3.5 mm screws (Fig. 123) was used and fixed over both joints.

Subcutaneous tissues are sutured with monocryl 3-0 and skin is closed with ethilon 3-0, then the limb is rapped in supportive bandage that is changed the day after surgery. Radiographic images in two views (dorsopalmar and mediolateral views) of the operated carpal joint are obtained directly after the arthrodesis to be sure about the correct alignment and positioning of the plate on the operated carpus (Figg. 124, 125).

At the first day postoperatively, of the twenty one operated patients there are two dogs and one cat show mild degree of oedema. This oedema is resolved at the second and third day by application of supportive bandage on the involved carpal joints. Two dogs show 2nd degree of lameness, one of them shows the lameness for four months post pancarpal arthrodesis as treatment of fracture of the third carpal bone and carpal joint hyperextension. Five months later the implant is removed and the dog becomes better as the owner said. The other dog shows the lameness for 14 weeks post pancarpal arthrodesis as treatment of intercarpal and carpometacarpal joint hyperextension. After that the dog becomes better. One dog has 4th degree of lameness for three months due to infection post pancarpal arthrodesis used as treatment of antebrachiocarpal joint hyperextension.

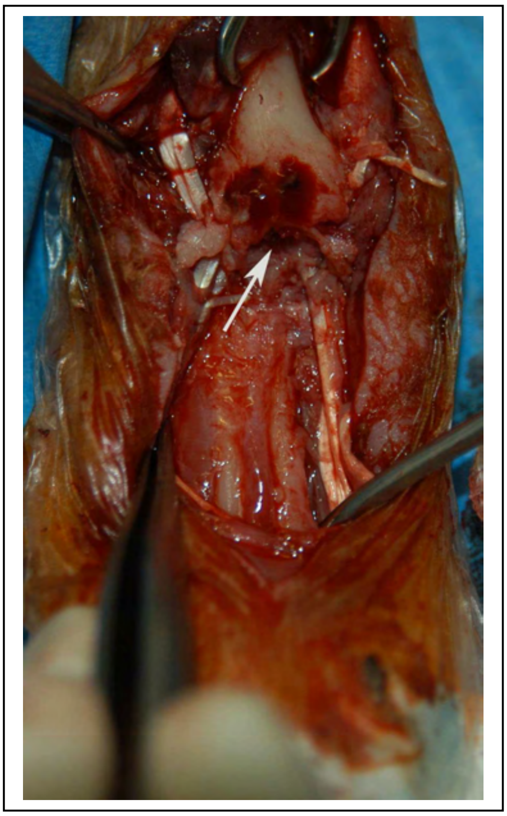

Fig. 106: Dorsal surgical view of the right carpal joint in a cat demonstrates palmar luxation of the antebrachiocarpal joint (arrow).

Fig. 107: Flexed surgical view of the right carpal joint in a dog demonstrates a fracture of intermedioradial carpal bone (arrow).

Table 10: Dogs and cats (N=21) used for Pancarpal Arthrodesis:

Animal species	Breed	Age	Sex	Weight (Kg BW)	Affection
1- cat	European Short Hair	2 years & 6 months	Male	5.6	Subluxation of antebrachiocarpal joint
2- dog	Mongrel	7 years	Male	38.0	Subluxation of antebrachiocarpal joint
3- dog	Mongrel	4 years	Male	21.5	Medial subluxation of antebrachiocarpal joint
4- dog	Bernese Mountain Dog	1 year	Male	38.0	Medial carpometacarpal subluxation (partial arthrodesis)
5- dog	Malenois	5 years	Female	28.0	Medial subluxation of antebrachiocarpal joint
6- dog	German Shepherd Dog	11 years	Female	32.0	Carpometacarpal subluxation
7- dog	Mongrel	8 years & 6 months	Male	31.5	Subluxation of intercarpal & carpometacarpal joints
8- dog	Mongrel	3 years	Female	40.0	Hyperextension of intercarpal joint and fracture of the 3rd carpal bone
9- dog	Great Dane Dog	10 months	Female	40.0	Carpal joint hyperextension
10- dog	Boxer	2 years and 6 months	Male	30.0	Intermedioradial carpal bone fracture, mild osteoarthritis and intercarpal joint hyperextension
11- dog	Labrador Retriever	6 months	Female	21.0	Subluxation of antebrachiocarpal joint
12- cat	European Short Hair	11 years	Female	4.0	Luxation of antebrachiocarpal joint

Table 10: (continued)

Animal species	Breed	Age	Sex	Weight (Kg BW)	Affection
13- dog	Longhaired Collie	8 years	Female	23.0	Osteoarthritis
14- dog	Mongrel	4 years and 4 months	Female	23.0	Antebrachiocarpal hyperextension
15- cat	European Short Hair	2 years and 8 months	Male	5.5	Antebrachiocarpal joint luxation
16- dog	Border Collie	1 year and 3 months	Female	22.0	Carpometacarpal hyperextension
17- dog	Papillon	4 years and 1 month	Female	3.5	Antebrachiocarpal joint luxation
18- dog	German Shepherd Dog	1 year and 6 months	Male	34.0	Intercarpal and carpometacarpal hyperextension
19- dog	(Malinois) Belgian shepherd Dog	9 years and 1 month	Female	25.0	Carpometacarpal hyperextension
20- dog	Longhaired Collie	4 years and 4 months	Male	27.0	Intercarpal joint hyperextension
21- cat	European Short Hair	3 years	Female	7.0	Antebrachiocarpal joint subluxation

Table 11: Types and sizes of plates used for Carpal Arthrodesis in 17 dogs and 4 cats:

Animal	Affection	Type of used plate	Screws number	Size of plate & screws
1- cat	Subluxation of antebrachiocarpal joint	Pancarpal Arthrodesis Plate (PCA- Plate)	9 screws	60 mm plate with 2.0 mm and 2.7 mm screws
2- dog	Subluxation of antebrachiocarpal joint	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
3- dog	Medial subluxation of antebrachiocarpal joint	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
4- dog	Medial carpometacarpal subluxation (partial Arthrodesis)	(T- Plate)	8 screws	75 mm plate with 3.5 mm screws
5- dog	Medial subluxation of antebrachiocarpal joint	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
6- dog	Carpometacarpal subluxation	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
7- dog	Subluxation of intercarpal & carpometacarpal joints	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
8- dog	Hyperextension of intercarpal joint and 3rd carpal bone fracture	(PCA- Plate)	11 screws	130 mm plate with 2.7 mm and 3.5 mm screws
9- dog	Carpal joint hyperextension	(PCA- Plate)	11 screws	140 mm plate with 2.7 mm and 3.5 mm screws
10- dog	Intermedioradial carpal bone fracture, mild osteoarthritis and intercarpal joint hyperextension	(PCA- Plate)	11 screws	130 mm plate with 2.7 mm and 3.5 mm screws
11- dog	Subluxation of antebrachiocarpal joint	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
12- cat	Antebrachiocarpal joint luxation	(PCA- Plate)	9 screws	60 mm plate with 2.0 mm and 2.7 mm screws
13- dog	Osteoarthritis	(DCP) Dynamic Compression Plate Buttress Plate	11 screws 8 screws	134 mm plate with 3.5 mm screws 65 mm with 2.0 mm screws
14- dog	Antebrachiocarpal joint hyperextension	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws

Table 11 (continued):

Animal	Affection	Type of used plate	Screws number	Size of plate & screws
15- cat	Antebrachiocarpal joint luxation	(PCA- Plate)	9 screws	60 mm plate with 2.0 mm and 2.7 mm screws
16- dog	Carpometacarpal hyperextension	(PCA- Plate)	11 screws	110 mm plate with 2.7 mm and 3.5 mm screws
17- dog	Antebrachiocarpal joint luxation	Dynamic Compression Plate (DCP)	9 screws	78 mm with 1.5 mm and 2.0 mm screws.
18- dog	Intercarpal and carpometacarpal hyperextension	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
19- dog	Carpometacarpal hyperextension	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
20- dog	Intercarpal joint hyperextension	(PCA- Plate)	11 screws	120 mm plate with 2.7 mm and 3.5 mm screws
21- cat	Antebrachiocarpal joint subluxation	(PCA- Plate)	9 screws	60 mm plate with 2.0 mm and 2.7 mm screws

Table 12: Position of the screws in Carpal Arthrodesis in 17 dogs and 4 cats:

Animal species	Position of the screws
1- cat	Four 2.7 mm screws are positioned in the distal radius, one 2.0 mm screw in the intermedioradial carpal bone and two 1.5 mm, 2.0 mm screws in the third metacarpal bone and two 1.5mm ,2.0 mm screws in the fourth metacarpal bone
2- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
3- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
4- dog	Two 3.5 mm screws are positioned in the intermedioradial carpal bone, one 2.7 mm screw in the third carpal bone and four 3.5 mm screws and one 2.7 mm screw in the third metacarpal bone
5- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
6- dog	Four 3.5 mm screws are positioned in the distal radius, one 2.7 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
7- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
8- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
9- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
10- dog	Four 3.5 mm screws are positioned in the distal radius, one 2.7 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
11- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
12- cat	Four 2.7 mm screws are positioned in the distal radius, one 2.0 mm screw in the intermedioradial carpal bone and two 2.0 mm screws in the third metacarpal bone and two 2.0 mm screws in the fourth metacarpal bone

Table 12: (continued)

Animal species	Position of the screws
13- dog	Five 3.5 mm screw and four 2.0 mm screws in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, five 3.5 mm screws in the third metacarpal bone and four 2.0 mm screws in the fourth metacarpal bone
14- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
15- cat	Four 2.7 mm screws are positioned in the distal radius, one 2.0 mm screw in the intermedioradial carpal bone and two 2.0 mm screws in the third metacarpal bone and two 2.0 mm screws in the fourth metacarpal bone
16- dog	Four 3.5 mm screws are positioned in the distal radius, one 2.7 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
17- dog	Four 2.0 mm screws are positioned in the distal radius, one 2.0 mm screw in the intermedioradial carpal bone, four 1.5 mm screws in the third metacarpal bone
18- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
19- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
20- dog	Four 3.5 mm screws are positioned in the distal radius, one 3.5 mm screw in the intermedioradial carpal bone, three 2.7 mm screws in the third metacarpal bone and three 2.7 mm screws in the fourth metacarpal bone
21- cat	Four 2.7 mm screws are positioned in the distal radius, one 2.7 mm screw in the intermedioradial carpal bone and two 2.0 mm screws in the third metacarpal bone and two 2.0 mm screws in the fourth metacarpal bone

Fig. 108: Lateromedial view demonstrates clipping and shaving the skin of the affected right limb from the elbow joint distally to the paw for carpal arthrodesis in a dog.

Fig. 109: Dorsopalmar view demonstrates clipping and shaving the skin of the affected right limb from the elbow joint distally to the paw for carpal arthrodesis in a cat.

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Fig. 110: Dorsal surgical approach of the left carpal joint for pancarpal arthrodesis in a dog, 10 cm skin incision, dissection of the subcutaneous tissue. Retraction of the tendon of extensor carpi radialis muscle, severing of the carpal ligaments is applied to expose the carpal joint.

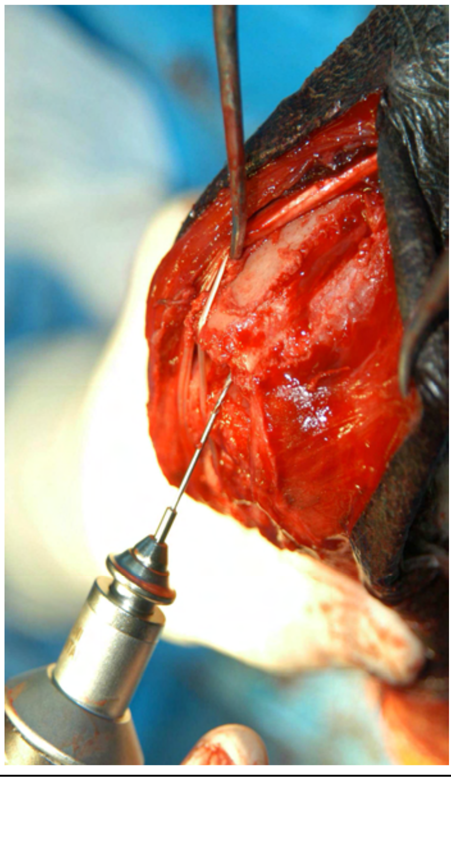

Fig. 111: Surgical drilling of the end plate of the radius with a high speed burr during pancarpal arthrodesis to enhance more blood supply and this help proper and faster fusion of the joint.

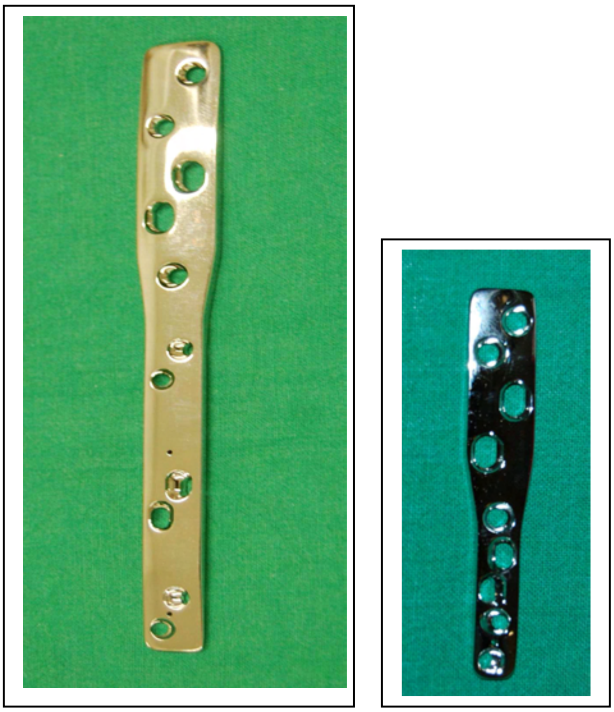

Fig. 112: Castless Pancarpal Arthrodesis Plate[*] 140 mm[°] in length and eleven screws with sizes of 2.7 mm / 3.5 mm is used in dogs (the left one). The right one is 60 mm in length and nine screws with sizes of 2.0 mm / 2.7 mm used in cats.

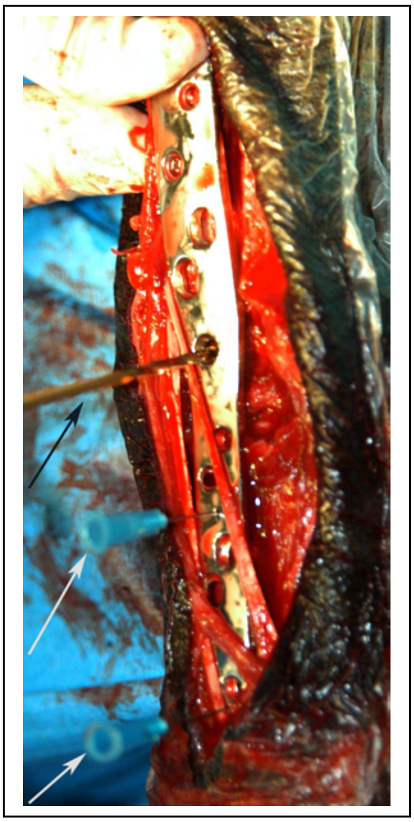

Fig. 113: Dorsal surgical view demonstrates two pins 0.6 mm or needles (white arrows) placed into the soft tissue between the third and fourth metacarpal bone for correct placement of 130 mm (PCA). 2.5 mm drilling of the intermedioradial carpal bone is applied (black arrow).

*Made in United Kingdom by Orthomed
° mm = millimeter

Table 13: Screws, drill bits and tap sizes in millimeter (mm) used for Carpal Arthrodesis in dogs and cats:

Screw Size	Drill Bit Diameter	Tap for
1.5	1.1	1.5
2.0	1.5	2.0
2.7	2.0	2.7
3.5	2.7	3.5

Fig. 114: For an arthrodesis of the carpal joint in dogs and cats different drill bits◊ are used.

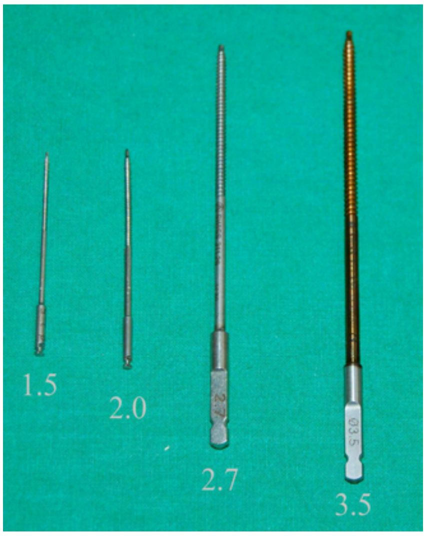

Fig. 115: For an arthrodesis of the carpal joint in dogs and cats different size of bone taps▫ are used.

◊ Made in Switzerland by Synthes
▫ Made in Switzerland by Synthes

Fig. 116: Dorsal surgical view demonstrates skin sutures in a dog with ethilon 3-0 post pancarpal arthrodesis.

Fig. 117: Dorsal surgical view demonstrates skin sutures in a cat with ethilon 3-0 post pancarpal arthrodesis.

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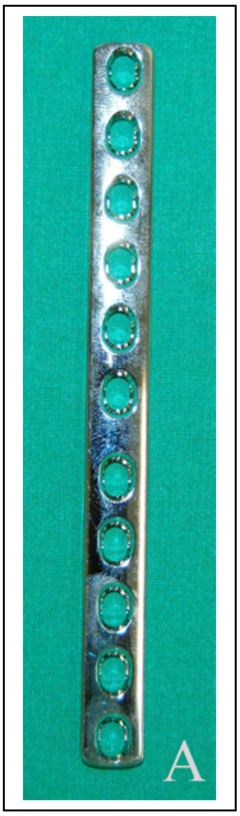
Fig. 118: Postoperatively mediolateral view of pancarpal arthrodesis in the right carpal joint of a dog. It was used as a treatment of the fractured intermedioradial carpal bone, which was accompanied by osteoarthritis. Castless Pancarpal Arthrodesis Plate (PCA- plate) 130 mm in length and eleven screws with sizes of 2.7 mm / 3.5 mm was used.

Fig. 119: Postoperative mediolateral view of pancarpal arthrodesis in the right carpal joint of a cat. It used as a treatment of subluxation of the antebrachiocarpal joint. Castless Pancarpal Arthrodesis Plate (PCA- plate) 60 mm in length and nine screws with sizes of 1.5 mm, 2.0 mm and 2.7 mm was used.



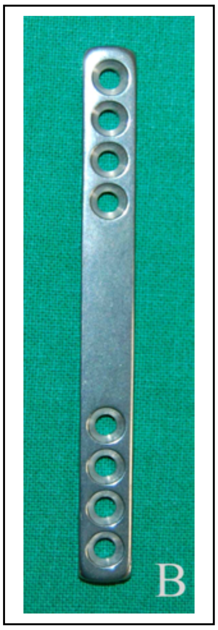


Fig. 120: Dynamic compression plate (DCP), 3.5 mm plate (A)* has eleven holes 134 mm and the other 2.0 mm Buttress plate (B)° has eight holes 65 mm. They were used for pancarpal arthrodesis as a treatment of the fractured ulnar carpal bone accompanied by osteoarthritis in a dog.

Fig. 121: Postoperatively mediolateral view of the left carpal joint in a dog that demonstrates a pancarpal arthrodesis as a treatment of fractured ulnar carpal bone accompanied by osteoarthritis. Two plates were used, one is 3.5 mm dynamic compression plate (DCP) has eleven holes 134 mm and the other 2.0 mm Buttress plate has eight holes 65 mm.

* Made in Switzerland by Synthes

° Made in United Kingdom by Veterinary Instrumentation

Fig. 122: Postoperatively dorsopalmar view of the left carpal joint in a dog that demonstrates pancarpal arthrodesis as a treatment of luxation of the left antebrachiocarpal joint. 78 mm dynamic compression plate (DCP) ten holes with 1.5 and 2.0 mm screws was used.

Fig. 123: 75 mm T- Plate* with 3.5 mm screws used for partial carpal arthrodesis as a treatment of medial subluxation of the carpometacarpal joint in a dog.

* Made in Switzerland by Synthes

Fig. 124: Postoperative dorsopalmar view of the left carpal joint in a dog that demonstrates partial carpal arthrodesis as a treatment of medial subluxation of the carpometacarpal joint. 75 mm T- Plate with 3.5 mm screws was used.

Fig. 125: Postoperatively mediolateral view of the left carpal joint in a dog that demonstrates a partial carpal arthrodesis as a treatment of medial subluxation of the carpometacarpal joint. 75 mm T- Plate with 3.5 mm screws was used.

6. Radiography after surgery of the different carpal affections in dogs and cats:

In the present study the radiographic follow up of the operated carpal joints in 17 dogs and 4 cats is applied postoperatively to demonstrate the progression of the healing process after luxation, subluxation, joint hyperextension, osteoarthritis and fracture of the carpal bones.

Radiographs are taken in dorsopalmar and mediolateral views to the carpal joint directly following surgery to be sure about the proper positioning of the plate and screws, also X- ray pictures are taken four, eight, twelve, sixteen and twenty weeks later. From the obtained pictures of twenty one operated carpal joints, 5 months postoperatively one cat (case No.1 at Table 10) has mild atrophy of the distal part of the radius (Fig. 126). This mild atrophy is due to pressure produced by the plate on the bone and high stability of the plate, therefore for destabilization of the plate, four screws are removed (two 2.7 mm screws from the distal radius and the other two 2.0 mm screws from the metacarpus) (Fig. 127).

In two dogs an osteophyte formation is formed on the distal radius at the proximal end of the castless pancarpal arthrodesis plate. In one dog it appears after two and half months after pancarpal arthrodesis (dog No. 8 at Table 10) following carpal joint hyperextension and fracture of the third carpal bone (Fig. 128). After five months the osteophyte formation becomes more prominent, the seventh screw from proximal is broken and the last distal screw is loose (Fig. 129) so the plate is removed (Fig. 130). In the other dog osteophyte formation appear three and half months after pancarpal arthrodesis following carpal joint hyperextension (case No. 9 at Table 10), the sixth screw from proximal is loose too (Fig. 131).

Osteophyte formation appears in one dog after four months after partial carpal arthrodesis using T- plate (case No.4 at Table 10) following medial subluxation of the carpometacarpal joint (Fig. 132).

The other seventeen operated carpal joints (fourteen dogs and three cats) show no problems radiographically until six months after pancarpal arthrodesis. The implants are situated in correct position; the joint spaces are not visible in addition to normal alignment of the operated carpal joints.

Four weeks post pancarpal arthrodesis in the operated carpal joints, the implant appears to be in correct position. The antebrachiocarpal, intercarpal, and carpometacarpal joint spaces are narrowed but still visible on the mediolateral projection (Fig.133) After eight weeks postoperatively these joint spaces are narrower in comparison with the pictures of four weeks after surgery, and they are still detectable (Fig.134).

After three months post pancarpal arthrodesis fusion of the joint spaces of the antebrachiocarpal, intercarpal and carpometacarpal joints are clearly identifiable (Fig. 135). After four months the fusion of these joints spaces become more clear than before (Fig. 136).

Five months postoperative advanced ankylosis of the carpal joints is visible, joint spaces are less clearly distinguished (Fig. 137) in comparison to the previous X- ray pictures.

Fig. 126: Radiographic dorsopalmar view 5 months postoperative of the right carpal joint in a cat that demonstrates mild atrophy of the radius (arrow) after pancarpal arthrodesis as a treatment of subluxation of the antebrachiocarpal joint (case No.1, Table 10). 60 mm castless pancarpal arthrodesis plate (PCA- plate) with nine screws of 1.5 mm, 2.0 mm and 2.7 mm was used.

Fig. 127: Radiographic dorsopalmar view 5 months postoperative of the right carpal joint in a cat (case No.1, Table 10) that demonstrates removal of two 2.7 mm screws from the distal radius and two 2.0 mm screws of the metacarpus to treat mild atrophy of the radius (arrow) developed after pancarpal arthrodesis as a treatment of subluxation of the antebrachiocarpal joint. 60 mm castless pancarpal arthrodesis plate (PCA- plate) with nine screws 1.5 mm, 2.0 mm and 2.7 mm diameters was used.

Fig. 128: Radiographic dorsopalmar view two and half months postoperative of the left carpal joint in a dog (case No. 8 at Table 10). It demonstrates osteophyte formation of the distal radius at the proximal end of the plate (arrow) developed after pancarpal arthrodesis as a treatment of a fracture of the third carpal bone and carpal joint hyperextension. 130 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws of 2.7 mm and 3.5 mm was used.

Fig. 129: Radiographic mediolateral view five months postoperative of the left carpal joint in a dog (case No. 8 at Table 10). It demonstrates osteophyte formation of the distal radius at the proximal end of the plate (white arrow) developed after pancarpal arthrodesis as a treatment of a fracture of the third carpal bone and carpal joint hyperextension. 130 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws of 2.7 mm and 3.5 mm was used. The seventh screw from proximal was broken and the last distal screw was loosed (black arrows).

Fig. 130: Radiographic mediolateral view five months postoperative of the left carpal joint in a dog (case No. 8 at Table 10). It demonstrates plate removal after pancarpal arthrodesis as a treatment of a fracture of the third carpal bone and carpal joint hyperextension. 130 mm castless pancarpal arthrodesis plate (PCA- plate), eleven screws with sizes of 2.7 mm and 3.5 mm was used. The seventh screw from proximal was broken (arrow).

Fig. 131: Radiographic mediolateral view three months and half postoperative of the left carpal joint in a dog (case No. 9 at Table 10). It demonstrates osteophyte formation of the distal radius at the proximal end of the plate (white proximal arrow) developed after pancarpal arthrodesis as a treatment of carpal joint hyperextension. 140 mm castless pancarpal arthrodesis plate (PCA- plate) and eleven screws with sizes of 2.7 mm and 3.5 mm was used. The sixth screw from proximal was loosed (white distal arrows).

Fig. 132: Radiographic mediolateral view four months postoperative of the left carpal joint in a dog (case No. 4 at Table 10). It demonstrates osteophyte formation at the distal radius after partial carpal arthrodesis as a treatment of a medial subluxation of the carpometacarpal joint. 75 mm T- Plate with 3.5 mm screws was used.

Fig. 133: Radiographic mediolateral view four weeks postoperative of the right carpal joint in a dog (case No. 18 at Table 10). It demonstrates narrowing of the antebrachiocarpal, intercarpal, and carpometacarpal joint spaces (arrows) developed after pancarpal arthrodesis as a treatment of carpal joint hyperextension. 120 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws with sizes of 2.7 mm and 3.5 mm was used.

Fig. 134: Radiographic mediolateral view eight weeks postoperative of the right carpal joint in a dog (case No. 10 at Table 10). It demonstrates narrowing of the antebrachiocarpal, intercarpal, and carpometacarpal joint spaces (arrows) developed after pancarpal arthrodesis as a treatment of a fracture of the intermedioradial carpal bone. 130 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws with sizes of 2.7 mm and 3.5 mm was used.

Fig. 135: Radiographic mediolateral view twelve weeks postoperative of the right carpal joint in a dog (case No. 2 at Table 10). It demonstrates a fusion of the antebrachiocarpal, intercarpal and carpometacarpal joint spaces (arrows) developed after pancarpal arthrodesis as a treatment of antebrachiocarpal joint subluxation. 120 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws of 2.7 mm and 3.5 mm was used.

Fig. 136: Radiographic mediolateral view four months postoperative of the right carpal joint in a dog (case No. 10 at Table 10). It demonstrates a fusion of the antebrachiocarpal, intercarpal, and carpometacarpal joint spaces (arrows) developed after pancarpal arthrodesis as treatment of a fracture of the intermedioradial carpal bone. 130 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws with sizes of 2.7 mm and 3.5 mm was used.

Fig. 137: Radiographic dorsopalmar view five months postoperative of the right carpal joint in a dog (case No. 10 at Table 10). It demonstrates ankylosis of the antebrachiocarpal, intercarpal, and carpometacarpal joint spaces (arrows) developed after pancarpal arthrodesis for treatment of a fracture of the intermedioradial carpal bone. 130 mm castless pancarpal arthrodesis plate (PCA- plate) with eleven screws with sizes of 2.7 mm and 3.5 mm was used.

Discussion

1.1. Anatomy of carpal joints in dogs and cats:

According to the finding of the present study, the carpal joint in dogs and cats comprises the antebrachiocarpal, middle carpal, intercarpal, and carpometacarpal articulations. The bones enter in the formation of these various articulations including distal extremities of the radius and ulna (forearm), the carpal bones and the proximal extremities of the metacarpal bones (**Bradley, 1959; Dyce et al., 1987; Farrow et al., 1994).**

The present examination shows that the distal extremity of the radius is wide and quadrangle in shape. It has a concave articular surface for the intermedioradial and ulnar carpal bones. The medial border projects downward to form the styloid process of the radius. The distal end of the ulna is small and reduced to a blunt point forming styloid process of the ulna. It articulates distally with ulnar carpal bone and has convex surface for the articulation with the radius. A similar result is obtained in the literature **(Sisson and Grossman, 1963; Getty, 1975; Dyce et al., 1987).**

With regard to the intermedioradial carpal bone, the results of this study show that the intermedioradial carpal bone is the largest one of the carpal bones in dogs and cats (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). It is the combination of the radial and the intermediate carpal bone and is situated medially and proximally and has a craniocaudal convex-concave articular surface. The bone articulates with the distal articular surface of the radius. Laterally it has a semicircular convex articular facet for articulation with the ulnar carpal bone. Distally, there are three concave articular facets for articulation with the distal row of the carpal bones. Medially it projects palmarly and there is a small round rough fossa. These results agree with the literature (**Sisson and Grossman, 1963; Getty, 1975; Dyce et al., 1987; Mikic et al., 1992; Evans, 1993; Fossum, 2002)**

With regard to our finding, the size of the intermedioradial carpal bone in dogs is larger than that in cats, so the size of the central screw of the used (PCA- plate) for pancarpal arthrodesis is larger in dogs than in cats. It is 2.7 or 3.5 mm for small and medium sized dogs and in cats it is 2.0 or 2.7 mm screws.

The ulnar carpal bone is a triangular bone which is situated on the lateral aspect of the carpal joint. It articulates proximally with the distal radius and ulna. Medially it articulates with the intermedioradial carpal bone. On the palmar aspect there is a small oval facet and a distal large round one for articulation with the accessory carpal bone. Distally the ulnar carpal bone articulates with the fourth carpal bone and the fifth metacarpal bone **(Sisson and Grossman 1963; Getty 1975; Mikic et al., 1992 and Evans 1993).**

The accessory carpal bone is rod in shape constricted in its middle and enlarged at its both ends. The dorsal border has a saddle shaped articular surface distally for the articulation with the ulnar carpal bone and another concave articular facet proximally for the articulation with the styloid process of the ulna **(Mikic et al., 1992 and Evans, 1993).**

The first carpal bone is the smallest one of the carpal bones in dogs and cats (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4). It is situated on the medial aspect of the carpal joint as stated by **Sisson and Grossman, 1963; Getty, (1975) and Evans, (1993).** The present study shows that the third carpal bone is larger than the second carpal bone in dogs and cats (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4) (**Evans, 1993).**

The fourth carpal bone is the largest one of the distal row of the carpal bones in dogs and cats (Table 6, 7, 8, 9 and Chart 1, 2, 3, 4), it has a wedge shape and articulated proximomedially with the intermedioradial carpal bone and with ulnar carpal bone proximolaterally. Medially it articulates with the third carpal bone **(Getty, 1975 and Evans, 1993).**

With regard to the carpal ligaments in dogs and cats, the present study shows that the dorsal aspect of the carpal joint is supported by dorsal radiocarpal, dorsal radioulnar, dorsal intercarpal, and dorsal carpometacarpal ligaments. The palmar aspect of the carpal joint is supported by palmar radiocarpal, palmar ulnocarpal, palmar intercarpal, and palmar carpometacarpal ligaments. In addition, there are the palmar accessory metacarpal, palmar medial accessory metacarpal, and palmar accessorioulnar ligaments, which support the accessory carpal bone in its position as reported by **Evans, (1993); Farrow et al., (1994); Mckee, (1994); Fossum, (2002); Johnson and Hulse, (2002).** Rupture of these ligaments leads to carpal joint instabilities like luxation and subluxation.

Our study indicates that disruption of these ligaments (palmar accessory metacarpal, palmar medial accessory metacarpal and palmar accessorioulnar ligaments) which attaching the accessory carpal bone to the intermedioradial carpal bone and metacarpal bones results in proximal displacement of the accessory carpal bone (**Piermattei et al, 1997).** There are two short collateral ligaments in the carpal joint in dogs and cats. The short radial (medial) collateral ligament supports the medial aspect (**Dyce et al., 1987; Mikic et al., 1992 and Evans, 1993)**. The short ulnar (lateral) collateral ligament supports the lateral aspect of the joint (**Dyce et al., 1987).**

The palmar carpal ligaments (palmar radiocarpal, palmar ulnocarpal, palmar intercarpal, and palmar carpometacarpal ligaments and in addition to the palmar accessory metacarpal, palmar medial accessory metacarpal and palmar accessorioulnar ligaments resist the hyperextension of the carpal joint in dogs and cats **(Piermattei et al, 1997).**

1.2. <u>Normal radiography of carpal joint in dogs and cats:</u>

All carpal bones in dogs and cats appear radiographically as irregular quadriangular or rectangular structures with four borders in dorsopalmar projection namely proximal, distal, medial and lateral except the accessory carpal bone that appears as a vertical rod structure.

Intermedioradial and ulnar carpal bones have superimposition with the distal extremity of the radius and ulna between each others and also with the proximal border of the first, second, third and fourth carpal bone. Also the distal row of the carpal bones has superimposition with the distal part of the bones of the proximal row with each others and with the proximal extremity of the metacarpal bones.

In mediolateral radiographs all bones of the proximal row are superimposed over each other except the accessory carpal bone which can be seen as a separate structure protrudes palmarly. In the flexed mediolateral view of the carpal joint some proximal and distal borders of the bones can be seen separately but they still have some degree of superimposition with neighbouring bones.

The available literatures in veterinary radiology lack any data about the degree of superimposition of different carpal bones over each others. They only demonstrate copy prints of the radiographs in different projections with sketch diagrams explaining different boundaries of each carpal bone. Nevertheless knowledge about areas of superimposition between carpal bones is of great importance in differential diagnosis between normal bone densities due to superimposition and abnormal bone densities due to diseased conditions. Also knowledge about the shape of different bone borders gives additional informations about presence of any abnormal bony formations in comparison to the normal presence of processes or eminences.

At the same time, superimposition of bone borders over each other can be considered in some cases as lines of fractures. This is a very important factor for radiographers to know. They must be trained to interpretate X- ray pictures of carpal joints to differentiate between lines of fracture and normal border lines of carpal bones.

Different radiographic projections are used to demonstrate different surgical affections of the carpal joints in dogs and cats. Dorsopalmar, mediolateral and mediolateral flexed views are usually indicated for demonstration of such affections. Additional oblique projections may be indicated in some special cases to demonstrate specific disorders affecting the carpal bones **(Butler et al., 2000).**

1.3. <u>Radiography of carpal joints affections in dogs and cats:</u>

According to the finding of the present study, carpal joints in dogs and cats are affected with different pathologies as osteoarthritis (twenty two dogs and four cats), luxation (one dog and two cats), subluxation (eleven dogs and two cats), hyperextension (ten dogs), and fractures of the carpal bones (five dogs), this can be diagnosed by different radiographic projections. Standard dorsopalmar and mediolateral views are used to evaluate the whole carpal joint for pathological findings **(Whittick, 1990; Fossum, 2002; Johnson et**

al., 2005). The present study shows, that the carpal joint instabilities in dogs and cats (subluxation and carpal hyperextension) and small avulsion fracture fragments are easily to diagnose with dorsopalmar stress views, with mediolateral hyperextended and mediolateral flexed views. A similar result is obtained in the literature **(Ryan, 1981; Morgan and Silverman, 1987; Lisa, 1994; Morgan and Wolvekamp, 1994; Jerry and Darryl, 1999; Johnson and Hulse, 2002).**

According to our investigation, osteoarthritis is one of the common affections of the carpal joints. It affects about 43% of the examined dogs and cats (22 dogs and 4 cats). It represents osteophyte formations in one or several carpal bones. 21% of the affected joints in the present study have osteophyte formation in the intermedioradial carpal bone. Additional signs like soft tissue swelling of articular and periarticular structures and collapse of the joints spaces are present. A similar result is obtained by **Owens and Biery, (1999); Morgan, (1999); Fossum, (2007) and Thrall, (2007).** Metacarpophalangeal and metatarsophalangeal osteoarthritis in 49 dogs are studied by **Franklin et al. (2009).** They state that osteoarthritis is a common and debilitating condition in the canine patient. Radiographic signs of osteoarthritis (OA) of metacarpophalangeal and metatarsophalangeal can be similar to signs of OA seen elsewhere in the body.

Ankylosis of the carpal joints is an affection that follows osteoarthritis or inflammatory diseases of the carpal joints in dogs and cats. It represents fusion of the joints (antebrachiocarpal, middle carpal and carpometacarpal articulations) due to alterations and ablations of these joints spaces which appear clearly in mediolateral radiographs in three affected cats and one dog in the present study. Additional periosteal reactions and osteophyte formations are formed.

The present study indicates that the dorsal and palmar carpal ligaments as well as medial and lateral collateral ligaments are forming the ligamentous support of the carpal joints articulations in dogs and cats (**Evans, 1993; Farrow et al., 1994; Mckee, 1994; Fossum, 2002; Johnson and Hulse, 2002).** A damage of these ligaments results in carpal joint instabilities including (luxation, subluxation and carpal hyperextension). Our study shows that luxation of the carpal joint can be diagnosed easily in the standard dorsopalmar and mediolateral radiographs. Radiographically it appears in form of complete palmar displacement of the antebrachiocarpal joint in one cat and complete dorsal displacement of the antebrachiocarpal joint in one cat and one dog. Additional radiographic findings like sever degree of articular and periarticular soft tissues swelling can be present. A similar result is obtained by **Pitcher, (1996) and Chris and Langley-Hobbs, (2006)** which show in two cats dorsal antebrachiocarpal joint luxation.

Subluxation affects the antebrachiocarpal joint in seven cases 11% (five dogs 8% and two cats 3%) and carpometacarpal joint in five dogs (8%) of the examined patients. It can be diagnosed radiographically by dorsopalmar view with medial and lateral stress of the affected carpus and this result agree with studies from **Ryan, (1981); Morgan and Silverman, (1987); Lisa, (1994); Morgan and Wolvekamp, (1994); Jerry and Darryl, (1999); Johnson and Hulse, (2002).** It appears in form of partial displacement of the involved joints (antebrachiocarpal and carpometacarpal joints) to the medial or lateral aspect accompanied by swelling of the soft tissues surrounding the carpal joint as reported by **Owens and Biery, (1999).**

Hyperextension of the carpal joint affects ten dogs (16%) of the examined carpal joints in the present study. It represents increased joint space of the intercarpal joint in addition to swelling of the soft tissues surrounding the affected carpal joint as reported by **Johnson and Hulse, (2002) and Johnson et al., (2005).** Our study suggests that the mediolateral hyperextended view and mediolateral-flexed view can be used to diagnose this abnormal laxity of the carpal joint. Nearly the same results are obtained in the literature **(Ryan, 1981; Ticer, 1984; Douglas et al., 1987; Morgan and Silverman, 1987 and Lisa, 1994).**

Fractures of the carpal bones in the present study are commonly associated with hyperextension injuries of the carpal joint. Four cases of five affected carpal joints are associated with the same hyperextension injuries. Our results agree with studies from **Farrow, (1977); Brinker et al., (1983) and Newton, (1985).** A fracture of the intermedioradial carpal bone is seen in 5% of the examined cases in the present study. It appears as a vertical fracture line that runs through the bone. The medial fragment is mildly distally displaced in the dorsopalmar radiograph. In the mediolateral and mediolateral flexed views the fracture line is proximally irregular outlined. In that region the fracture gap is incompletely fused. A similar result is obtained by **Newton, (1985); Johnson et al., (2005).** Fracture of the radial carpal bone in 15 dogs is studied by **Bennett et al. (2000).** They find that one longitudinal fracture line is present accompanied by varying degrees of the fragment displacement in twelve cases. In the other three affected dogs, two longitudinal fracture lines are present. Our study indicates that by mediolateral hyperextended view and mediolateral flexed radiograph a fracture of the distal row of the carpal bones can be easily diagnosed. It appears like a separated bone fragment from the dorsal surface of the fractured carpal bones associated with swelling of the soft tissues surrounding the affected carpal joint **(Johnson et al., 2005).** One dog in the present work shows fracture of the third carpal bone accompanied by hyperextension injury of the carpal joint.

1.4. Surgical procedures for treatment of different carpal joints affections in dogs and cats:

According to the finding of the present study, pancarpal arthrodesis is applied for treatment of different carpal joint affections in sixteen dogs (26%) and four cats (7%) (e.g. luxation, subluxation, carpal joint hyperextension, osteoarthritis, and fracture of the carpal bones when complicated with other affections like osteoarthritis or joint hyperextension). This is similar to the veterinary literature (**Dyce, 1996; Brinker et al, 1998; Harasen, 2002; Voss et al. 2003; Oszoy and Altunatmaz, 2004; Johnson et al. 2005; Worth and Bruce, 2008).** The present study indicates that in these twenty surgeries of the carpal joint (sixteen dogs and four cats) the antebrachiocarpal, middle carpal, and carpometacarpal joints are involved in the pancarpal arthrodesis **(Willer et al, 1990; Oszoy and Altunatmaz, 2004; Théoret and Moens, 2007).** The present study shows that complete surgical approach of the carpal joint required severing of the short carpal ligaments (dorsal radiocarpal ligament, dorsal radioulnar, dorsal intercarpal, and dorsal carpometacarpal ligaments) at the level of the antebrachiocarpal, middle carpal, and carpometacarpal joints. A similar result is obtained by **Oszoy and Altunatmaz, (2004)** in operated 6 dogs. In the present study, eighteen affected cases (fourteen dogs and four cats) are treated with pancarpal arthrodesis using castless pancarpal arthrodesis plate (PCA-plate) with different sizes ranging from 60 mm for cats and 110 – 140 mm according the sizes of the operated dogs. Fifteen cases (twelve dogs and three cats) heal normally without any problem (**Worth and Bruce, 2008; Clarke et al., 2009).**

Different carpal joint affections are treated with pancarpal arthrodesis plate by means of a castless pancarpal arthrodesis plate (PCA- plate). Our investigation would suggest that this plate must cover at least 80% of the length of the third and fourth metacarpal bones. This percentage of plate coverage decreases the possibility of plate breakdown and gives more support and stabilization of the operated carpal joints. It prevents metacarpal bone fractures. This result agrees with the study from **Whitelock et al. (1999).** Clinical evaluation of pancarpal arthrodesis using a castless plate in 11 dogs is studied by **Clarke et al. (2009)**. They state that the mean of metacarpal length which was covered by the implant was 83.8% (range, 75.8-92.5%). More of the third metacarpal bone is covered by the plate. The combination of greater plate coverage and smaller screws reduces the frequency of iatrogenic metacarpal fracture **(Li et al., 1999).**

Our study shows that thorough debridement and complete removal of intraarticular cartilage is an important step to have success by using a pancarpal arthrodesis. This leads to a proper healing, better and faster fusion of operated carpal joints resulting in fusion of the different carpal bones and joints. A similar result is obtained by **Slatter, (2003); Guilliard, (2006).** In the study of **Clarke et al. (2009)** a high speed burr is used to remove all the articular cartilage from the antebrachiocarpal, middle carpal, and carpometacarpal joints in eleven dogs. With regard to the fixation of castless pancarpal arthrodesis plate (PCA-plate) in the operated carpal joints of our fourteen dogs and four cats, the central hole of the plate is centered over the intermedioradial carpal bone **(Harasen, 2002; Clarke et al. 2009).** The central hole accepts either 2.7 or 3.5 mm screw for the attachment of the intermedioradial carpal bone. The small-sized plate 60 mm uses for cats accept either 2.0 or 2.7 mm screws **(Harasen, 2002).** Most of our operated dogs (ten dogs) had 3.5 mm in the central hole as reported by **Clarke et al. (2009).**

Partial carpal arthrodesis using T- shaped plate is performed only in one dog who suffered from a medial subluxation of the carpometacarpal joint associated with medial proximal dislocation of the second metacarpal bone. Only the middle carpal and carpometacarpal joints are involved in the arthrodesis of the affected carpal joint **(Fossum, 2002; Slatter, 2003; Oszoy and Altunatmaz, 2004; Théoret and Moens, 2007).** In summary, our present study gives good results using pancarpal arthrodesis in dogs and cats as a treatment of luxation, subluxation, carpal hyperextension, fractures of the carpal bones, and osteoarthritis (**Worth and Bruce, 2008).**

At the first day postoperatively, of the twenty one operated patients there are two dogs and one cat show mild degree of oedema in distal part of the forelimb. This oedema is resolved at the second and third day by application of supportive bandage on the involved carpal joints. Two dogs show 2nd degree of lameness, one of them shows the lameness for four months post pancarpal arthrodesis as treatment of fracture of the third carpal bone and carpal joint hyperextension. Five months later the implant is removed and the dog becomes better as the owner said. The other dog shows the lameness for 14 weeks post pancarpal arthrodesis as treatment of intercarpal and carpometacarpal joint hyperextension. After that the dog becomes better. One dog has 4th degree of lameness for three months due to infection post pancarpal arthrodesis used as treatment of antebrachiocarpal joint hyperextension. A similar result is obtained in the literature **(Worth and Bruce, 2008; Clarke et al. 2009).**

1.5. <u>Radiography of carpal joints in dogs and cats after treatment:</u>

In twenty one carpal joints (seventeen dogs and four cats) radiographic follow-up is applied postoperatively in the present study. It should demonstrate the progression of the healing process of the operated joints as a treatment of luxation, subluxation, joint hyperextension, osteoarthritis, and fractures of the carpal bones. According to the finding of the present study, the healing process starts four weeks after surgery and progresses for three months. This result agrees with the studies from **Michal et al., (2003) and Guerrero and Montavon, (2005).**

Our present examinations indicates that three months post carpal arthrodesis, the radiographic evidence of incorporation of the corticocancellous bone strips is observed in carpal joints of seventeen dogs and four cats **(Fossum, 2002; Guerrero and Montavon, 2005).** In addition to small joint spaces of the antebrachiocarpal, intercarpal, and carpometacarpal joints and an absence of the joint opacity between the proximal and distal carpal bones on the mediolateral projection are observed**.** A similar result is obtained by **Guilliard and Mayo (2001). Oszoy and Altunatmaz, (2004)** report that fusion post pancarpal arthrodesis in 6 dogs is established earlier radiographically (between days 45-75 postoperatively).

In two dogs an osteophyte formation has grown at the distal radius at the proximal end of the plate after pancarpal arthrodesis. In one dog it appears after two and half months post pancarpal arthrodesis for treatment of carpal joint hyperextension and fracture of the third carpal bone. In the other dog osteophyte formation appears three and half months after pancarpal arthrodesis for treatment of carpal joint hyperextension (**Smith and Spagnola, 1991).**

In one dog an osteophyte formation appears after four months post partial carpal arthrodesis using a T- plate for treatment of the medial subluxation of the carpometacarpal joint. The osteophyte formation appears due to an interference of this T- plate on the antebrachiocarpal joint and the distal end of the radius as reported by **Smith and Spagnola (1991); Harasen (2002) and Guilliard (2006).** Arthrodesis increases the stress on adjacent joints frequently, resulting in degenerative joint disease, which would be a probable occurrence in the radiocarpal joint when a partial arthrodesis is performed **(McKee, 1994).**

Our study suggests that it is better to remove the implant from the operated joints after complete ankylosis because of these osteophyte formations and screws loosening. It leads to decrease this periosteal reaction related to presence of the plate within the operated carpal joints (**Denny and Barr, 1991).**

Summary

The aim of the present study is to describe the anatomy and normal radiographic anatomy of the carpal joints in dogs and cats and to clarify the role of radiography as a diagnostic tool of carpal joint affections in dogs and cats in addition to detection of the surgical procedures which can be used as treatment of these joints affections in dogs and cats.

The anatomical part of the present study was carried out on carpal joints of 20 dogs and 6 cats. The specimens of these carpal joints were dissected and the carpal ligaments were identified and photographed. Then the specimens were macerated and the soft tissues were removed. The bones were collected and prepared for description and measuring of the dorsopalmar, mediolateral and proximodistal diameters (see Table 6, 7, 8, 9 and Chart 1, 2, 3, 4).

Radiographic examinations of the carpus in dogs and cats were made with the patient under anesthesia. Standard dorsopalmar, mediolateral, and mediolateral flexed view were used for description of normal radiographic anatomy of the carpal joints. Additional views were used for examination of affected carpal joints in 50 dogs and 11 cats such as oblique views (dorsomedial palmarolateral oblique view and dorsolateral palmaromedial oblique view), hyperextended mediolateral view, and dorsopalmar view with medial and lateral stress of the affected carpus.

Radiographically all carpal bones in dogs and cats appears as irregular quadriangular or rectangular structures with four borders in dorsopalmar projection namely proximal, distal, medial, and lateral except the accessory carpal bone appears as a vertical rod structure. The intermedioradial and ulnar carpal bones have superimposition with the distal extremity of the radius and

ulna, between each others and with the proximal border of the first, second, third and fourth carpal bones. Also the distal row of the carpal bones has superimposition with the distal part of bones of the proximal row, with each others and with the proximal extremity of the metacarpal bones.

Sixty one affected carpal joints of 50 dogs and 11 cats are examined in the present study. There are twenty six (43%) carpal joints affected with osteoarthritis (twenty two dogs and four cats). Four cases had ankylosis (one dog and three cats); thirteen cases (21%) suffering from subluxation (five dogs and two cats had antebrachiocarpal carpal joint subluxation), (five dogs had carpometacarpal joint subluxation and one dog had subluxation of intercarpal joint). Two cats (3%) and one dog (2%) had luxation of antebrachiocarpal joint and ten dogs (16%) had a carpal hyperextension syndrome. Five dogs (8%) had carpal bone fractures (three intermedioradial carpal bone fractures and one ulnar carpal bone fracture and one third carpal bone fracture).

Carpal joint instabilities (subluxation and carpal hyperextension) and small avulsion fractures of the carpal bones are easily diagnosed by dorsopalmar view with medial and lateral stress of the affected carpus, with mediolateral hyperextended and mediolateral flexed views. Osteoarthritis is the most common affections of the carpal joint in the present study; it affects about 43% of the examined patients. Radiographically the signs of osteoarthritis of carpal joints in dogs and cats are soft tissue swelling, osteophytes formations in the carpal bones and loss of joint spaces of the antebrachiocarpal, intercarpal and carpometacarpal joints. In the present study eleven dogs (18%) and two cats (3%) have osteoarthritis with osteophyte deposition in the intermedioradial carpal bone. Nine dogs (15%) and two cats (3%) have osteoarthritis with osteophyte formations in the accessory carpal bone. Two dogs (3%) have the same radiographic findings of the osteoarthritis with several osteophyte formations present on the distal radius, intermedioradial carpal, ulnar carpal, accessory carpal, first, second, third and fourth carpal bones.

Hyperextension of the carpal joint is deviation of the normal upright position of the carpus. It affects ten dogs (16%) of the examined carpal joints in the present study. It represents increase joint space of the intercarpal joint in addition to swelling of the soft tissues surrounding the carpal joint. Mediolateral hyperextended view and mediolateral flexed view can used to diagnose this abnormal laxity of the carpal joint.

Affected carpal joints of sixteen dogs and four cats were going under pancarpal arthrodesis with a special plate (using PCA-plate in fourteen dogs and four cats and by using DCP in two dogs) for treatment of luxation, subluxation, carpal hyperextension, fracture of carpal bones, and osteoarthritis. Partial carpal arthrodesis using T- plate was performed only in one dog suffering from a medial subluxation of the carpometacarpal joint accompanied by medial proximal dislocation of the second metacarpal bone.

Radiographic follow-up of the operated carpal joints in seventeen dogs and four cats is applied postoperatively in the present study to demonstrate the progression of the healing process of the operated joints. Radiographs were taken in dorsopalmar and mediolateral views to the carpal joint directly following the surgery to make sure that the alignment and positioning of the plate and screws on the bones are correct. Also X- ray images are taken four, eight, twelve, sixteen and twenty weeks later. From the obtained images of twenty one operated carpal joints. One cat showed mild atrophy of the distal part of the radius 5 months post operatively. This mild atrophy is due to pressure produced by the plate on the bone. An osteophyte formation is formed on the distal radius at the proximal point of the PCA- plate post pancarpal arthrodesis in two dogs. It appeared in one dog after two and half months post pancarpal arthrodesis as a treatment of carpal joint hyperextension and fracture of the third carpal bone. In the other dog osteophyte formation appeared three and half months after pancarpal arthrodesis for treatment of carpal joint hyperextension. In one dog an osteophyte formation appeared after four months post partial carpal arthrodesis using T- plate for treatment of a medial subluxation of the carpometacarpal joint. The osteophytes formations appeared due to interference of this plate on the antebrachiocarpal joint and the distal end of the radius.

Radiographically the other seventeen operated carpal joints (fourteen dogs and three cats) had no problems until six months after pancarpal arthrodesis for treatment of different carpal joint affections. The implants were situated in a correct position and the joint spaces of the operated carpal joints were not visible any more.

Zusammenfassung

Das Ziel der vorliegenden Studie ist die Darstellung der normalen Anatomie und Röntgenanatomie der Karpalgelenke bei Hunden und Katzen sowie die Rolle der Radiologie als Diagnostikum bei Karpalgelenk Erkrankungen.

Zusätzlich werden chirurgischen Verfahren beschrieben, die zur Therapie der verschiedenen Erkrankungen eingesetzt wurden.

Die anatomischen Untersuchungen der vorliegenden Studie wurden an Karpalgelenken von 20 Hunden und 6 Katzen durchgeführt. Die Karpalgelenke wurden präpariert und die Bänder identifiziert und fotografiert. Dann erfolgte die Mazeration der Proben und die Entfernung des Weichteilgewebes. Die knöchernen Bestandteile der Gelenke wurden für die Beschreibung und Vermessung der Durchmesser der einzelnen Karpalgelenksknochen in dorsopalmarer, mediolateraler und proximodistaler Ausrichtung gesammelt (siehe Tabelle 6, 7, 8, 9 und Säulengrafik 1, 2, 3, 4).

Die Röntgenaufnahmen des Karpus wurden unter Vollnarkose angefertigt. Standardaufnahmen in dorsopalmarem und mediolateralem Strahlengang ergänzt durch mediolateral gebeugte Aufnahmen dienten als Basis für die Beschreibung der normalen Röntgenanatomie des Karpalgelenkes.

Zur Untersuchung der Karpalgelenke von 50 Hunden und 11 Katzen mit orthopädisch veränderten Gelenken wurden zusätzliche Aufnahmen in schräger Projektion (dorsomedial palmarolateral oblique und dorsolateralen palmaromedial oblique), überstreckt mediolateral und dorsopalmar mit medialer und lateraler Belastung der betroffenen Handwurzel verwendet. Die Handwurzelknochen bei Hunden und Katzen erscheinen in dorsopalmarer

Projektion sowie proximalen, distalen, medialen und lateralen Aufnahmen als viereckige bis rechteckige Körper mit Ausnahme des Os accessorium, das eine längliche Form hat. Die intermedioradialen und ulnaren Handwurzelknochen überlagern sich mit dem distalen Ende des Radius und der Ulna, sowie auch untereinandere und mit dem proximalen Rand der ersten, zweiten, dritten und vierten Handwurzelknochen. Auch die distale Reihe der Handwurzelknochen überlagert sich mit dem distalen Teil der Knochen der proximalen Reihe, und auch untereinander sowie mit dem proximalen Ende des Metakarpalknochen.

61 Karpalgelenke von 50 Hunden und 11 Katzen mit orthopädischen Erkrankungen sind in der vorliegenden Studie untersucht worden. Es sind 26 (43%) Karpalgelenke mit Osteoarthritis diagnostiziert worden (zweiundzwanzig Hunde und vier Katzen). Vier Fälle hatten eine Ankylose (ein Hund und drei Katzen); bei dreizehn Fällen (21%) lag eine Subluxation vor (fünf Hunde und zwei Katzen hatten antebrachiokarpale Subluxationen), (fünf Hunde hatten karpometakarpale Subluxationen und ein Hund zeigte eine Subluxation des interkarpalen Gelenks). Zwei Katzen (3%) und ein Hund (2%) zeigten Luxationen des Antebrachiokarpalgelenks und zehn Hunde (16%) hatten ein Hyperextensions syndrome. Fünf Hunde (8%) wiesen Frakturen der Handwurzelknochen auf (drei Os intermedioradiale, ein Os carpi ulnarae und ein Os carpi tertium).

Instabilitäten des Vorderfusswurzelgelenkes (Subluxation und Karpal-Hyperextension) und kleine Abrissfrakturen der Handwurzelknochen können leicht durch dorsopalmare Aufnahmen mit medialen und lateralen gehaltenen Aufnahmen der betroffenen Gelenke diagnostiziert werden. Arthrosen stellen die häufigste Erkrankung des Karpalgelenks in der vorliegenden Studie dar, sie betrifft etwa 43% der untersuchten Patienten. Radiologische Merkmale der

Arthrose des Karpalgelenkes bei Hunden und Katzen sind Weichteilschwellung, Osteophytenformationen in den Handwurzelknochen und der Verlust der Gelenkspalten der antebrachiokarpal, interkarpalen und Karpometakarpalgelenke. In der vorliegenden Studie hatten elf Hunde (18%) und zwei Katzen (3%) mit Arthrose osteophytäre Ablagerungen am intermedioradialen Handwurzelknochen. Neun Hunde (15%) und zwei Katzen (3%) zeigten neben der Arthrose Osteophytenformationen auf dem Os accessorium. Zwei Hunde (3%) wiesen Arthrosen mit mehreren Osteophytenformationen am distalen Radius sowie am Os carpi intermedioradiale, ulnare, accessorium und den ersten bis vierten Handwurzelknochen auf.

Eine Überstreckung des Handgelenkes hatte eine Abweichung von der normalen Position der Handwurzelknochen zur Folge das betraf zehn Hunde (16%) in der vorliegenden Studie. Es führte zu einer Erweiterung des Gelenkspaltes der interkarpalen Knochen und einer Schwellung der Weichteile um die Karpalgelenke. Mediolateral überstreckte und mediolateral gebeugte Aufnahmen zeigten deutlich diese abnorme Laxizität des Handgelenke.

Luxation, Subluxation, Hyperextension, Fraktur der Handwurzelknochen und Arthrose an den Karpalgelenke von sechzehn Hunden und vier Katzen wurden mit einer Pankarpal-Arthrodese versorgt. Bei einem Hund mit einer medialen Subluxation des Karpometakarpalgelenks und medialproximaler Luxation des zweiten Metakarpus wurde die Karpal-Arthrodese mit einer T-Platte durchgeführt. Postoperative Röntgenkontrollen operierter Karpalgelenke lagen bei siebzehn Hunden und vier Katzen vor. Anhand dieser wurde das Fortschreiten des Heilungsprozesses kontrolliert. Die Röntgenaufnahmen wurden in dorsopalmarem und mediolateralem Strahlengang direkt nach der

Operation angefertigt, um sicherzustellen, dass die Ausrichtung und Positionierung der Platten und Schrauben am Knochen korrekt sind. Zusätzlich wurden nach vier, acht, zwölf, sechzehn und zwanzig Wochen Kontrollaufnahmen erstellt. Eine Katze zeigte eine leichte Atrophie des distalen Anteils des Radius 5 Monate nach der Operation. Diese geringgradige Atrophie war auf Druck der Platte auf den Knochen zurückzuführen. Bei zwei Hunden hatten sich Osteophyten am distalen Radius nahe dem proximalen Punkt der PCA-Platte nach Pankarpal-Arthrodese gebildet. Bei einem weiteren Hund zeigte sich zweieinhalb Monaten nach der Pankarpal-Arthrodese zur Behandlung einer Karpalgelenks- Hyperextension eine Fraktur des dritten Handwurzelknochens. Bei anderen Hunden erschienen Osteophyten dreieinhalb Monate nach pankarpaler Arthrodese. Bei einem Hund, der mit einer T-Platte zur Behandlung einer medialen Subluxation des Karpometakarpalgelenks therapiert wurde, traten nach vier Monaten Osteophyten auf. Diese sind auf die Irritation der Karpalknochen und des distalen Endes des Radius durch die Platte zurückzuführen.

Im Röntgenbild der anderen siebzehn Karpalgelenke (vierzehn Hunde und drei Katzen) waren bis sechs Monate nach pankarpaler Arthrodese keine Auffälligkeiten zu erkennen. Die Implantate lagen in korrekter Position und die Gelenkspalten der operierten Karpalgelenke waren radiologisch nicht mehr sichtbar.

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