ACCESSORY CARPAL BONE FRACTURE IN GREYHOUNDS: ASSESSMENT OF PROGNOSTIC INDICATORS AND OUTCOME FOLLOWING SURGICAL MANAGEMENT BY FRAGMENT REMOVAL

by

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DEDICATION

To my parents-for their moral support whenever I have needed it.

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Finally, I wish to accord my appreciation to all my family and closest friends for their continuous moral support.

DECLARATION

I, Alfonso Carlos Chico, do hereby declare that the work in this dissertation is original, was carried out by myself or with due acknowledgment and has not been presented for the award of a degree at any other University.

Signed:

Date:

AIMS

This dissertation has three aims:

1) To review the anatomy of the carpal region and the characteristics of accessory carpal bone fractures, with special attention to the factors that have been implicated in the pathogenesis of these fractures.

2) To present an objective study to determine the outcome of accessory carpal bone fractures in racing greyhounds managed by fragment removal.

3) To analyse the value of some aspects of the injury and the patient as potential prognostic indicators that the surgeon can evaluate at the time of presentation, before surgery is undertaken. These indicators included: duration of the injury, age of the patient, weight of the patient, radiological evidence of osteophytes at presentation, size of the fragments and displacement of the fragments.

SUMMARY

A retrospective analysis of accessory carpal bone fractures in racing greyhounds was undertaken. The outcome following surgical management by fragment removal and the potential factors influencing this outcome were evaluated.

To pursue these goals, the clinical records and follow-up questionnaires of the cases treated by this technique at Glasgow University Veterinary School (G.U.V.H.) during the period 1979-1990 were analysed. The results are presented and discussed in the light of the published literature.

The major conclusions drawn from this study were:

• The outcome following surgery for accessory carpal bone fractures treated by fragment removal was as follows:

Seventy per cent of the dogs (13/19) returned to racing.
Forty seven per cent of the dogs (9/19) returned to win races.

• No statistically significant correlation was found between any of the analysed prognostic indicators and the outcome following surgery.

INTRODUCTION

Racing greyhounds sustain a number of specific injuries that are rarely seen in other breeds. The conditioned musculo-skeletal system and the extraordinary physical strength that racing involves, together with some peculiar aspects of the track result in fractures in greyhounds occurring primarily through indirect forces. This is in contrast to fractures in companion animals which are usually due to direct trauma (Dee and Dee 1985).

This characteristic of fractures in greyhounds, which also applies to soft tissue injuries, determines the pattern of the anatomical distribution of the lesions. The surveys of musculo-skeletal injuries in greyhounds by Walpole (1944), Gannon (1972) and Prole (1976) all confirm that the left fore is by far the most affected limb, followed by the right fore. Injuries in the hind legs seem to be less frequent than in the fore legs, the right hind being more affected than the left. Carpal injuries, however, do not conform to this distribution. The most commonly affected carpus is the right, accounting for 66% of all the carpal injuries (Prole 1976), and accessory carpal bone fractures do not constitute an exception. The data of three surveys (Gannon 1972, Prole 1976, Johnson and others 1988) reveal a highly marked predisposition for this fracture to occur in the right carpus.

The carpus of the greyhound is a fairly common site of injury, representing 11% of the total number of racing injuries (Prole 1976), the vast majority of carpal injuries being carpal sprains (78.5%), although strains of the insertion of the flexor carpi ulnaris (7%) and bursitis of the extensor carpi radialis (1.5%) have also been recorded. Fractures in the carpal region are produced almost solely in the accessory carpal bone. The percentage of accessory carpal bone fractures in the literature has ranged from 10% (Gannon 1972) to 25.5% (Prole 1976) of the total number of fractures in the greyhound.

Fractures in carpal bones other than the accessory carpal bone are not so well documented. Yore (1983) has reported occasional flakes of bone pulled off within the middle carpal joint by the ligaments joining the radial carpal bone to the second and third carpal bones. However, fractures of the radial carpal bone usually take the form of small fragments from the medial edge or thin slabs from the dorsal surface. Avulsion fractures of the attachment of the palmar radial carpal-metacarpal ligaments have also been described (Dee and others 1984, Earley 1990). Fractures of the distal row of carpal bones are rare and usually are manifested as a small chip or slab of the dorsal surface (Brinker and others 1983).

The clinical and radiological signs associated with fracture of the accessory carpal bone are consistent with a type III sprain or strain-avulsion fracture (Farrow 1978). A sprain may be defined as an injury to a ligament resulting from overstress that causes some degree of damage to the ligament fibres or their attachments. A strain involves the muscle-tendon unit, damaging some part of it (muscle, tendon or associated attachment sites). These injuries may be either chronic, as a result of a repeated stretching of the involved muscle-tendon unit, or acute, as occasioned by a single, sudden hyperextension or hyperflexion. In either case, classification schemes focus on the qualitative aspects of the injury: mild (first degree), moderate (second degree) and severe (third degree).

Third degree carpal sprains and strain-avulsion fractures are therefore characterized by severe lameness (often non weight-bearing lameness), gross swelling, which may extend well into the proximal metacarpal region and digits of the affected paw, and extreme pain on palpation. Manipulation of the carpus may reveal different degrees of instability in the accessorioulnar carpal joint and crepitation can be felt.

The radiological signs of accessory carpal bone fracture will confirm the physical findings, with gross regional soft tissue swelling and instability often apparent and readily demonstrable with stress radiographs. These fractures are best seen in the medio-lateral projection, although the dorso-palmar view occasionally is useful in detecting fractures that extend to the medial border of the articular surface. When accessory carpal bone fractures become chronic, they can be seen surrounded by a periosteal proliferation, but not healed.

The size of the avulsed fragments is quite variable. Some are single large slabs up to 10x5x2 mm, whereas other consist of numerous comminuted chips. Intra-articular fragments are usually larger than avulsions of the flexor carpi ulnaris, which are extra-articular (Dee and Dee 1985). When necropsy is performed, the fragment is found to be attached by fibrous tissue to the accessory carpal bone and to the ulnar carpal bone (Johnson 1987).

The accessory carpal bone is exceptionally vulnerable to avulsion fractures, with its unique structure serving as the site of origin or insertion of strong ligaments and tendons. The mechanical forces involved in the pathogenesis of these fractures have been well documented (Bateman 1960, Davis 1967[a], Dee 1981, Johnson and others 1988, Johnson and others 1989).

A recent publication (Johnson 1987), recognising that little was known about the optimal treatment, incidence or prognosis for recovery of these injuries, established a classification system as a basis for further studies of these fractures (Figure 1). Five types of fracture were defined as follows:

Type I: Avulsion fracture of the distal margin of the articular surface of the accessory carpal bone at the attachment of the ligaments connecting the accessory carpal bone to the ulnar carpal bone.

Type II: Avulsion fracture of the proximal margin of the articular surface of the accessory carpal bone at the origin of the ligaments that connect it to the caudomedial surface of the distal ulna and caudal surface of the distal radius.

Type III: Avulsion fracture at the distal surface of the caudal end of the accessory carpal bone at the origin of the two ligaments that insert to the fourth and fifth metacarpal bones.

Type IV: Avulsion fracture at the tendon of insertion of the flexor carpi ulnaris muscle.

Type V : Comminuted fracture of the accessory carpal bone.

The following methods of treatment have been used for accessory carpal bone fracture repair: conservative management, abductor digiti quinti muscle resection, fragment excision and internal fixation. Only the last two surgical techniques are currently used.

Accessory carpal bone fracture is one of the most common fractures in greyhounds and it is usually seen in very fast and valuable dogs (Davis 1967[a]). Greyhound fracture repair always represent a source of concern for the orthopaedic surgeon : the goals of any surgical management should be not only the return of the greyhound to soundness, but the return to former performance. The establishment of an accurate prognosis and an evaluation of possible prognostic indicators are therefore of prime importance when dealing with accessory carpal bone fractures. The results and prognosis of internal fixation have been recently published (Johnson and others 1989). However, no objective reports have been found in the literature concerning the results and prognosis of fragment removal. Led by Johnson and other's statement (1989) that further studies are needed to define objectively the success of the different treatment regimes, a comparison of the results obtained with internal fixation and fragment removal will be carried out in the present study, as well as an evaluation of some prognostic indicators taken from the clinical history and records of the patient.

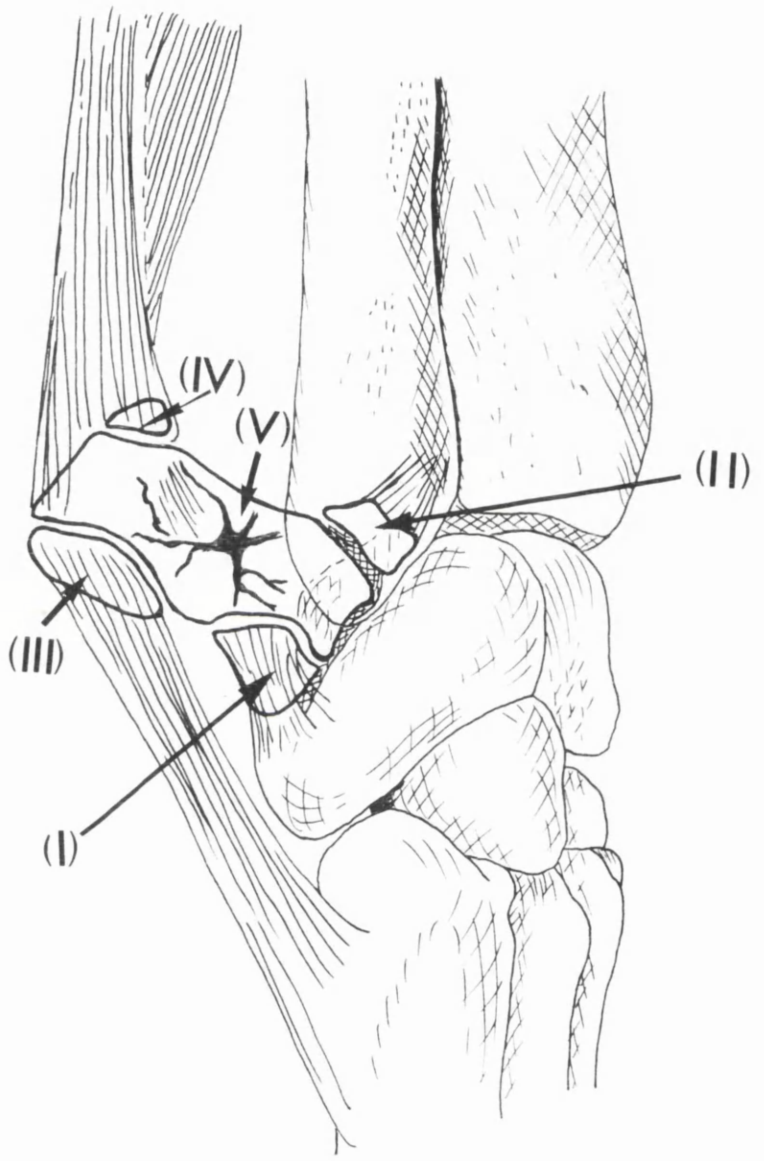

Figure 1. Classification of accessory carpal bone fractures. (Modified from Johnson and others 1989).

Type I: Avulsion fracture at the origin of the accessorio-carpoulnar ligament.

Type II: Avulsion fracture at the insertion of the palmar ulnocarpal and palmar radiocarpal ligaments.

Type III: Avulsion fracture at the origin of the accessorio-metacarpal IV and V ligaments.

Type IV: Avulsion fracture at the tendon of insertion of the flexor carpi ulnaris muscle.

Type V: Comminuted fracture.

CHAPTER 1:

SURGICAL ANATOMY

ACCESSORY CARPAL BONE

The accessory carpal bone is a truncated rod of bone with a basal enlargement that bears a saddle-shaped articular surface for the ulnar carpal bone, separated by an acute angle from a proximally directed articular surface for the styloid process of the ulna.

It acts as an important site of origin and insertion of ligaments and tendons. No other carpal bone receives as strong muscle insertions and the accessory carpal bone does not directly bear weight.

The radiologic interpretation of the accessory carpal bone in puppies may be confusing before the carpal ossification centres appear and fuse. The centre of ossification for the body of the accessory carpal bone appears in the second week, while the centres for the other carpal bones appear from three to six weeks old (Vaughan 1985). The epiphyseal centre of ossification for the accessory carpal bone, which elaborates the enlarged end of the bone, is the last carpal ossification centre to be apparent radiographically, at six to seven weeks (Vaughan 1985). This epiphyseal plate usually closes at 110 days (range: 70-150) (Sumner-Smith 1966), but in greyhounds the time for closure is not before 160-180 days (Smith and Allock 1960).

CARPAL JOINTS

The carpal joints are composite articulations which include the antebrachiocarpal, middle carpal, carpometacarpal and the joints between the carpal bones of each row, that constitute the intercarpal joints.

The antebrachiocarpal joint capsule has an extensive synovial sac, which also encloses the distal radioulnar joint. The synovial sac of the middle carpal joint is smaller and communicates with the sac of the carpometacarpal joint between the third and fourth carpal bones (Nickel and others 1981). In order to provide stability, the joint capsule is thickened on the dorsal and palmar surfaces of the carpus much more than is usually the case on the extensor and flexor surfaces of hinge joints (Evans and Christensen 1979). The lateral and medial aspects of the carpus are stabilised by the ulnar and radial short collateral ligaments respectively (see below for anatomical description).

Other anatomical structures in close relationship with the carpal joints are the flexor retinaculum and palmar carpal fibrocartilage. The flexor retinaculum, formerly called transverse palmar carpal ligament, attaches laterally to the accessory carpal bone and then crosses the palmar aspect of the carpus to attach medially to the radius, radial carpal bone and first carpal bone. The palmar carpal fibrocartilage flattens the palmar irregularities at the carpo-metacarpal joint, providing a smoother surface for the structures contained in the carpal canal. It attaches to the proximal part of the metacarpals and to all the carpal bones except the accessory carpal bone (Evans and Christensen 1979).

LIGAMENTS OF THE CARPUS

Multiple ligamentous structures provide support for the carpus. The carpal joints permit flexion-extension, medial and lateral deviation and axial rotational movements. The movements and degrees of motion of the different carpal joints are summarized in Table 1.

Joint	Movement	Degrees of motion
Antebrachiocarpal Joint	Flexion	100
	Extension	10
	Medial Deviation	5
	Lateral Deviation	15
Middle carpal Joint	Flexion	40
	Extension	0
Carpometacarpal Joint	Flexion	10
	Extension	0
Axial Rotation of the Carpus		40

Table 1. Movements and degrees of motion of the carpal joints (Yalden 1970).

Unlike the tarsal joints, there are no continuous collateral ligaments spanning all the carpal joints. The two collateral ligaments are named after the bone in which they originate.

The short radial collateral ligament consists of two parts (Figure 2.1):

*The straight portion originates on a tubercle proximal to the styloid process of the radius and inserts in the medial part of the radial carpal bone.

*The oblique portion runs from the styloid process to the palmar aspect of the radial carpal bone (Miller and others 1990).

The short ulnar collateral ligament extends from the styloid process of the ulna to the ulnar carpal bone (Figure 2.1).

The distal radius and ulna are attached to each other by means of the **radioulnar ligament** (Figure 2.1).

The dorsal radiocarpal ligament originates in the radius medial to the radioulnar ligament and inserts in the ulnar carpal bone, close to its articular surface with the radius (Figure 2.1).

From the palmar aspect of the radial carpal bone, a strong ligamentous band called **palmar radiocarpal-metacarpal ligament** runs distally to diverge and attach proximally in the palmar aspects of the metacarpal bones II and III (Figure 2.1).

Multiple short ligaments link every carpal bone with adjacent bones, both on the dorsal and palmar aspects of the carpus. Some of these ligaments are difficult to demonstrate on their own, being often connected to the joint capsule or to other ligaments. They are named according to the bones that they unite. Four of these ligaments are directly implicated in the pathogenesis of accessory carpal bone fractures: accessorio-carpoulnar ligament, palmar ulnocarpal and palmar radiocarpal ligaments and accessorio-metacarpal ligaments

The **accessorio-carpoulnar ligament** is involved in type I fractures. Its origin is in the accessory carpal bone, at the craniodistal part of the articular surface of the accessorioulnar carpal joint. This ligament inserts in the ulnar carpal bone (Figure 2.2).

Palmar ulnocarpal and **palmar radiocarpal ligaments** run from the palmaromedial aspect of the ulna and the palmar surface of the radius respectively to the palmar surface of the radial carpal bone. These ligaments fuse together and a portion of them attaches to the accessory carpal bone (Figure 2.3).

The origin of the **accessorio-metacarpal ligaments**, distally in the free end of the accessory carpal bone, is involved in type III fractures. These ligaments insert on the palmar aspect of the fourth and fifth metacarpal bones, with the palmar branch of the ulnar nerve and interosseus artery running in between them (Figure 2.4).

Rupture of the accessorio-carpoulnar and accessorio-metacarpal ligaments allows for unrestricted hyperextension of the antebrachiocarpal joint, with proximal displacement of the accessory carpal bone (Slocum and Devine 1982).

MUSCLES

The palmar surface of the carpus is crossed by the superficial digital flexor, deep digital flexor, flexor carpi radialis and flexor carpi ulnaris.
The tendon of insertion of the flexor carpi ulnaris is implicated in type IV accessory carpal bone fractures. This muscle is divided into two parts: ulnar and humeral head (Figure 2.5.1).

- The ulnar head is the most superficial of the two, arising medially on the proximal end of the ulna. In the proximal antebrachium the tendon of insertion passes beneath the humeral head before ending independently on the accessory carpal bone. The strong antebrachial fascia fuses with its tendon of insertion throughout its length.

- The humeral head, much stronger than the ulnar head, runs from the medial humeral epicondyle to the accessory carpal bone, between the deep and superficial digital flexors. A synovial bursa is found beneath its tendon of insertion, extending proximally 1.5 cm from the accessory carpal bone (Evans and Christensen 1979).

Muscles with special surgical significance are the abductor digiti quinti and flexor digiti quinti (Figure 2.5.2). These two muscles are found in the surgical approach to the accessory carpal bone.

- The abductor digiti quinti is the strongest of the three special muscles of the fifth digit (abductor, adductor and flexor) and lies immediately under the skin. It arises from the caudodistal border of the accessory carpal bone and after joining the flexor digiti quinti, both tendons insert on the lateral sesamoid bone and proximal phalanx of the fifth digit.

- The flexor digiti quinti originates from the accessorio-metacarpal IV ligament and runs obliquely over the interosseus muscles of the fifth digit before its tendon joins the abductor digiti quinti.

VESSELS AND NERVES

The palmar aspect of the carpus is crossed by numerous vessels and nerves. Of them, only the caudal interosseus and ulnar arteries and the palmar branch of the ulnar nerve are to be considered when surgically approaching the accessory carpal bone (Figure 2.4).

- The caudal interosseus and ulnar arteries anastomose as they cross the carpal canal.

- The palmar branch of the ulnar nerve converges towards the ulnar and caudal interosseus arteries distally in the antebrachium and they pass medially to the accessory carpal bone, between the two accessorio-metacarpal ligaments.

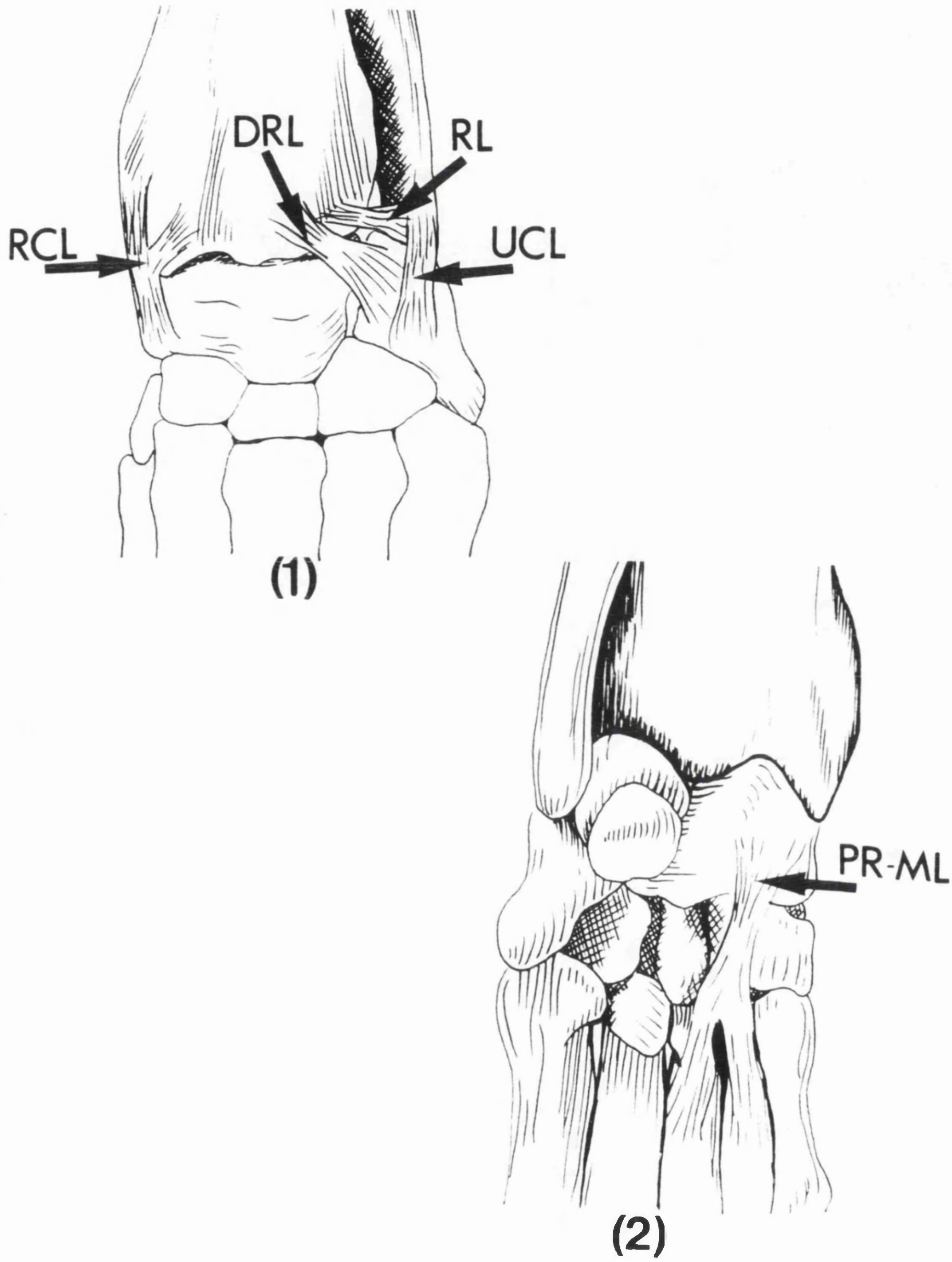

Figure 2. Anatomical structures of the carpus.

Figure 2.1: Dorsal (1) and palmar (2) aspects of the carpus.

DRL: Dorsal radiocarpal ligament. RL: Radioulnar ligament. UCL: Short ulnar collateral ligament. RCL: Short radial collateral ligament. PR-ML: Palmar radiocarpal-metacarpal ligament.

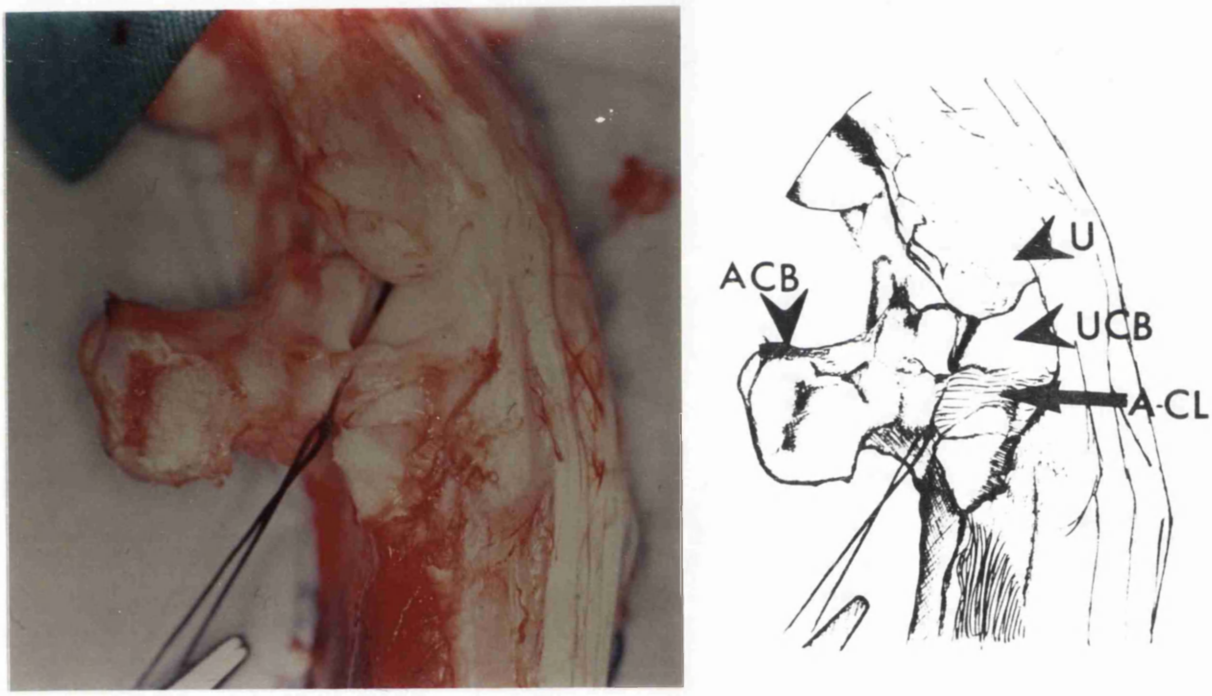

Figure 2.2. Lateral aspect of the carpus.

U: Ulna; ACB: Accessory carpal bone; UCB: Ulnar carpal bone; A-CL: Accessorio-carpoulnar ligament.

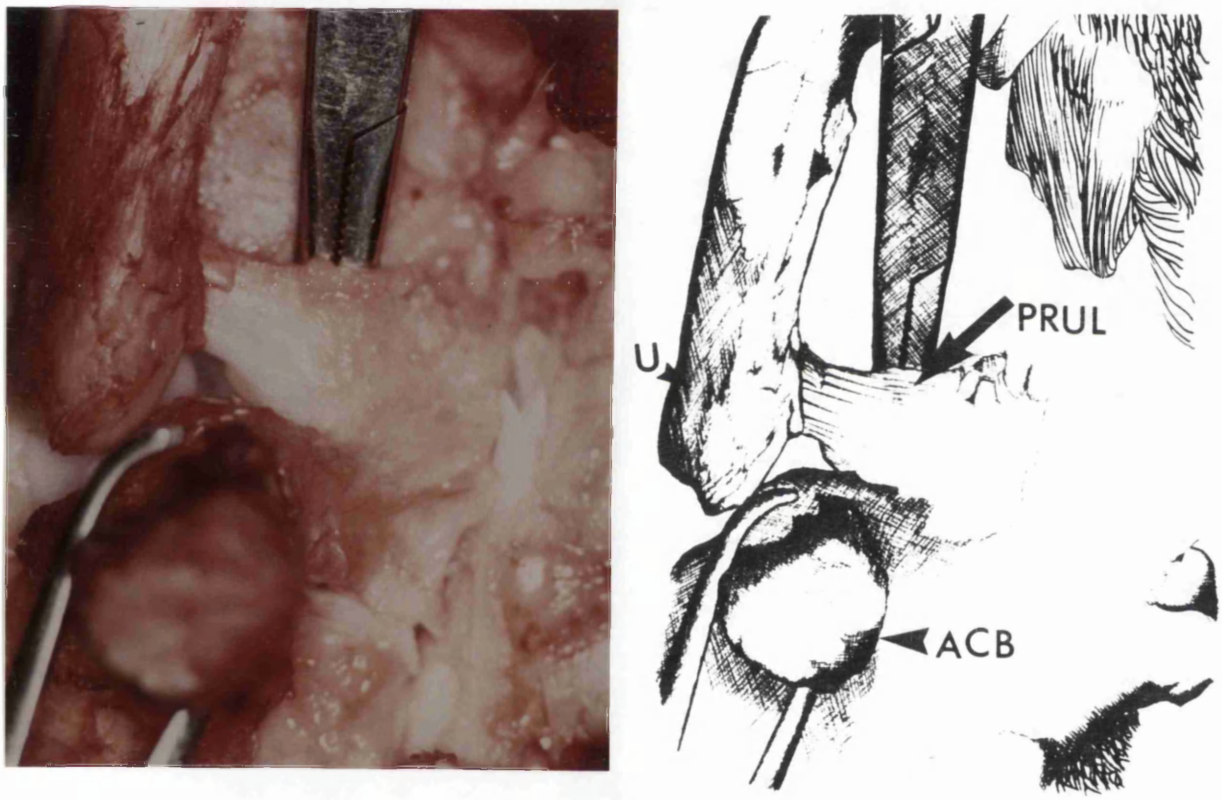

Figure 2.3. Palmar aspect of the carpus showing the palmar radiocarpal and palmar ulnocarpal ligaments (PRUL). ACB: Accessory carpal bone; U: Ulna.

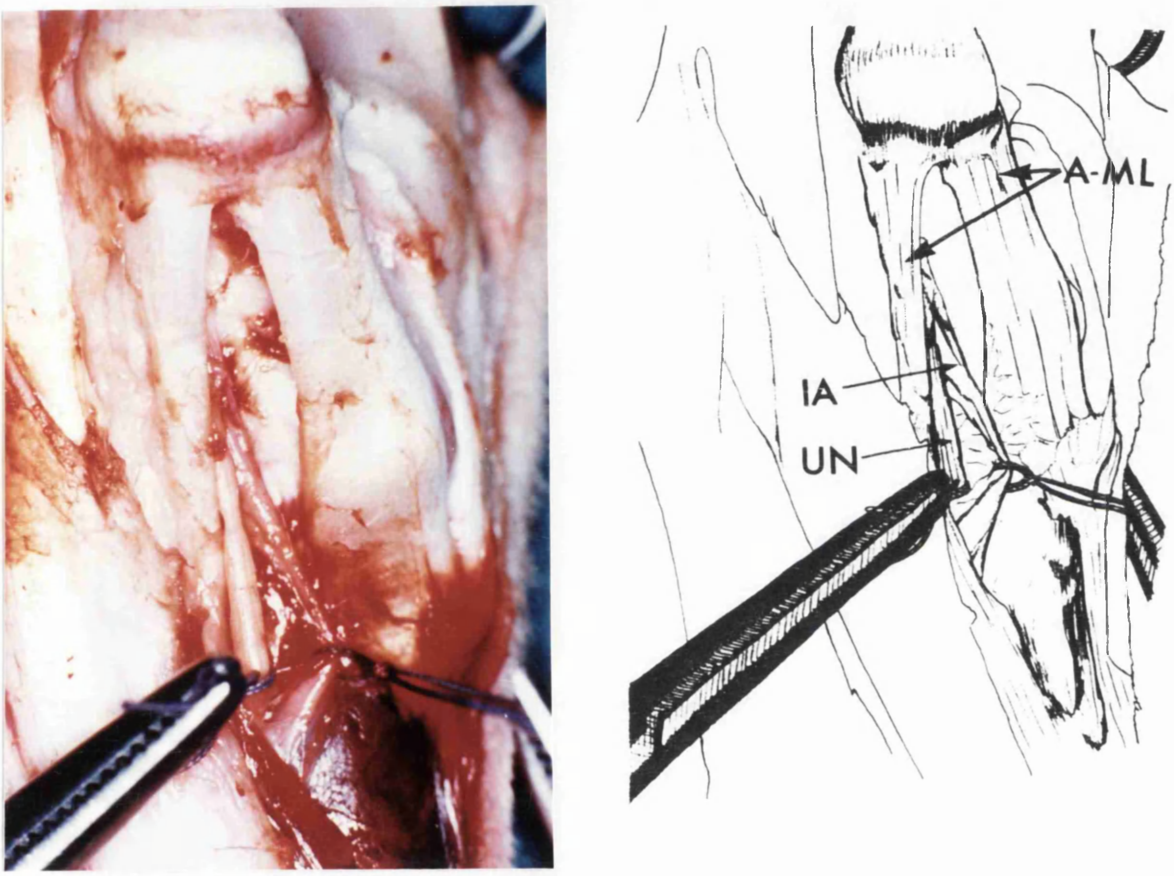

Figure 2.4: Palmar aspect of the carpus.
A-ML: Accessorio-metacarpal ligaments. IA: Interosseus artery. UN: Ulnar nerve.

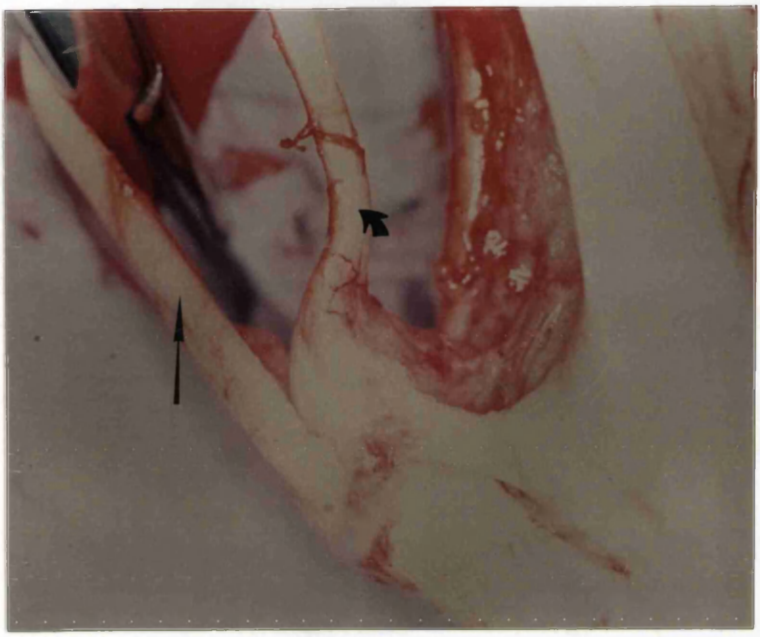

Figure 2.5.1.

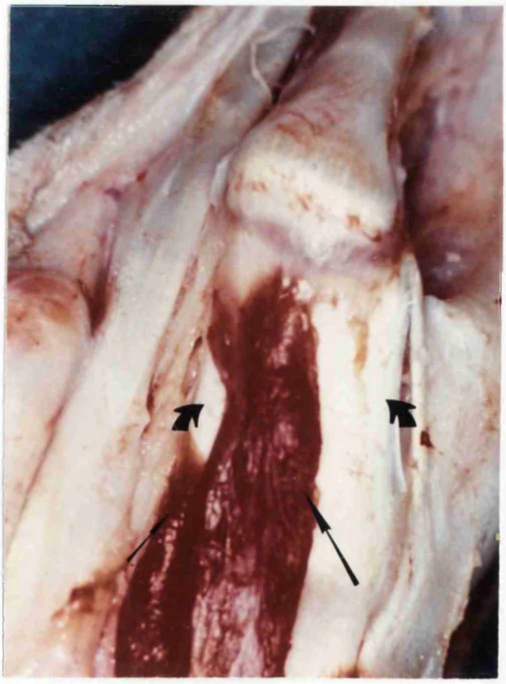

Figure 2.5.2.

Figure 2.5.1. Lateral view of the carpus. Flexor carpi ulnaris: humeral head (straight arrow) and ulnar head (curved arrow)

Figure 2.5.2. Palmar view of the carpus. Abductor digiti quinti (big arrow). Flexor digiti quinti (small arrow). Accessorio-metacarpal ligaments (curved arrows).

CHAPTER 2:

LITERATURE REVIEW

SECTION 1: CHARACTERISTICS OF THE FRACTURE

TYPES OF FRACTURE

The first report of accessory carpal bone fracture was by Bateman (1950), who described the radiological characteristics of a chip fracture in the craniodistal surface of the bone. Subsequently, different fracture sites were noted: Bateman (1960) mentioned a comminuted fracture and Prole (1976) reported for the first time a strain-avulsion fracture at the attachment of the tendon of the flexor carpi ulnaris to the accessory carpal bone, thus differentiating it from the classical sprain-avulsion fracture. Vaughan (1985) described a longitudinal fissure in the accessory carpal bone and also a fragmentation of the epiphysis in puppies. It was not until 1987 that Johnson established a classification of the different types of fracture according to the ligament or tendon implicated. The five types of fracture have already been described (see Introduction).

INCIDENCE AND ANATOMICAL DISTRIBUTION

The incidence of accessory carpal bone fractures and their anatomical distribution have been a debatable subject. Although most authors regarded these fractures as common (Gannon 1972, Hickman 1975, Dee and Dee 1985, Kealy 1987, Johnson 1987, Johnson and others 1989), their incidence in two surveys of greyhound injuries indicated unequal results; Gannon (1972) affirmed that in greyhounds, accessory carpal bone fractures account for 10% of the total number of fractures, whereas Prole's figures (1975) were much higher (25.5%).

Contradictory results have also been obtained by the different authors who have tried to determine which is the most commonly affected limb. Bateman (1960), Prole (1975), Dee (1981), Brinker and others (1983), Dee and Dee (1985), Moore (1985) and Johnson and others (1988) all agreed that this fracture is most common in the right leg. Vaughan (1985), however, observed that the right and left carpi were similarly affected during bouts of fast exercise and that both legs are equally vulnerable in dogs used for coursing. This observation supports a previous report (Gannon 1972), in which the same number of fractures occurred in each leg. Only one author (Hickman 1975) reported a higher frequency in the left leg, although no percentages were provided to support this view.

SEX AND AGE DISTRIBUTION

Little data are available regarding the sex and age distribution of these fractures. Gannon (1972) gave a full breakdown of 100 consecutive cases of stress fractures in greyhounds, while Johnson and others (1988) provided details of the cases of accessory carpal bone fracture presented at the Hospitals of the Universities of Sydney and Colorado State. The sex distribution was quite similar: 70% males (7/10) in the first report and 64% males (32/50) in the second.

No major variations were found either when reviewing the age of the patients; it ranged from 14 to 42 months (mean: 23.8) in the first report and from 10 to 50 months (mean: 27.9) in the second.

PATHOLOGY

Histologic studies were carried out in some of the patients with accessory carpal bone fracture (Johnson 1987, Johnson and others 1989). Chronic type I fractures (of more than 6 months duration) were displaced and surrounded by a periosteal proliferation, but not healed. The fragment was attached to the articular surface of both the ulnar carpal bone and the accessory carpal bone. Examination of the articular cartilage of these bones revealed gross ulceration and fibrillation after 8 weeks. At the distal articular margin there was a loss of articular cartilage and necrosis of the exposed subchondral bone (Johnson 1987). The fragment was surrounded by callus that consisted of woven bone and fibrocartilage and a pannus of fibrous synovial tissue had formed over the disrupted proximal articular surface.

A thin layer of new bone can form on the surface of the accessory carpal bone and on the external margin of the fragment as a result of a fracture healing response, traumatic or surgical irritation of periosteum, periarticular osteophytosis or traumatic enthesopathy (Johnson and others 1989). Enthesophytes developed at the insertion of the flexor carpi ulnaris and at the origin of the accessorio-carpoulnar ligament in some of the cases described by these authors.

SECTION 2: METHODS OF TREATMENT

Four different treatments have been used when dealing with accessory carpal bone fractures, namely: conservative, abductor digiti quinti resection, fragment removal and internal fixation.

CONSERVATIVE MANAGEMENT

Conservative methods have been advised when the fracture has not been diagnosed early, ie., when more than two weeks have elapsed after the injury. If the injury is older than 2 weeks, there is less chance of surgery being successful (Davis 1967[a]). This author stated, however, that without surgery, the area is always a weak point and dogs always tend to show pain in the carpus for the rest of their racing careers.

More recently, conservative management, together with the use of physiotherapy, has been advocated by Yore (1983) for the treatment of type IV fractures, although no success rate has been given. The proposed management consists of the following measures:

- Injection of 1 ml of Ethanolamine oleate 5%, with 1 ml of lignocaine 2% around the insertion of the flexor carpi ulnaris.
- Padded bandage over the carpus and splint in slight flexion for two weeks.
- After a further two weeks, a limited exercise program can be started and gradually increased (one month in small run and a second month in long run).
- On return to work, the area needs constant physiotherapy (flexion and forced extension).

Conservative management has also been used for the treatment of type V fractures where surgical repair is not feasible. These cases are best managed by casting the carpus in decreasing degrees of palmar flexion for 6 to 12 weeks (Dee 1988).

RESECTION OF THE ABDUCTOR DIGITI QUINTI MUSCLE

Resection of the abductor digiti quinti was the first surgical technique described for the repair of accessory carpal bone fractures. It has been used both alone (Bateman 1950) and in conjunction with fragment removal (Bateman 1960, Davis 1967[a]).

Bateman (1950) suggested that, since the abductor digiti quinti muscle had its origin in the distal surface of the accessory carpal bone, it is impossible for a detached fragment of bone to become reattached proximally, as long as this muscle is pulling it away and preventing healing. This author claimed good results in the dogs treated with this method, achieving healing of the fragments to the bone. The dogs returned to racing within three months and finished quite sound after their races.

Hickman (1975) disagreed that resection of the abductor digiti quinti muscle was a necessity. He argued that, although the detached piece of bone was embedded in the attachment of this muscle, once the fragment had been removed, no adverse effects should be expected to arise from the normal union of muscle to bone. This view was further supported by Dee and Dee (1985), Vaughan (1985) and Johnson and others (1989), who stated that most accessory carpal bone fractures fail to heal because they are distracted by their distal ligamentous attachments, not by the abductor digiti quinti. The origin of this muscle in the accessory carpal bone lies in the caudal angle in the free end of the bone, between the accessorio-metacarpal ligaments, too far caudal to contribute in the pathogenesis of intra-articular fractures (Johnson and others 1989).

The operation, as described by Bateman (1950) is straightforward. The two strong bands that constitute the accessorio-metacarpal ligaments are palpated and the incision, of about one inch in length, is made directly over the interligamentous area. A guide is then inserted and the muscle raised. When the body of the muscle is above the guide, a pair of artery forceps is applied to the muscle belly and about an inch is resected from its length.

The dog is allowed to walk after 4-5 days, galloping in the straight in a month's time and gradually increasing the amount of exercise until finally, after two months, trial on a track may be ordered.

FRAGMENT REMOVAL

Fragment removal has been the traditional surgical treatment for years. It was originally described by Bateman (1960) and subsequently used by most of the authors.

To gain access to the fracture site, the accessorioulnar carpal joint is approached through a slanting incision across the lateral surface of the carpus, beginning over the accessory carpal bone and running to the proximal end of metacarpal V. Care must be exercised to avoid severing blood vessels, since haemorrhage will make identification of the fragments difficult. An Esmarch-type bandage will help avoid this. Haemostasis is maintained during surgery by application of a tourniquet around the proximal region of the antebrachium. This practice is advisable especially in chronic cases because of the inevitable increase in vascularity (Vaughan 1985, Johnson and others 1989).

Subcutaneous fascia is incised and retracted along with the skin. An incision is made through the deep antebrachial fascia along the cranial border of the abductor digiti quinti muscle, revealing a tendinous slip from the ulnaris lateralis tendon to the free end of the accessory carpal bone (Brinker and others 1983). The abductor digiti quinti is bluntly separated from the accessorio-metacarpal ligaments, transected at its origin and reflected distally. Access to the free end of the bone is aided by the use of a pair of Gelpi retractors. The fragment is identified, grasped with forceps and traction is applied.

Synthetic absorbable material is used to suture the origin of the abductor digiti quinti muscle (PDS, Ethicon Inc.[1]) and the palmar carpal fascia (Vicryl, Ethicon Inc.[1]). The skin is closed with nonabsorbable monofilament nylon suture (Ethilon, Ethicon Inc.[1]).

A well padded soft dressing is applied post-operatively. Walking exercise begins from the third day and is then gradually increased, but fast work is not allowed for three months. Racing should not be permitted until flexion of the carpus is free of discomfort and there is no lameness at speed (Vaughan 1985). Yore (1983) recommended instead a splint in slight flexion for two weeks, followed by kennel rest for another two weeks, with a light supporting bandage. After the first month, the dog starts walking and then exercise is gradually increased for the next two months. Excessive formation of fibrous tissue and adhesions may give rise to adverse effects on function and performance during the ligament healing process, but this complication does not develop provided passive manipulation of the carpus is instituted and conscientiously carried out during healing (Hickman 1975).

Complementary measures to fragment removal have been described. In type IV fractures, primary tendon repair may be accomplished with nonabsorbable material after the chip is removed, if sufficient tissue remains to hold sutures. If this is not possible, a suture around the accessory carpal bone can be passed to reattach the flexor carpi ulnaris, or alternatively, a hole can be drilled in the accessory carpal bone to accommodate this suture (Gannon 1981).

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(1) Ethicon Inc. 408 Bankhead Avenue. Edinburgh EH11 4HE, U.K.

SCREW FIXATION OF THE FRAGMENT (INTERNAL FIXATION)

Internal fixation of the avulsed fragments by means of one or more screws was first described by Brinker and others (1983). The advocates of this technique suggested that it was a more rational method to repair accessory carpal bone fracture than fragment removal, since it permitted restoration of ligamentous integrity. These authors contended that with fragment removal, successful healing depends on scar tissue reattachment of the ligament to the bone. Failure to do so can result in instability of the accessory carpal bone that will lead to degenerative joint disease. Furthermore, as scar tissue does not have nearly the tensile strength of ligamentous tissue, it does not replace the ligament successfully in areas of high tensile stress (Brinker and others 1983). In this regard, Johnson and others (1989) raised the question whether fragment excision was a highly successful procedure, based on the assumption that after the removal of avulsed fragments of the accessory carpal bone, the attachments of the ligaments and tendons are lost and subluxation of the accessory carpal bone may persist.

Johnson and others (1989) conceded, however, that in type I and type II fractures, because they are intra-articular, removal of the avulsed fragments may be of some benefit; chronic intra-articular chip fractures mechanically traumatise the apposing articular surface of the ulnar carpal bone and release enzymes from the degraded articular surface, thus causing degenerative joint disease.

The surgical approach to the bone is virtually identical to that of fragment removal, but in dogs with type I or type II fractures, lateral arthrotomy of the accessorioulnar carpal joint is performed to inspect the cartilage. This permits an appreciation of the number and size of fragments and facilitates precise anatomical reduction.

Once the abductor digiti quinti is dissected from the bone, additional exposure may be gained by transection of the accessorio-metacarpal IV ligament. Care must be exercised not to damage the palmar branch of the ulnar nerve or the common interosseus artery, both of which run in close proximity with this ligament. This desmotomy was later abandoned due to the slow regaining of tensile strength and also to the possibility of secondary breakdown of the ligament and subsequent instability and subluxation (Johnson and others 1989). The fragment is identified and reduction is maintained with pointed reduction forceps.

Fractures are fixed with 1.5 mm or 2.0 mm cortical screw. In larger fragments, it may be possible to insert the screws in lag fashion. In most of the cases, however, the pilot hole is not overdrilled because of concern of splitting the fragment. Therefore, interfragmentary compression is induced by the use of reduction forceps and fixation is achieved using a positional screw (Brinker and others 1983).

Using screw fixation, types I, II, III and severe type IV fractures, have been fixed. The position of the screws in each case is shown in Figure 3. In accessory carpal bone fractures with more than one detached fragment, the major fragment is repaired with a screw and the lesser secondary chips are either excised or left in place. Nevertheless, if the fragments are big enough, more than one screw can be inserted. Johnson and others (1989) described a dog with a type I and two type III fractures repaired with three 1.5 mm screws. Alternatively, the secondary fragments can be reattached with Kirschner wires. The use of tension band wire for the fixation of the fragment has also been described (Earley 1990).

Post-operative management involves the application of a molded palmar splint or plaster-of-Paris cylinder cast with the carpus in 20 to 40 degrees of flexion. The splint is maintained for 4 to 6 weeks and after this period, strict confinement is continued for another 4 to 6 weeks. Regular training usually commences by the 12^{th} to 16^{th} post-operative week (Johnson and others 1989).

Accessory carpal bone fracture has also been described in equine orthopaedics. Although successful cases managed conservatively or by fragment removal have been reported (Stashack 1987), the treatment of choice for this fracture in horses is internal fixation (Easley and Schneider 1981).

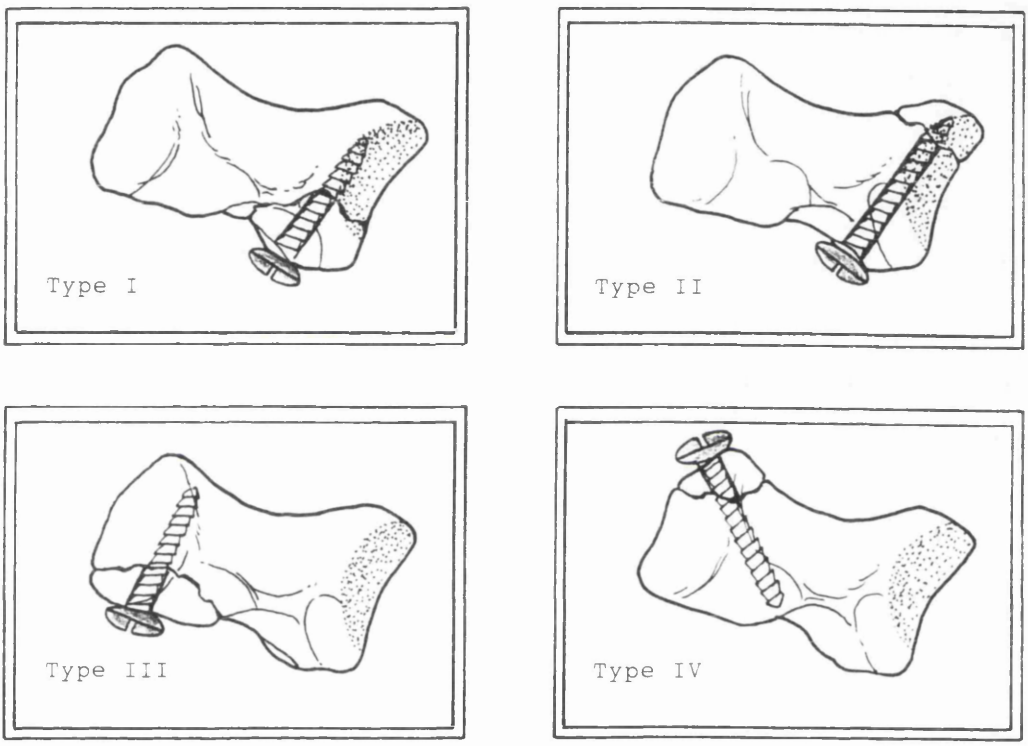

Figure 3. Position of the screw for the repair of the different types of accessory carpal bone fracture.

SECTION 3: PATHOGENESIS

Racing greyhounds sustain a number of injuries rarely seen in other breeds. Some factors have been implicated in the pathogenesis of these injuries, namely: mechanical properties of bone and ligament, action of the carpus during the racing gallop, leading with the wrong fore limb, limb conformation and some aspects of the track.

MECHANICAL PROPERTIES OF TENDON AND LIGAMENT INSERTION INTO BONE

Accessory carpal bone fractures result from a disruption of the tendon and ligament insertion into bone.

The histological appearance of the insertion has been divided for its study into four zones: ligament or tendon, fibrocartilage, mineralized fibrocartilage and bone (Cooper and Misol 1970). Although each zone possesses clearly defined characteristics, the zones merge one into the other by a gradual change in morphology.

It has been suggested that fibrocartilage might afford a gradual transition of forces at insertion sites, avoiding a sudden interface between soft tissue and bone (Cooper and Misol 1970). This ability of ligament and tendon insertions to dissipate forces evenly decreases the chance of failure under force (Resnick and Niwayama 1983).

When an excessive tensile load is applied to a ligament or tendon insertion, it can result in an avulsion fracture. The phenomenon of strain rate sensitivity of bone-ligament-bone complexes tested *in vitro* with longitudinal tensile loading has been described (Frank and others 1985). Ligaments respond to higher loading rates by becoming stronger and stiffer. Bone is even more strain rate-sensitive and gets extremely strong and stiff when loaded quickly.

Bone-ligament-bone complexes are thus remarkably suited to resistance of fast loading rates, such as those which occur during physical exercise. This sensitivity accounts for a higher incidence of midsubstance ligament failure under such fast loading conditions because of the higher strengthening of bony insertions at those speeds (Frank and others 1985).

This situation changes, however, when the failure mode in the bone-ligament-bone complex is analysed in animals that have been exercised, because of the strengthening effect of physical exercise on ligaments described by several authors (Laros and others 1971, Noyes and others 1974, Bukowiecki and others 1987).

In this regard, some experiments have been conducted on the suspensory apparatus of the horse. The suspensory apparatus consists of the suspensory ligament, the proximal sesamoid bones and the distal sesamoidean ligaments (Kainer 1987). Failure can occur within the ligamentous part of the apparatus or within the proximal sesamoid bone, resulting in a fracture of that bone.

The strength of the suspensory ligament in horses that have undergone continuous racing and training activity was compared with animals stall rested or merely pasture activity (Bukowiecki and others 1987). It was found that the location of the failure corresponded to the level of activity that the horses had received. In most instances, fractures occurred in the trained group, as opposed to rupture of the ligament in the untrained group, indicating that exercise may play a role in strengthening the ligaments of the suspensory apparatus. With exercise, the ligamentous segments of the apparatus get stronger than the sesamoid bones and respond faster to training (Bukowiecki and others 1987).

Johnson and others (1989) suggested that the strengthening effect of exercise on ligaments may explain why accessory carpal bone fracture is a injury seen almost exclusively in canine athletes (racing greyhounds and coursing sight hounds); in companion dogs, carpal hyperextension injuries frequently result in a midsubstance rupture of ligaments (Johnson 1980).

ACTION OF THE CARPUS DURING THE RACING GALLOP

The carpus moves as a hinge joint, although most of the bony components do move among themselves (Sumner-Smith 1988). The degrees of motion of the carpal joints are listed in Table 1 (see Chapter 1).

The gallop is a type of gait used for high speed locomotion. The action of the different limbs when the dog is galloping is depicted in Figure 4.

The movement sequence in the racing gallop begins with support of the trunk by one of the forward swinging hind limbs (Figure 4.1). The other hind limb immediately follows (Figure 4.2). While the hind limbs are being extended, pushing the trunk forwards, the fore limbs are swung forwards and the back begins to stretch. The hind limb which was the first to touch the ground is then pushed off while the other one continues to drive and the back is extended even further. Thereby, the body is thrown forwards and upwards. It is fully extended with the fore limbs reaching forwards and the hind limbs fully outstretched (first gliding phase, Figure 4.3). The trunk is supported first by one fore limb (Figure 4.4) and then the other

(Figure 4.5). In the mean time the hind limbs are swung forwards while the back is fully arched, with the fore limbs pushing off as the body is catapulted forwards (second gliding phase, Figure 4.6). The sequence begins again as the hind limbs contact the ground.

The angular changes of the joints increase as the speed of the animal and its stride length increase (Nunamaker and Blauner 1985). The carpus can be flexed very easily, but it appears to be very little extended at rest. However, when the greyhound is racing, this joint is extended at an angle of 45 degrees to the radius and ulna and the whole area from the stopper pad to the toes can be flat on the ground (Gannon 1972). This carpal hyperextension is believed to be the cause of most accessory carpal bone fractures (Dee 1988). Furthermore, in a slow gait - walk- each limb is in contact with the ground for approximately 75% of a cycle and therefore, at any time, three limbs are in ground contact, affording the animal great stability. Whilst galloping, however, stability is sacrificed for speed (Whittick and Simpson 1990); in some moments of the cycle, only one or no limb is in contact with the ground. The biomechanics of the gallop on the straight changes when the greyhound is negotiating a bend, since the different limbs are subjected to different stresses. It is hypothesized (Bateman 1960) that accessory carpal bone fracture occurs as the dog is travelling at full speed and rounding a bend. Being required to continually turn in the same direction while racing is an important factor in the pathogenesis of these fractures. The whole weight of the body is momentarily held on the fourth and third toes of the right fore foot. At this moment, the direction must be changed at once to the left as the dog extends the right carpus. The tension of the flexor tendons during extreme extension is transmitted through the long axis of the accessory carpal bone to terminate at the palmar carpal ligaments. This tension can cause a third degree sprain or strain with an associated avulsion fracture; most commonly, this avulsion fracture is produced distally in the articular surface, since the leverage exerted by the accessory carpal bone is focused at its base (Dee 1981).

LEADING FORE LIMB

Leading with the wrong fore limb has been considered as a predisposing factor for certain stress fractures in greyhounds (Bateman 1958). Good railers lead with the railing fore limb, ie., the left fore limb in anticlockwise tracks (Davis 1967[b]) This means that the right fore leg contacts the ground first, pushing the dog into the bend.

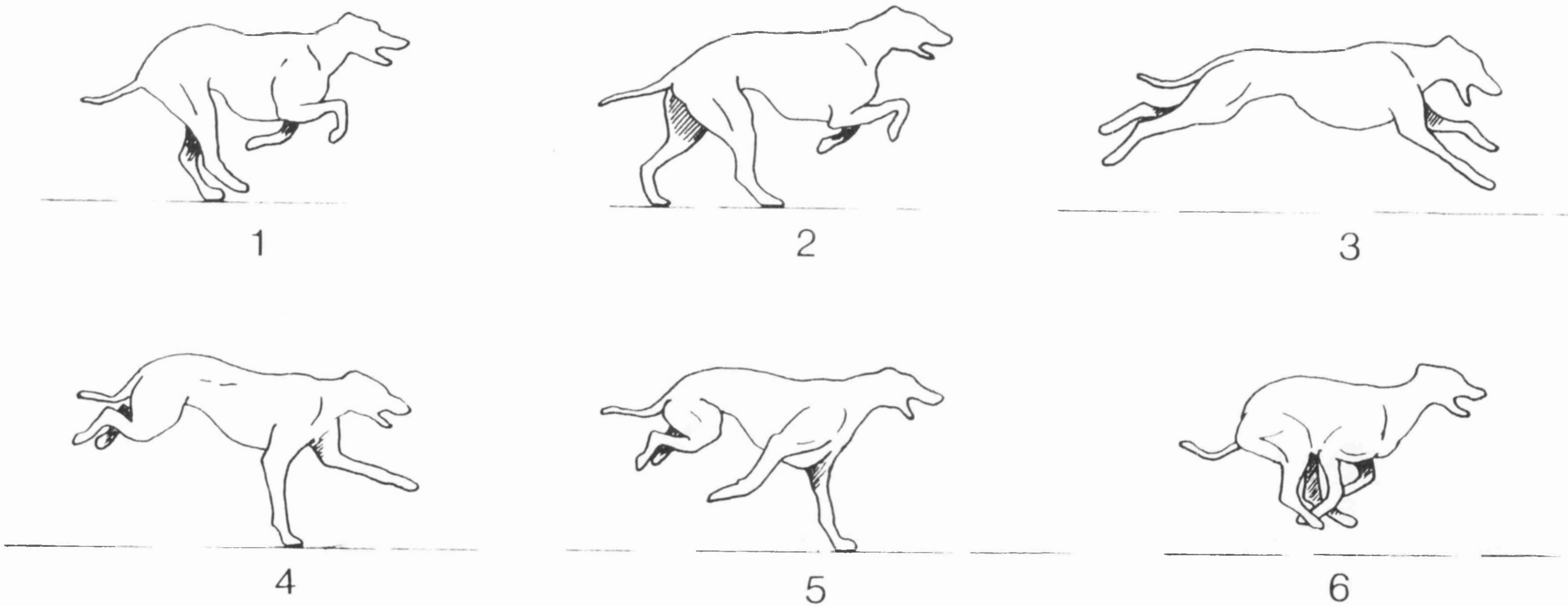

Figure 4. Sequence of movements in the racing gallop. Figures 4.1-4.6 described in the text.

It has been suggested that some dogs are inherently left or right handed (Bateman 1960, Davis 1967[b]). Fatigue or musculo-skeletal discomfort have also been implicated as causes of leading with the wrong limb (Davis 1967[b]).

CONFORMATION

Although no objective data have been provided, some aspects of conformation have been implicated as predisposing factors to injury (Davis 1967[b], Adams 1986).

It has been suggested (Davis 1967[b]) that dogs with a high degree of cornering ability and speed on the bends have the fore feet turned in and the hind feet slightly turned out. In contrast, splayed footed dogs do not corner as well, being slow on the bends or, in maintaining speed, being more predisposed to injuries.

Conformation has also been associated with the strain placed on the carpal and digital flexors tendons (Adams 1986). A vertical line drawn through the centre of the scapula would intersect the metacarpal pad in a normal limb. If the pad is cranial to this line, the carpus would tend to sink, stressing the flexor tendons. If the pad is caudal to this line, the dog would tend to walk on its toes with continual danger of knuckling over or stumbling.

INFLUENCE OF THE TRACK

The influence of the track in greyhound injuries has been widely recognised (Walpole 1940, Gannon 1972, Prole 1976, Poulter 1984, Sweeney 1987, Johnson and others 1988, Johnson and others 1989). Unfortunately, there is a paucity of objective studies assessing the effect of the track on lameness in greyhounds, whilst the literature concerning equine race courses is extensive (Frederick and Henderson 1970, Cheney and others 1973, Dalin and others 1973, Fredricson and others 1975[a], Fredricson and others 1975[b]).

It has been suggested (Johnson and others 1988) that the same factors that may contribute to lower limb lameness in horses (direction of the races, racetrack surface and geometric design) can also apply to greyhounds.

DIRECTION

The counterclockwise direction of the races is a major determinant of the anatomical distribution of stress fractures in greyhounds. When the dog is rounding a bend, stresses are concentrated in some particular areas of the limbs, that become apparent as more predisposed to fracture. Table 2 summarizes the reports in which the distribution of the fractures was biased towards one limb.

Report	Fracture	Distribution
Bellenger and others (1981)	Metacarpus	68% in the fifth left metacarpal bone
Boudrieau and others (1984)	Central tarsal bone	96% in the right tarsus
Ost and others (1987)	Fibular tarsal bone	96% in the right tarsus
Johnson and others (1988)	Accessory carpal bone	80% in the right carpus

Table 2. Anatomical distribution of fractures in greyhounds.

The importance of the direction of the races on stress fractures can be deduced from the observation that, although central tarsal bone fractures occur most of the times in the right leg, fractures in the left leg have been well documented when the dog was racing in a clockwise direction (Dee 1981).

SURFACE

Greyhound racetrack surfaces are varied and may consist of turf, sand or a mixture of the two. Davis (1967[a]) noted that the different incidence of central tarsal bone fractures in British and Australian greyhounds could be related to the racetrack surface. This fracture is an uncommon injury in Australia, where greyhounds race predominantly on turf, whilst it is relatively common in British circuits, where mainly sandy surfaces are found.

The different surfaces did not affect, however, the incidence of accessory carpal bone fractures, as reported by Johnson and others (1989). These authors studied the characteristics of this fracture in two populations geographically separated, combining the data from the cases presented to the University of Sydney and Colorado State University. Although tracks are turf in Sydney and sandy loam in Colorado, their results showed no statistical difference either in the mean age of the patients, male to female ratio, anatomical distribution or the incidence of the different types of fracture.

Studies on thoroughbred racehorses placed great emphasis on the importance that the track surface exerts over the incidence of lameness. Cheney and others (1973) found a linear correlation between the force sustained by the limb when racing and the rate of occurrence of lameness.

In this regard, Prole (1976), after examining the records of lameness injuries of two tracks, found an annual variation in the incidence of lameness: in wet years there were fewer injuries, whilst dry years, with faster running conditions, showed a greater number of injuries. A seasonal variation was also found: there was a fairly constant peak occurring in August and September with a seasonal low in the winter months of December to February. This author suggested that the main factor contributing to this annual variation is the weather, because of its influence on the hardness of the surface; in harder surfaces the nails of the greyhounds grip more firmly, therefore allowing for faster speeds.

RACETRACK DESIGN

Two aspects of the racetrack design have been implicated as predisposing factors to lameness: the radius of the bends and the underbanked semicircular curves.

Length of the radius

When moving at speed along a curved track, the greyhound is subjected to a centrifugal force which exerts an outward pull, tending to make the animal follow a straight tangential course. The centrifugal force increases as the radius of the curve is reduced and at faster speeds.

The two semicircular curves that comprise the bends of a racing circuit should have a radius of at least 100 yards to enable greyhounds to gallop around in reasonable safety (Sweeney 1987). Otherwise, they are forced to lean to overcome centrifugal force and in this position, the safe biomechanical load in the musculo-skeletal system may be exceeded. Many tracks conform to a tighter radius than 100 yards and hence greyhounds are prone to serious injury on these tracks.

Underbanking

Underbanked tracks have been shown to cause gait asymmetries in horses (Dalin and others 1973, Fredricson and others 1975[a], Fredricson and others 1975[b]). These asymmetries are accentuated at the beginning and especially at the end of the curves. The horses are not capable of maintaining their habitual action and make galloping movements with the hind limbs while trotting with the fore limbs. This incoordination leads to abnormal stresses, especially in the distal joints, which probably predispose them to lameness (Dalin and others 1973).

CHAPTER 3:

MATERIALS AND METHODS

RETROSPECTIVE STUDY

The clinical records and radiographs of 215 greyhounds undergoing surgery at G.U.V.H. between 1979 and 1990 were reviewed to determine the nature of the complaint.

The records and radiographs of the cases presented with accessory carpal bone fracture were further analysed. The data collected included:

Signalment:
Sex, age, weight.

Limb affected

History of the patient:

Circumstances of the injury, ie., whether it occurred negotiating a bend or in the straight.

Duration of the injury, understood as the time elapsed between the onset and the presentation at G.U.V.H.

Aetiology:

Fractures associated with a direct traumatic incident

Stress fractures(1).

Clinical signs:

Soft tissue swelling in the carpal region

Crepitation on manipulation of the carpus

Presence of lameness

Pain on manipulation of the carpus

Restriction in the range of movement of the carpus

Type of fracture:
The classification of accessory carpal bone fractures proposed by Johnson (1987) was followed to determine the type of fracture (see Introduction for details).

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(1) Stress fractures were defined as those that arose without external trauma and as a result of self-applied stresses within the musculo-skeletal system.

Previous management:
Where the dog had received treatment prior to referral to G.U.V.H., the nature of the treatment was recorded

Other injuries:
Information was gathered concerning any systemic disease that could have affected the health of the animal, or any concurrent injury likely to hinder its performance.

Radiological evaluation:
Standard medio-lateral and dorso-palmar projections were taken in all cases and, where indicated, additional oblique and stressed views. Follow-up radiographs were taken in some of the dogs.

An objective measurement of the following characteristics of the fracture was made:

Fragment size
Displacement of the fragment from the accessory carpal bone
Number of fragments detached from the accessory carpal bone
Number of fragments not removed during the surgery

A subjective assessment of another group of parameters was carried out. This group included:

Extent of soft tissue swelling
Degree of new bone formation, in the form of periosteal reaction, osteophyte or enthesophyte formation
Subluxation of the accessorioulnar carpal joint, defined as an abnormally increased joint space

In an attempt to quantify this second group of parameters, a scoring system was devised. The radiographic scores were as follows:

No radiographic abnormalities detected:	0
Mild changes:	1
Moderate changes:	2
Severe changes:	3

FOLLOW-UP QUESTIONNAIRE

The owners of the greyhounds presented with accessory carpal bone fractures were contacted either by letter or telephone. The follow-up questionnaires requested the following information:

1) Did the dog become sound after the operation?
2) Did the dog return to racing activity?
3) Did the dog ever win or place?

For purposes of comparison, these 3 questions were similar to those of a similar follow-up study used to evaluate the dogs treated by internal fixation (Johnson and others 1989). Other questions were also included:

4) Did the dog sustain any other injury after the operation?
5) Was the reason for retirement related to the accessory carpal bone fracture?
6) Were any other abnormalities noticed?
7) Any other comments?

EVALUATION OF PRE-OPERATIVE PROGNOSTIC INDICATORS

Once the data from the retrospective and follow-up studies had been collated, an evaluation of the following potential prognostic indicators was carried out:

Duration of the injury
Radiological evidence of osteophytes at the time of presentation
Age of the dog
Weight of the dog
Fragment size
Displacement of the fragments

The values of each of the prognostic indicators for the 19 dogs in which the follow-up was available were statistically analysed using the Minitab Statistics Software[1] (Mann-Whitney test), with $p<0.05$ set as the criterion for significance (Monk 1991).

(1) Minitab Version 8, Minitab Inc. 3081 Enterprise Drive, PA, USA.

CHAPTER 4:
RESULTS

SECTION 1: RETROSPECTIVE STUDY

INCIDENCE OF THE FRACTURE

The case records of the 215 greyhounds presented to G.U.V.H. between 1979-1990 revealed that 149 of them (70%) had suffered any kind of racing injuries. Seventy seven of these injuries were fractures of the appendicular skeleton (Figure 5). The anatomical distribution of these fractures reflects the most predisposed sites:

> Accessory carpal bone fracture was the most common fracture. It was recorded in 31/77 cases (40%).
> Fractures of the central tarsal bone occurred in 13/77 cases (17%).
> Fractures of the tibia (including tibial tuberosity) and fractures of the radius and ulna (including olecranon) occurred 7/77 (10%) and 11/77 times (14%) respectively.
> The 11 remaining recorded fracture sites (hind and fore sesamoids, hind and fore phalanges, metacarpals and metatarsals, acetabulum, femur, patella, fibular tarsal bone and third tarsal bone) accounted for 15/77 cases (19%).

Only 25 of the 31 cases of accessory carpal bone fracture were further analysed. Of the remaining 6 cases, 2 were operated on using a technique other than fragment removal. In the other 4 cases, there was a paucity of information regarding their clinical history, or the records were not available.

SEX

Of these 25 cases of accessory carpal bone fracture, 14 were males (56%) and 11 were females (44%) (Table 3).

AGE

The age of the cases included in this study is shown in Table 3.
The age range for males (24-36 months) is narrower than for females (19-36 months).
The mean age for males (28.2 months) was 2.8 months younger than for females (32.0 months).

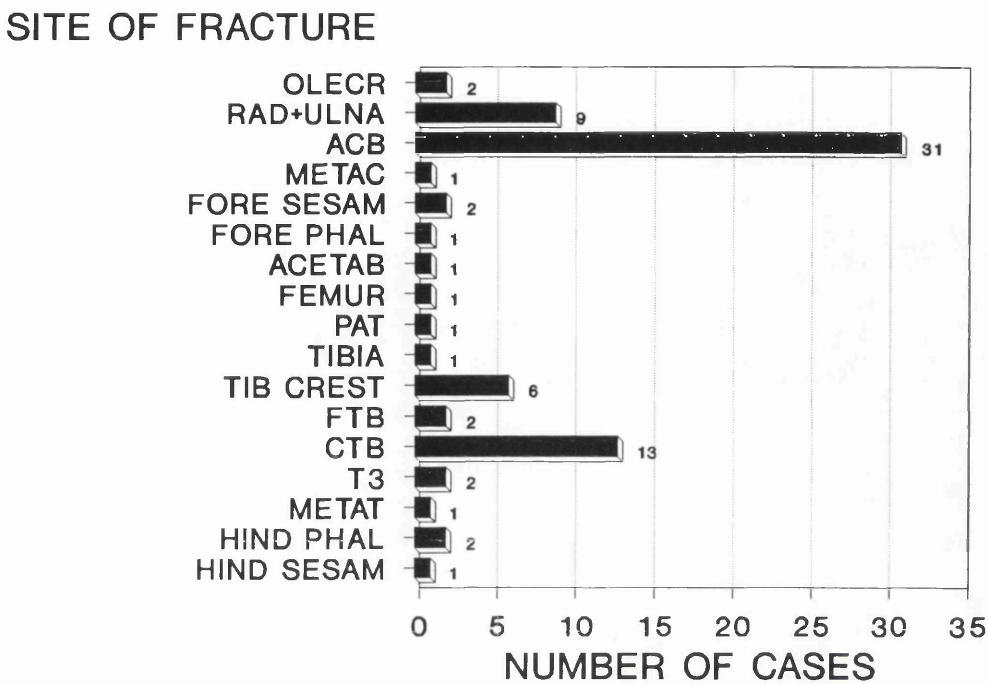

Figure 5. Anatomical distribution of 77 cases of fractures. (See Appendix 1 for abbreviations).

WEIGHT

The weight of the cases is presented in Table 3. The weight range for males (28-38 Kg) is wider than the range for females (25-29 Kg). The conformational differences between males and females are reflected when the two mean weights are analysed separately, males being 5 Kg heavier than females.

CLINICAL SIGNS

The clinical signs associated with accessory carpal bone fracture are summarized in Table 4. The most consistent signs recorded were swelling of the carpal region: 13 patients (Figure 6), lameness: 11 patients and pain on flexion of the carpus: 9 patients. Other clinical signs, such as restriction in the range of movement and crepitation were found only in 3 cases.

RADIOLOGICAL ASSESSMENT

The radiological features investigated are presented in Table 5. Figures 8-11 show some examples.

- Number of fragments: In 11 dogs, there was only one fragment detached from the accessory carpal bone. Two fragments were found in seven dogs and three or more fragments in three dogs.
- Size of the fragments: Fragments smaller than 2 mm were not considered. The 6 largest fragments (10 mm or more) involved the articular surface.
- Displacement of the fragments: Displacement of more than 2 mm from the accessory carpal bone occurred in 8 fractures. In these cases, the fragment was displaced by 2 to 5 mm. Fragments that were either in contact with the accessory carpal bone or minimally displaced (less than 1 mm) were not considered.
- On post-operative radiographs in 6 dogs, some fragments of variable size were still present after surgery. Five of these fragments were intra-articular and the other one was embedded in the tendon of the flexor carpi ulnaris.
- Subluxation of accessorioulnar carpal joint was detected in 8 dogs. In patient number 20, the subluxation appeared to be much more marked after the check radiographs at three months (score: 3) than in the post-operative films (score: 1).
- Soft tissue swelling was the most consistent radiological finding, being appreciated in 17 limbs. In 13 cases the swelling was considered moderate or severe.

• New bone formation on the carpal bones at the time of presentation was observed in 12 dogs. Periosteal reaction in the surface of the accessory carpal bone and osteophytes were the most common manifestations of new bone formation, although enthesophyte formation was also found.

TYPE OF FRACTURE

The distribution of the fractures in types is shown in Table 6. Some dogs sustained more than one fracture, so the number of fractures exceeded the number of dogs.

Intra-articular fractures (types I and II) accounted for 90% of the cases (28/31 fractures). Type I fractures represented 71% of the cases, being by far the most common. They occurred in 22 cases, 16 times alone and 6 times in combination with type II. Type II fractures only occurred in combination with type I. Type IV and type V fractures occurred on one and two occasions respectively. No type III fractures were recorded.

LIMB INVOLVED

Twenty four fractures were sustained in the right limb. The only fracture that affected the left limb was the one type IV fracture (Table 6).

DURATION OF THE INJURY

The time that elapsed from the injury to presentation at G.U.V.H. ranged from 1 day to 1 year (Table 6). The mean duration of the injury was 6.9 weeks. If dog number 8 (52 weeks duration) was excluded, the mean duration would be 4.9 weeks.

TREATMENT

The most common treatment received before referral to G.U.V.H. was some type of external coaptation (bandage, cast) and rest. Medication (Non Steroidal Anti-Inflammatory Drugs, Steroids) was instituted in 7 cases (Table 6).

AETIOLOGY

In all cases, the fracture occurred whilst the dog was racing, without evidence of any external trauma and therefore they were considered as stress fractures. In 3 cases, however, (dogs number 9, 17 and 22), the fracture could have been precipitated by collisions during the race (Table 6).

Dog number	Sex	Age (months)	Weight (Kg)
1	F	27	27
2	M	24	31
3	M	36	37
4	F	30	27
5	F	30	27
6	F	36	28
7	M	24	31
8	F	36	29
9	F	19	25
10	M	36	30
11	M	24	28
12	M	24	30
13	F	24	27
14	F	36	28
15	F	36	27
16	M	24	28
17	M	30	38
18	F	36	28
19	M	24	33
20	M	36	33
21	M	29	34
22	F	/	26
23	M	24	30
24	M	30	30
25	M	25	35
	M	28.2+/-1.3	32.0+/-0.8
MEAN+/-SD:	F	31.0+/-1.9	27.1+/-0.3
	Total	29.3+/-1.1	29.8+/-0.6

Table 3. Signalment of the cases of accessory carpal bone fracture.

KEY:

M: Male, **F:** Female, **/:** Not recorded, **SD:** Standard Deviation

Dog number (1)	Lam	Crep	Sw	ROM	Pain
1	NO	YES	YES	/	/
2	YES	/	YES	YES	YES
3	NO	/	NO	/	NO
5	/	/	/	/	YES
6	/	/	YES	/	NO
7	YES	/	YES	/	/
8	/	/	YES	YES	/
10	YES	YES	/	/	/
13	NO	/	YES	/	YES
14	YES	/	YES	/	/
15	NO	/	YES	/	YES
17	YES	/	YES	/	YES
18	YES	/	YES	/	YES
19	YES	/	NO	/	NO
20	YES	YES	YES	/	/
21	YES	/	YES	/	/
22	/	/	YES	/	YES
23	YES	/	/	/	YES
24	/	/	/	YES	/
25	YES	/	/	/	YES

Table 4. Clinical signs of the cases of accessory carpal bone fracture.

KEY:

Lam: Lameness, **Crep:** Crepitation of the carpal joints, **Sw:** Swelling in the carpal region, **ROM:** Restriction in the range of movement, **Pain:** Pain on manipulation of the carpus, /: Not recorded.

(1) No data were available for dogs 9, 11, 12 and 16.

Dog nº(*)	New Bone F	Subl	Sw	Size (mm)	Displ (mm)	F.*In situ* •
1	1	0	0	6		
2	2	0	1	8		
3	1	2	1	12	2	
4	0	2	2	**	5	
5	2	0	0	8		
6	1	0	2	6+4		Yes
7	1	0	2	10	3	
8	1	0	0	8	5	
9	0	0	2	10+5	8	
10	0	0	2	11	5	
11	0	2	2	10+8		Yes
12	1	2	3	8+2		
13	0	0	1	3		Yes
16	1	2	0	**		
17	0	0	2	4	2	Yes
18	1	0	1	4		Yes
19	1	2	2	8		Yes
20	0	1	2	10+9	2	
21	0	0	2	10+2	3	
22	0	0	1	9		
24	1	2	2	6+4		

Table 5 . Radiological evaluation of cases of accessory carpal bone fracture.

KEY:

Dog nº: Dog number. **Subl:** Subluxation of the accessorioulnar carpal joint. **Sw:** Swelling in the carpal region. **New Bone F:** New bone formation. **Displ.:** Displacement of the fragments. **F. *in situ:*** Fragments left *in situ*.

(*) No data were available for dogs 14, 15, 23 and 25.
(•) The size of these fragments varied from 1 to 4 mm.
(**) The degree of comminution did not allow an accurate measurement of the fragment size.

Dog nº	Durat (w)	Type (limb)	Aetiology	Tx. prior to ref.
1	8	I (R)	Stress #	Rest+Ext. Coapt.
2	2	I (R)	Stress #	Rest+Ext. Coapt.+NSAID's
3	1	I (R)	Stress #	Rest
4	1.5	V (R)	Stress #	Rest
5	12	I (R)	Stress #	Rest+Ext. Coapt.
6	10	I+II (R)	Stress #	Rest+Ext. Coapt.+NSAID's
7	6	I (R)	Stress #	Rest+Ext. Coapt.
8	52	I (R)	Stress #	Rest+Ext. Coapt.
9	0.7	I+II (R)	Collision	Rest+Ext. Coapt.
10	16	I (R)	Stress #	Rest+Ext. Coapt.+Steroids
11	0.1	I (R)	Stress #	Rest+Ext. Coapt.+NSAID's
12	8	I+II (R)	Stress #	Rest+Ext. Coapt.+Steroids
13	0.6	IV (L)	Stress #	Rest+Ext.Coapt
14	0.5	I (R)	Stress #	/
15	2	I (R)	Stress #	Rest+Ext. Coapt.
16	16	V (R)	Stress #	Rest+Ext. Coapt.
17	1.5	I (R)	Collision	Rest+Ext. Coapt.
18	2	I (R)	Stress #	/
19	5	I (R)	Stress #	Rest+NSAID's
20	6	I+II (R)	Stress #	Rest+Ext. Coapt.
21	0.7	I (R)	Stress #	Rest
22	3	I (R)	Collision	Rest+NSAID's
23	10	I+II (R)	Stress #	/
24	2	I+II (R)	Stress #	Rest+Ext. Coapt.
25	/	I (R)	Stress #	Rest+Ext. Coapt.

Table 6. Characteristics of accessory carpal bone fracture.

KEY:

Dog nº: Dog number. **Durat. (W):** Duration (weeks). **TX prior to ref:** Treatment prior to referral to G.U.V.H. **R:** Right limb. **L:** Left limb. **/:** Not recorded. **Ext.Coapt.:** External Coaptation (bandage, cast). **NSAID's:** Non Steroidal Anti-Inflammatory Drugs. **#:** Fracture.

Figure 6. Swelling on the palmar aspect of the carpus. Case not included in the retrospective study. Compare affected (right) with non-affected limb (left).

Figure 7. Case number 9 (type I accessory carpal bone fracture). Palmaromedial-dorsolateral oblique view of the right carpus. Two detached fragments can be seen distal to the articular surface of the accessory carpal bone.

Radiographic score: Subluxation: 0, Swelling: 2, New bone formation: 0.

Figure 8.1.

Figure 8.2.

Figure 8. Case number 20 (type I+II accessory carpal bone fracture). Lateral view of the right carpus.

Figure 8.1. Radiographic score of the X ray at the time of presentation: Subluxation: 0, Swelling: 2, New bone formation: 0.

Figure 8.2. Same dog three months after surgery. Severe new bone formation has developed along the margins of the accessory carpal bone.

Figure 9. Case number 17 (type IV accessory carpal bone fracture). Lateral view of the left carpus. Arrow shows small fragments at the site of insertion of the flexor carpi ulnaris.

Radiographic score: Subluxation: 0, Swelling: 2, New bone formation: 0.

Figure 10. Case number 4 (type V accessory carpal bone fracture). Lateral view of the right carpus. The arrows show the fracture lines traversing the body of the accessory carpal bone.

Radiographic score: Subluxation: 2, Swelling: 2, New bone formation: 0.

SECTION 2: FOLLOW-UP QUESTIONNAIRE

Questionnaires were answered by 19 of the 25 owners. In a few instances: questions number 6 and 7 (see Materials and Methods), the information obtained depended entirely on a subjective evaluation by the owner and, as such, it could not be considered totally reliable. The information gathered is summarised in Table 7.

The accessory carpal bone fracture or subsequent degenerative joint disease were the reasons for retirement in only 2/13 greyhounds of the group "good outcome". In 3 cases (dogs number 7, 13 and 15) retirement was due to a different injury.

Loss of speed on the bends was the most common abnormality noticed by the owners when the dog resumed racing activity. In 4 cases of the group "good outcome", the owner reported that the operation had not affected the performance of the greyhound.

RESULTS ACHIEVED BY THE DOGS MANAGED BY FRAGMENT REMOVAL

According to the results achieved by the dogs following surgery, two groups were formed: "Good outcome" (13/19 dogs) and "Poor outcome" (6/19 dogs). Each group was further divided into two sub-groups, which were defined as follows:

GOOD OUTCOME

Return to win: Excellent results were achieved when the dogs of this group resumed racing activity, winning one or more races. Dogs number 1 to 9 were included here. Of these dogs, 6 won more than one race, with 3 of them winning 10 or more races.

Return to racing: Four greyhounds (numbers 10 to 13) returned to racing activity following surgery, although none of the dogs in this group won any races.

POOR OUTCOME

Sound, not raced: This group included 3 dogs (numbers 14 to 16) which became sound after surgery but did not resume racing activity, since lameness reappeared as soon as the dog was trialled.

Remained lame: Another group of 3 dogs (numbers 17 to 19) never became sound again and no benefit from surgery was reported by the owner.

According to these results, the outcome following surgical repair of accessory carpal bone fracture by fragment removal was as follows:

- Seventy per cent of the dogs (13/19) returned to racing.
- Forty seven per cent of the dogs (9/19) returned to win.
- Fifteen per cent of the dogs (3/19) became sound but were unable to race.
- Fifteen per cent of the dogs (3/19) remained lame.

Dog number	Return to soundness	Return to race	Return to win	Reason for retirement	Other abnormalities	Other injuries	Additional comments
1	Yes	Yes, 8 weeks after the operation	6 wins				Used for breeding
2	Yes	Yes (10 times in 3 months)	3 wins				Used for breeding
3	Yes	Yes	Yes		Loss of speed on the bends		Returned to pre-operative performance
4	Yes	Yes	40 wins				Returned to pre-operative performance
5	Yes	Yes	17 wins/18 second places				
6	Yes	Yes	Yes	ACB fracture			Returned to pre-operative performance
7	Yes	Yes	4 wins	Pelvic fracture		Pelvic fracture 2 months after the operation	Returned to pre-operative performance
8	Not completely	Yes, 6 months after the operation	6 wins	Arthritis in the affected carpus		Split web in the affected leg	Retired at 4.5 years (1.5 years after the operation)
9	Yes	Yes	Yes				
10	Yes	Yes	No		Loss of speed on the bends		
11	Yes	Yes	No		Loss of speed on the bends		

Table 7. Follow-up questionnaire. (ACB fracture: accessory carpal bone fracture).

Dog Number	Return to soundness	Return to race	Return to win	Reason for retirement	Other abnormalities	Other injuries	Additional comments
12	Yes	Yes	No		Loss of speed on the bends		
13	Yes	Yes	No			Sesamoid fracture	
14	Yes	No	No	ACB fracture			
15	Yes	No	No	Second ACB fracture (same leg)		Subsequent ACB fracture in the first race (2.5 months after the surgery for the first ACB fracture)	Second ACB fracture operated upon. Poor outcome. Used for breeding
16	Yes	No	No	ACB fracture			
17	No	No	No	ACB fracture			
18	No	No	No	ACB fracture			
19	No	No	No	ACB fracture			

Table 7. Follow-up questionnaire (Cont.) (ACB fracture: accessory carpal bone fracture).

SECTION 3: EVALUATION OF PROGNOSTIC INDICATORS

The following evaluation was only carried out in the 19 dogs in which the follow-up was available. The mean values of the different prognostic indicators for the groups "good outcome" and "poor outcome" are shown in Table 8.

DURATION OF THE INJURY

The differences between the mean duration of the two groups were not significant. It is noteworthy that the mean duration for the group "poor outcome" is half the duration for the group "good outcome". Even if dog number 8 (52 weeks duration) was excluded, the mean for the group "good outcome" would be still higher than for the group "poor outcome".

RADIOLOGICAL EVIDENCE OF OSTEOPHYTES AT THE TIME OF PRESENTATION

Radiological evidence of osteophytes in the carpal joints was detected in 9/13 dogs of the group "good outcome" and in 3/4 dogs of the group "poor outcome". No differences were found between the scores of the two groups.

AGE AT THE TIME OF PRESENTATION

Dogs of the group "good outcome" were 2.6 months younger than dogs of the group "poor outcome". The difference between the mean ages, however, was not statistically significant.

WEIGHT OF THE DOG

The mean weights for the groups "good outcome" and "poor outcome" were similar, with the former being 1.3 Kg lighter, although this difference was not significant.

FRAGMENT SIZE

The mean fragment size for the group "good outcome" was 0.9 mm larger than for the group "poor outcome". No statistically significant difference was found between the two groups.

DISPLACEMENT OF THE FRAGMENTS

The mean displacement for the group "good outcome" was 0.6 mm greater than for the group "poor outcome", although the difference between the two was not significant.

Prognostic indicator	Good outcome	Poor outcome
Duration of the injury (weeks)	9.0+/-3.8	4.5+/-2.3
Rad. Evid. Ophytes (score)	1.0+/-0.1	1.0+/-0.4
Age of the dog (months)	28.4+/-1.6	31.0+/-2.4
Weight of the dog (Kg)	29.0+/-0.8	30.3+/-1.7
Size of the fragment (mm)	7.9+/-0.6	7.0+/-0.5
Displacement of the fragment (mm)	1.2+/-0.2	0.6+/-0.1

Table 8. Mean values+/-SD of the different prognostic indicators.

KEY:

Rad. Evid. Ophytes: Radiological evidence of osteophytes, **SD:** Standard Deviation.

CHAPTER 5:

DISCUSSION

SECTION 1: CHARACTERISTICS OF THE FRACTURE

INCIDENCE OF THE FRACTURE

Accessory carpal bone fractures accounted for 21% of the total number of racing injuries at G.U.V.H. (Figure 11.1). This is a higher frequency than was shown in Prole's report (1976), in which this percentage was only 1.5%.

Accessory carpal bone fracture was the most common presented at G.U.V.H., accounting for 40% of the total number of fractures (Figure 11.2). Previous surveys of racing injuries in greyhounds do not confirm this observation. Fractures of the metacarpal bones and central tarsal bone were the most common fractures reported by Gannon (1972) and Prole (1976) respectively.

Table 9 compares the incidence of accessory carpal bone fractures seen at G.U.V.H. with the different figures taken from the literature.

Report	ACB fracture/Total number of fractures (%)
Gannon (1972)	10/100 (10%)
Prole (1976)	12/47 (25.5%)
G.U.V.H.	31/77 (40%)

Table 9. Percentage of accessory carpal bone fractures in relation to the total number of fractures. (ACB: Accessory carpal bone).

The fact that G.U.V.H. is a referral centre could have accounted for this difference. Since a higher percentage of specific fractures are presented, an accurate reflection of the real incidence of fracture types cannot be expected. In this regard, metacarpal and metatarsal fractures have only been recorded once each, although they are generally regarded as common (Gannon 1972, Dee and Dee 1985). In contrast, the rare stress acetabular fracture (Dee and Dee 1985, Wendelburg and others 1988) has been recorded once at G.U.V.H.

TYPES OF FRACTURE

The relative frequencies of the cases reported in this study are consistent with the only existent paper in the literature concerning the occurrence of the different types of fracture (Johnson and others 1988). The distribution of accessory carpal bone fractures according to type in both studies is shown in Figure 12.

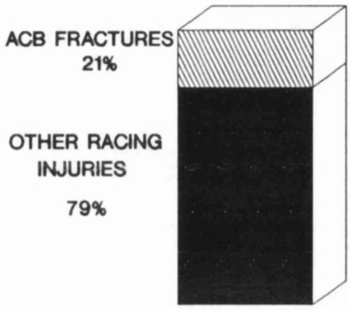

Figure 11.1

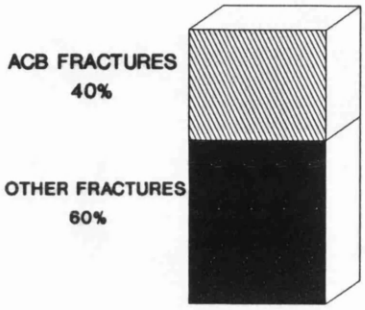

Figure 11.2

Figure 11. Incidence of accessory carpal bone fractures as a percentage of racing injuries (Figure 11.1) and as a percentage of all fractures (Figure 11.2).

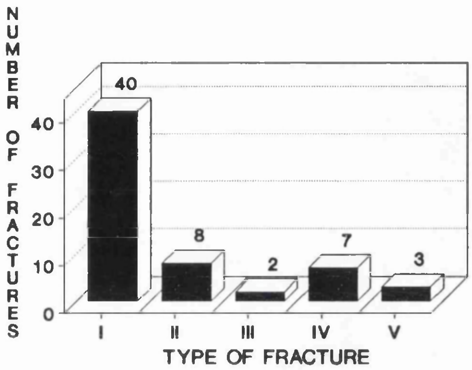

Figure 12.1

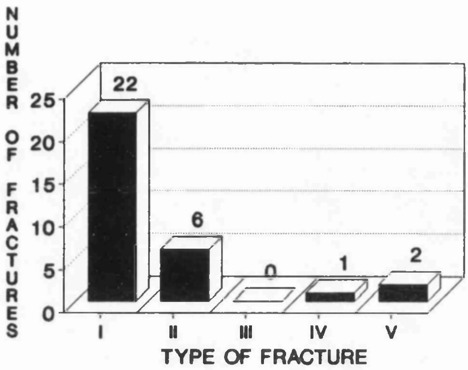

Figure 12.2

Figure 12. Distribution of accessory carpal bone fractures according to type. **(Figure 12.1: Johnson and others 1989, Figure 12.2: GUVH).**

It has been stated that there are some basic biomechanical differences in the pathogenesis of the various types of fracture (Johnson and others 1988).

Hyperextension of the carpus has been regarded as the most probable mechanism for this injury (Dee and Dee 1985, Dee 1988). The accessory carpal bone acts as a fulcrum for strong ligaments and tendons, thus preventing hyperextension of the carpus during full weight-bearing. The tension of the flexor tendons during extreme extension is transmitted through the long axis of the bone, to terminate at the palmar ligaments. Type I is the most common type of fracture and always accompanies types II and III. This situation suggests that the leverage exerted by the accessory carpal bone is focused at its base, resulting most of the time in an avulsion fracture of the craniodistal articular surface. It is difficult to elucidate the sequence of occurrence of types I+II and I+III fractures.

Despite the fact that 80% of accessory carpal bone fractures occur in the right limb (Johnson and others 1988), type IV fractures occur most commonly in the left limb. This was the case in the only type IV fracture recorded in the study at G.U.V.H., and in Johnson and others' report (1988), 5/7 type IV fractures were in the left leg. Based on the different roles of each fore limb during the racing gallop (the left fore leg is used as a pivot when negotiating the bends), these findings would suggest that the pathogenesis of type IV fractures may be different to that of the other types.

Type V fractures (comminuted) have been considered age-related, as they only occurred in young dogs of less than 18 months old that were being schooled or trained (Johnson and others 1988). Bone mineral content is low in young animals. There is a gradual increase in the degree of collagen cross-linking and bone mineralisation with aging, which makes bone tissue stiffer and stronger (Carter and Spengler 1982).

However, the amount of strain required to produce failure of a bone generally decreases with aging, therefore rendering it slightly more brittle than the bone of younger individuals (Carter and Spengler 1982). This might account for the transition to avulsion type fractures in mature greyhounds (Johnson and others 1988). The two dogs with type V fracture reported in the present study, numbers 4 and 16, were older than 18 months (30 and 24 months old respectively).

In the cases seen at G.U.V.H. , no correlation could be established between the different types of fracture and the outcome following surgery.

It has been stated that the prognosis of accessory carpal bone fractures worsens as a result of degenerative joint disease, insofar as some dogs with extra-articular fractures will return to racing after an extended rest; on the contrary, an intra-articular fracture usually results in early retirement if surgery is not performed (Dee and Dee 1985). Although fractures type I and II are intra-articular and therefore susceptible of initiating degenerative joint disease, it did not seem to affect the prognosis in the cases treated at G.U.V.H: in 11/16 dogs with type I or type I+II fractures, the outcome was good; a similar proportion of dogs (2/3) with the other fracture types had a good outcome.

Although type V fractures are regarded as the most severe, one of the two cases recorded at G.U.V.H. returned to win (number 4) and the other (number 16) became sound, although lameness reappeared when training was resumed.

The dog with the only type IV fracture had a good outcome, therefore confirming previous observations (Dee and Dee 1985). Type IV fractures were not reported in the study of the prognosis of accessory carpal bone fractures treated by internal fixation (Johnson and others 1989).

AETIOLOGY

All the fractures in this study occurred whilst the dog was racing or trialling. In 22/25 cases (88%) they were considered as stress fractures, since no external trauma was recorded. This finding is in accordance with Gannon (1972), who reported that 94 out of 100 greyhound fractures reviewed (94%) were stress-induced. In dogs number 9, 17 and 22, however, the fracture could have been precipitated by a collision with another dog.

There are no objective data regarding the moment of the race or the site of the track where accessory carpal bone fractures take place. Anecdotal observations (Miller 1991, personal communication(1)) would indicate that they tend to occur late in the meetings and especially at the end of each race, probably due to the uneven surfaces and the fatigue of the flexor tendons to overcome the carpal hyperextension, placing therefore more stress on the palmar carpal ligaments.

Most authors agree that these fractures are usually sustained as the dog is rounding a bend (Bateman 1960, Dee 1981, Dee and Dee 1985, Johnson 1987). This was the case in the three dogs seen at G.U.V.H. in which this information was recorded.

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(1) Miller, A. Department of Veterinary Surgery, Glasgow University Veterinary School.

LIMB INVOLVED

In the scant literature pertaining to accessory carpal bone fractures there has been little agreement on which limb was most frequently involved. Table 10 summarizes the different author's data regarding the anatomical distribution of this fracture, compared with the cases seen at G.U.V.H.

Report	Limb most frequently involved
Gannon (1972)	50% each limb
Hickman (1975)	Left
Prole (1975)	Right (91%)
Johnson and others (1988)	Right (80%)
G.U.V.H.	Right (96%)

Table 10. Anatomical distribution of accessory carpal bone fractures.

The current view, however, is that the right limb is more predisposed than the left. This was the case in the present study, where 96% of the fractures occurred in the right leg.

Most fractures in greyhounds result from indirect forces acting on the limb and not from direct trauma. The predisposition for the right limb therefore reflects the areas subjected to greatest stresses when racing. As the greyhound approaches the bend the right fore leg, moving in an arc, provides propulsion, pushing the body along the line of the curve. This movement concentrates great stresses on the palmar ligaments of the right carpus (Bateman 1960, Vaughan 1985, Johnson 1987).

Type IV fractures seem to be more frequent in the left limb and this could account for the figures given by Gannon (1972) and Hickman (1975) if they had had a greater number of type IV injuries.

SEX INCIDENCE

The studies of accessory carpal bone fracture found in the literature where a sex distribution was reported are compared with the results found at G.U.V.H. in Table 11.

Author	Males	Females
Gannon (1972)	7	3
Johnson and others (1988)	32	18
G.U.V.H.	14	11

Table 11. Sex distribution of the cases of accessory carpal bone fracture.

In the series of fractures seen at G.U.V.H. no sex predisposition could be established. A slightly higher percentage of males was found (56%), similar however to the percentage of racing males in the Glasgow area (60%) (Lithgow 1991, personal communication[1]). The higher proportion of males: 7/10 (70%) in Gannon's report (1972) would indicate a probable sex relationship, but a random selection of adult racing greyhounds examined by this author showed a similar pattern: 643/1000 males (64.3%). Bearing in mind this positive selection for racing males over females, Gannon concluded that sex predisposition in his series of fractures was not significant.

The male to female ratio in another report (Johnson and others 1988) was 2.75 to 1 at Colorado State University, not significantly different from the male to female ratio of racing greyhounds in this State: 2 to 1. Therefore, at least in Colorado State, male greyhounds were not at a higher risk of sustaining this fracture.

A sex predisposition has been suggested for other stress fractures in greyhounds (Gannon 1972). This author stated that males seemed to be more prone to metacarpal fractures (25/32 dogs in his report) and tibial fractures (14/16 dogs)[2]. Apart from the higher number of male racing greyhounds, several reasons for this predisposition can be put forward. Firstly, the greater body weight of the male compared with their female counterparts. This difference would account for a greater centrifugal force acting upon the limbs of the male greyhound when negotiating the bends. Secondly, the female greyhound matures in bone development at an earlier age than male litter-mates; the metacarpals of the lighter female are therefore more completely ossified and more mature than those of the heavier males at comparable age and as such, are more able to withstand the stresses of training and racing (Gannon 1972). None of these factors seemed to affect the sex distribution of accessory carpal bone fractures at G.U.V.H.

(1) Lithgow, R. (Racing Manager, Shawfield Stadium, Glasgow)
(2) Fourteen of these sixteen fractures were tibial tuberosity avulsions and two were fractures of the shaft.

AGE

The mean age incidence in the cases treated at G.U.V.H. is similar than that cited by Johnson and others (1988), and higher than Gannon's figures (1972). The mean age of these three studies is compared in Table 12.

Author	Mean age +/-SD (months)
Gannon (1972)	23.8*
Johnson and others (1988)	27.9+/-1.2
G.U.V.H.	29.3+/-1.1

Table 12. Mean age and SD of cases of accessory carpal bone fracture. (*) The SD was not given in this report.

The age distribution of the dogs seen at G.U.V.H. shows 2 peak ages for the occurrence of the fracture: 20-24 and 35-39 months. These two periods represented 20/31[1] of the dogs. This distribution is slightly different to that reported in another study (Johnson and others 1988). These authors found that most of their cases (34/60[1]) occurred between 20-29 months of age (Figure 13).

A relationship between the site of the stress fracture in greyhounds and the age of the patient has been suggested (Gannon 1972). In general, in dogs under 12 months of age, most fractures were sustained in the long bones of the skeleton, whereas in dogs after 12 months of age, the fractures almost exclusively affected the lower limbs and the spine. This is related to the fact that age determines the state of bone development and activity to which the patient is subjected. In terms of biomechanics, the failure in bones under 12 months of age occurred mainly in the lever system, whereas after 12 months of age the failure appeared in the gearing and pulley systems of the skeleton (Gannon 1972).

Accessory carpal bone fractures presented at G.U.V.H. conformed to this distribution and the 25 patients were well over 12 months of age, with only one (number 25) under 24 months old. This finding was to be expected, since greyhounds in the Glasgow area commence trainings at around 15 months old (Lithgow 1991, personal communication[2]).

(1) These figures correspond to the number of fractures, not to the number of dogs.
(2) Lithgow, R. (Racing Manager, Shawfield Stadium, Glasgow).

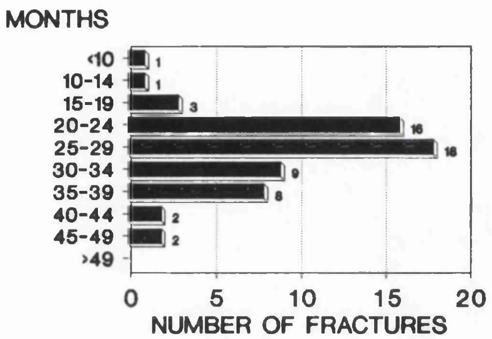

Figure 13.1.

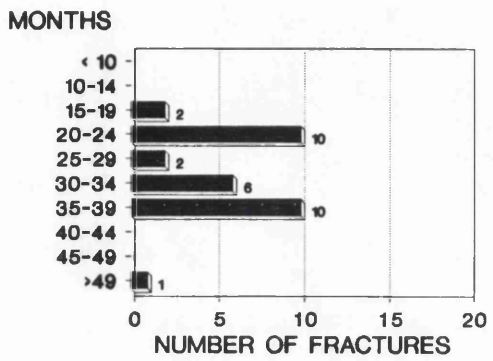

Figure 13.2.

Figure 13. Distribution of accessory carpal bone fractures according to age. (Figure 13.1: Johnson and others 1988. Figure 13.2: GUVH).

CLINICAL SIGNS

The typical history of accessory carpal bone fractures at presentation is that during a race or trial, the dog became lame whilst rounding a turn and finished last, or the lameness was noticed at the completion of the race. Very occasionally, the dog finishes with a good time or even wins. The lameness is usually worse the following day and will persist for two to four days. The relatively rapid disappearance of soft tissue swelling and apparent improvement of the lameness with rest may cause the trainer to postpone presentation of the patient until the injury becomes chronic. Depending on the type and extent of both the ligamentous and bony damage, the dog may come back into training and even to the races, but invariably will come off lame again (Vaughan 1985).

Although lameness at the time of presentation, together with swelling in the carpal region has been the most consistent clinical sign in the cases seen at G.U.V.H., it was not present in 4 of the 15 dogs in which this information was available. Therefore, it cannot be considered a constant clinical sign of accessory carpal bone fractures. Previous reports agree with this finding (Hickman 1975, Brinker and others 1983, Vaughan 1985).

RADIOLOGICAL SIGNS

New bone formation in the carpal joints was present in 14/21 dogs, most commonly in the form of osteophytes. Periosteal reaction along the margins of the accessory carpal bone and enthesophyte formation were also observed.

Strains or sprains at tendon or ligament insertions can cause enthesophyte formation (Resnick and Niwayama 1983). Enthesophytes developed at the insertion of the flexor carpi ulnaris in two dogs with type I fractures. This finding, also reported by other authors (Johnson and others 1989), might indicate a concomitant injury to this tendon at the time of the fracture.

The relevance of the accessorioulnar carpal joint subluxation in cases of accessory carpal bone fracture is questionable. Disruption of the ligamentous attachments in this joint permitted an increase in the joint space in 8 dogs. However, where more than one view was taken, it was noticed that different degrees of flexion/extension or rotation of the carpus significantly modified the width of the joint space. For this reason, subluxation of the accessorioulnar carpal joint was regarded as an unreliable radiological sign.

SECTION 2: ASSESSMENT OF PRE-OPERATIVE PROGNOSTIC INDICATORS

Due to the limitations of any retrospective study, a small number of cases (nineteen) were available for analysis. This situation reduced the likelihood that a given factor would appear to be statistically significant. However, useful information can be deduced.

DURATION OF THE INJURY

Although most authors agree that the duration of the injury is one of the main factors influencing the prognosis for accessory carpal bone fractures, the results of this study do not support this view; the mean duration of the injury did not correlate with the outcome following surgery.

It has been suggested that where the injury is older than three months, success could be expected in less than 45% of the cases, and where is more recent than three months, in 60-90% of the cases (Dee and Dee 1985).

Such a difference in the prognosis was not observed in the cases presented at G.U.V.H. A good outcome was observed in twelve out of fifteen dogs (80%) in which the injury was more recent than 3 months, but a similar proportion, three out of four dogs (75%), was found when the injury was older than 3 months.

AGE

It has been stated that greyhounds younger than 30 months have a better prognosis than older dogs (Dee and Dee 1985). The results in this study do not conform to this observation. Although the mean age for the group "poor outcome" was older than 30 months (31 months), the difference with the group "good outcome" (mean age: 28.4 months) was not statistically significant.

WEIGHT

Heavier dogs are more likely to develop greater stresses on the limbs whilst negotiating the bends. This has been considered as a predisposing factor to injury (Poulter 1984, Sweeney 1987). However, the difference in weight was not significant when the groups "good outcome" and "poor outcome" were compared.

RADIOLOGICAL EVIDENCE OF OSTEOPHYTES AT THE TIME OF PRESENTATION

Most accessory carpal bone fractures result from a disruption of the ligamentous attachments to this bone.

Instability caused by ligament damage has long been regarded as an initiating factor in osteophyte formation (Marshall 1969). While in itself the presence of osteophytes is probably not evidence for a diagnosis of degenerative joint disease, it is indicative of abnormal activity within a joint (Lipowitz and Newton 1985).

Correlation between the presence of lameness when the dog returned to racing and the presence of osteophytes could not be established in the present study at G.U.V.H. These findings are in accordance with those of other authors who stated that correlation between the degree of lameness and the presence of osteophytes cannot be established in the stifle joint following rupture of the anterior cruciate ligament (Pond and Campbell 1972, Heffron and Campbell 1979, Ligonday 1990). Similar studies involving the carpal joints could not be found in the literature.

FRAGMENT SIZE

Fragment size was not considered a reliable parameter of the disruption of the articular surface in fracture types I and II. No significant correlation could be found between the mean fragment size of the two groups and the results of the operation. In addition, radiological assessment of the chip size can be inaccurate since some fragments show up in the radiographs a different size than they actually are (Davis 1967[a]). In this regard, it has been stated that radiographs of chronic avulsion fractures may not be diagnostic because of the lysis of bone fragments (Dee and others 1990).

DISPLACEMENT OF THE FRAGMENTS

Displacement of the fragments from the accessory carpal bone was regarded as a questionable parameter of the disruption of tendon and ligament insertion into bone. The positioning of the carpus when taking the radiographs may alter the displacement of the fragments; views taken with the carpus in hyperextension distract the fragments and increase the gap between them and the accessory carpal bone (Dee 1988). No correlation could be established between this parameter and the outcome following surgery.

SECTION 3:
DETERMINATION OF THE PROGNOSIS IN ACCESSORY CARPAL BONE FRACTURES

The data collected from the follow-up questionnaire revealed that 70% of dogs undergoing surgery by fragment removal returned to racing. Only 47% of the dogs returned to win. Although due to the reduced number of cases treated these results cannot be generalised, they can give an indication of the prognosis of the fracture managed by fragment removal.

The success of fragment removal has not been objectively evaluated before. The determination of the prognosis in the cases treated at G.U.V.H. supports previous observations that this technique is not a highly successful procedure (Vaughan 1985). Yore (1983) quoted a success rate of 50-60% and Brinker and others (1983) stated that less than 50% of the greyhounds treated with this technique had ever won a race. The most recent attempt to give a prognosis following fragment removal was made by Dee and Dee (1985). According to these authors, the likelihood of return to racing after surgery varied from 45% to 90%. Three factors were implicated in this variation: age of the dog, duration of the injury and development of degenerative joint disease.

All of these reports, however, were presented without supporting data. The only documented study on the prognosis of accessory carpal bone fractures referred to internal fixation (Johnson and others 1989). The characteristics of the surgical repair of twelve cases reviewed by these authors are summarised in Table 13.

Dog number	Fracture type	Comments
1 to 8	I	No fragments left *in situ*
9	I+II	Unrepaired fragment left *in situ*
10	I+II	Unrepaired fragment excised K wire augmenting the screw
11	I+III	3 screws used
12	I+III	Unrepaired fragment left *in situ*

Table 13. Characteristics of the surgical repair of 12 cases of accessory carpal bone fracture by internal fixation (Johnson and others 1989). (K. wire: Kirschner wire).

Reattachment of sprain-avulsion fracture fragments with internal fixation would appear a more rational approach to the reestablishment of the anatomical and functional integrity of the accessory carpal bone, since it counteracts the distracting forces exerted by the ligament and confers stability to the fracture. This is in contrast with fragment removal, where the proximal attachment of the ligament and joint congruity are lost and subluxation may persist (Johnson and others 1989). However, internal fixation requires the investment of more time and material, as well as being technically more demanding. Some complications derived from the use of implants can also be expected.

The complications that may affect the outcome of accessory carpal bone fractures using internal fixation have been described (Johnson and others 1989).

These authors stated that poor reduction resulted in incongruity of the articular surface in 3 of the dogs described in their report. The use of positional screws, so that a gliding hole was not drilled in the avulsed fragment, places complete reliance on the bone reduction forceps to gain interfragmentary compression. Without interfragmentary compression, there is not friction created between the apposing fracture surfaces, allowing the fragment to rotate around the screw. This technique can therefore result in a less desirable fracture reduction and fixation, with a greater likelihood of instability or widening of the fracture gap.

Failure to use drill-centering sleeves can result in serious misalignment of the gliding hole with respect to the pilot hole. As a consequence of that, final tightening of the screw may have caused screw bending and loss of fracture reduction seen in one of the dogs described by Johnson and others (1989).

Radiographic signs of union usually develop by 5-8 weeks after screw fixation. Delayed union occurred in 1/12 cases in Johnson and other's report (1989). These authors suggested that this could have been the result of incomplete fracture reduction, fracture instability or traumatically damaged blood supply during the surgical repair.

Eleven dogs were available for follow-up evaluation in Johnson and other's report (1989). Ten dogs (90%) returned to racing or training activity and the other dog (number 11) was euthanased before having the opportunity to race, after developing distemper 7 weeks following surgery. Five of these dogs (45%) had won one or more races (numbers 1, 2, 3, 8 and 10).

Although the outcome following surgery in this report and in the retrospective study at G.U.V.H. cannot be compared statistically, some observations can be made. It is noteworthy that a higher percentage of dogs treated with fragment removal returned to racing and won at least one race. However, the overall percentage of dogs that returned to racing was not as great as with internal fixation.

No reports have been found in the literature comparing a similar number of cases treated by these two techniques. It is suggested that such a study would be beneficial in determining whether fragment removal is an alternative technique to internal fixation.

SECTION 4: INTRA-OPERATIVE AND POST-OPERATIVE FACTORS THAT MIGHT INFLUENCE THE PROGNOSIS OF ACCESSORY CARPAL BONE FRACTURES

Some factors occurring during surgery or in the post-operative period have been associated with a negative influence on the prognosis of accessory carpal bone fractures (Johnson and others 1989):

*Iatrogenic ligament transection involved in the surgical approach
*Progression of the bony changes of degenerative joint disease
*Fragments not removed after surgery
*Inadequate period of convalescence
*Occurrence of a second injury or disorder
*Undiagnosed co-existing ligament and tendon injuries

A statistical evaluation of these factors could not be carried out in the cases seen at G.U.V.H. due to insufficient information.

IATROGENIC TRANSECTION OF LIGAMENTS

Avoidance of transection of accessorio-metacarpal ligaments as part of the surgical approach has been regarded as decisive for the success of the surgical repair of accessory carpal bone fractures (Johnson and others 1989).

If this desmotomy is inevitable, optimum repair results when the ends of this ligament are brought into apposition and immobilised until adequate tensile strength is attained (Earley 1978). However, other methods of repair can be contemplated. Two procedures for the surgical repair of the accessorio-metacarpal ligaments have been described in dogs (Earley 1978). One of the procedures involves the use of orthopaedic wire and the other is based on autogenous tissue reconstruction, with transposition of either part of the ulnaris lateralis tendon or the caudal antebrachial fascia. Repair of the transection of these ligaments in greyhounds has been attempted with transposition of the flexor carpi ulnaris tendon (Brinker and others 1983).

Surgical repair of the accessorio-metacarpal ligaments was attempted in one of the cases treated at G.U.V.H.[1]. On return to training activity the lameness persisted, therefore confirming previous observations (Johnson and others 1989).

(1) The case record did not specify which technique was used

PROGRESSION OF THE BONY CHANGES OF DEGENERATIVE JOINT DISEASE

Degenerative joint disease of the accessorioulnar carpal joint is not only a sequel to unrepaired fractures of type I and II and/or coexisting ligamentous insufficiency, but also to sub-optimal surgical techniques (Johnson and others 1989). In order to prevent degenerative joint disease, the goals of any intra-articular fracture repair are accurate anatomical reduction of the fracture and joint surface, stable internal fixation with interfragmentary compression and early post-surgical controlled mobilisation of the joint (Frank and others 1985). Accessory carpal bone fractures treated by fragment removal do not meet these requirements and are therefore prone to cause degenerative joint disease.

An assessment of the progression of the bony radiological signs of degenerative joint disease following surgical management by fragment removal could only be made in the 9 dogs in which follow-up radiographs were available. The radiographic scores of these dogs at presentation and at follow-up examination are compared in Table 14.

Dog number	Present. score	Follow-up score (months post-op)
3	1	1 (3 months)
7	1	2 (6 months)
9	1	2 (2 months)
10	0	0 (1 month)
16	1	1 (2 months)
17	0	0 (1 month)
18	1	1 (3 months)
20	1	3 (3 months)
22	0	0 (2 months)

Table 14. Radiographic scores for bony changes

(**KEY: Present. score:** Score at the time of presentation. **Months post-op:** Number of months after surgery).

Due to variations in the timing of the follow-up check, an accurate assessment of the evolution of the radiological changes could not be made.

In 6 of these 9 cases (minimum follow-up: 1 month), no difference between both radiological scores was noted. In the remaining 3 cases (minimum follow-up: 2 months), a progression of the radiological changes was observed. The clinical significance of the radiological evidence of degenerative joint disease has already been discussed in this chapter (Section 2).

FRAGMENTS NOT REMOVED AFTER SURGERY

Because of the difficult access to intra-articular fragments, it is not always feasible to remove them all. In the three dogs that remained lame after surgery (dogs number 17, 18 and 19), an intra-articular fragment or fragments were still radiographically visible after surgery. Intra-articular chips mechanically traumatize and cause cartilage breakdown in the articular surfaces (Dee and Dee 1985), and this is likely to have contributed to the poor outcome in these three dogs. However, fragments left *in situ* were also seen in three dogs of the group "good outcome".

INADEQUATE PERIOD OF CONVALESCENCE

In the cases treated at G.U.V.H., the period of convalescence varied according to the surgeon, but as a rule involved a period of 2 months before a return to training was allowed. In two cases which did not return to racing (dogs number 15 and 18), lameness could have been precipitated by an inappropriate recovery period (4 and 6 weeks respectively).

The period of convalescence is not to be underestimated when dealing with ligamentous injuries (Ogata and others 1980). It has been stated that premature return to full use of the limb following accessory carpal bone fracture will risk additional damage to the carpus, whilst excessive joint immobilisation risks decreased range of movement (Dee and Dee 1985).

Another aspect of the post-operative period, the necessity for physiotherapy, has been emphasized (Yore 1983). After removal of the fragment, the excessive formation of fibrous tissue and adhesions may give rise to adverse effects on function and performance, but these complications do not develop provided passive manipulation of the carpus is instituted during healing (Hickman 1975).

OCCURRENCE OF A SUBSEQUENT INJURY OR DISORDER

In the cases seen at G.U.V.H., 4/19 dogs available for follow-up suffered subsequent injuries (see Table 7). As a result of these injuries, three of these four dogs were retired from competition.

A similar proportion of dogs (3/11) suffered a second injury in Johnson and other's report (1989). In these 3 cases, the dog was euthanased.

UNDIAGNOSED COEXISTING LIGAMENTOUS AND TENDINOUS INJURIES

Midsubstance ruptures and other ligament and tendon injuries may accompany strain and sprain-avulsion fractures. These injuries may go undiagnosed because they are not always apparent radiographically (Farrow 1977). Stressed view radiography is usually not sufficiently sensitive to detect grade I and grade II sprains and strains (Farrow 1978).

CONCLUSIONS

The conclusions drawn from this study were as follows:

1) The outcome following surgical treatment by fragment removal was:

- Seventy per cent of the dogs (13/19) returned to racing.
- Forty seven per cent of the dogs (9/19) returned to win.
- Fifteen per cent of the dogs (3/19) became sound but were unable to race.
- Fifteen per cent of the dogs (3/19) remained lame.

Although these results and those obtained with internal fixation (Johnson and others 1989) cannot be compared statistically, it is noteworthy that a higher percentage of dogs treated with fragment removal returned to win, although the overall percentage of dogs that returned to racing was not as great as with internal fixation. No definite conclusions can be drawn in this respect until a larger prospective study assessing both techniques is conducted.

2) No statistically significant correlation could be found between the outcome following surgery and any of the pre-operative prognostic indicators, namely: duration of the injury, age of the patient, weight of the patient, radiological evidence of osteophytes at presentation, size of the fragments and displacement of the fragments.

3) Some intra-operative and post-operative factors may affect the outcome of surgical management, namely: iatrogenic transection of ligaments, progression of the radiological signs of degenerative joint disease, fragments not removed after surgery, inadequate period of convalescence, undiagnosed co-existing ligament and tendon injuries and occurrence of a second injury or disorder. Further studies are needed to assess the influence that each of these factors exerts over the prognosis.

APPENDIX

APPENDIX 1

ACB	Accessory carpal bone
Acetab	Acetabulum
CTB	Central tarsal bone
FTB	Fibular tarsal bone
Interphal	Interphalangeal
Metac	Metacarpal bones
Metat	Metatarsal bones
Olecr	Olecranon
Pat	Patella
Phal	Phalanges
Rad+Ulna	Radius and ulna
Sesam	Sesamoid bones
T3	Third tarsal bone
Tib. cr	Tibial crest

Table 15. List of abbreviations.

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