ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM NO. 108

From the Department of Bone and Joint Surgery (Head: Professor Erik Moberg, M.D.) (clinical investigation) and the Biomechanical Laboratory at the Department of Orthopaedic Surgery (Head: Professor Carl Hirsch, M.D.) (experimental investigation), University of Göteborg, Sweden

FRACTURE OF THE DISTAL RADIUS INCLUDING SEQUELAE — SHOULDER-HAND-FINGER SYNDROME, DISTURBANCE IN THE DISTAL RADIO-ULNAR JOINT AND IMPAIRMENT OF NERVE FUNCTION

A clinical and experimental study

By
GÖSTA FRYKMAN

MUNKSGAARD
Copenhagen 1967

Translated from Swedish

by

Patrick Hort

GÖTEBORG 1967

ELANDERS BOKTRYCKERI AKTIEBOLAG

CONTENTS

INTRODUCTION

The clinical picture and late results of distal fractures of the radius have recently in Sweden been discussed by Lidström (1959). Certain aspects, however, seem to me to call for further consideration. The series which I chose for this purpose represents somewhat different forms of treatment, while some of the examination techniques employed are also new. This has facilitated a more thorough penetration of the aspects in question and is expected to lead to better end results and more satisfactory treatment of the sequelae.

The aim of my study is therefore to use a clinical and statistical analysis of a consecutive series of distal radius fractures, including the functional end results, to try to establish the incidence and degree of such sequelae as disturbance in the distal radio-ulnar joint, nerve lesions, shoulder-hand-finger syndrome and subcutaneous tendon rupture. I also aim at investigating to what extent the treatment employed has been able to prevent the development of such sequelae.

The study also includes a biomechanical investigation, the aim of which is to study whether different types of violence are able to reproduce clinical types of distal radius fractures. These experiments are intended to provide an indication of the amount of force required to produce the fracture and to show which factors apart from the force are responsible for a fracture arising.

CHAPTER I

ANATOMY

The distal end of the radius is formed of cancellous bone covered by a fairly thin cortical layer that attains its minimum thickness a few centimetres proximally in the metaphysis. The distal end of the ulna has a similar structure. The radius presents two articular surfaces at its distal end, one being the carpal articular surface—comprising two concave surfaces for articulation with the scaphoid and lunate bones—and the other the ulnar notch, for radial articulation with the head of the ulna. This is in fact the only direct bony articulation involving the head of the ulna.

Both the radio-carpal and the radio-ulnar joint have relatively thin and slack capsules but these are reinforced by several ligaments. They lie close to the borders of the articular surfaces on the radius and ulna, the articular disc

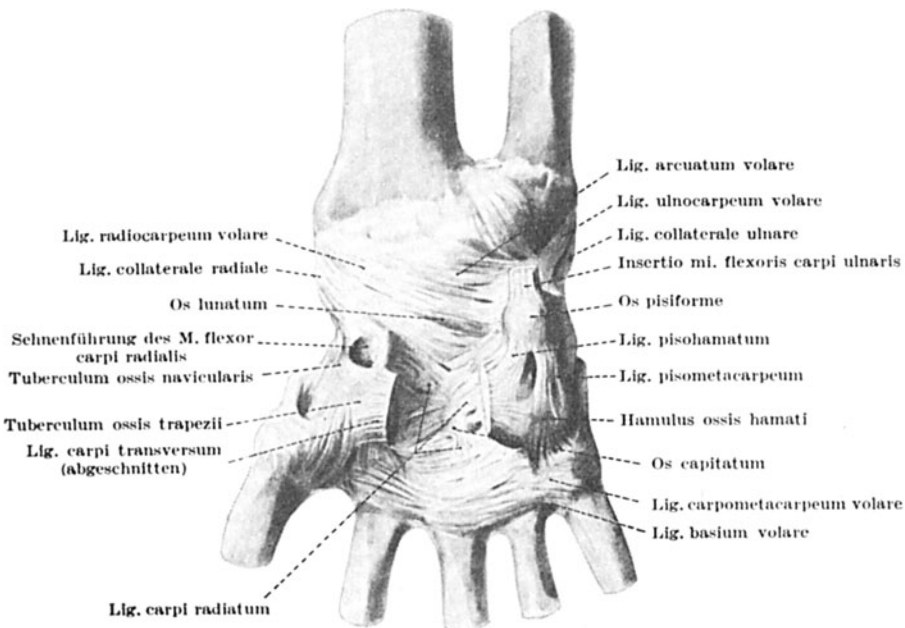

Fig. 1. Volar aspect of the wrist. After von Lanz & Wachsmuth (1959).

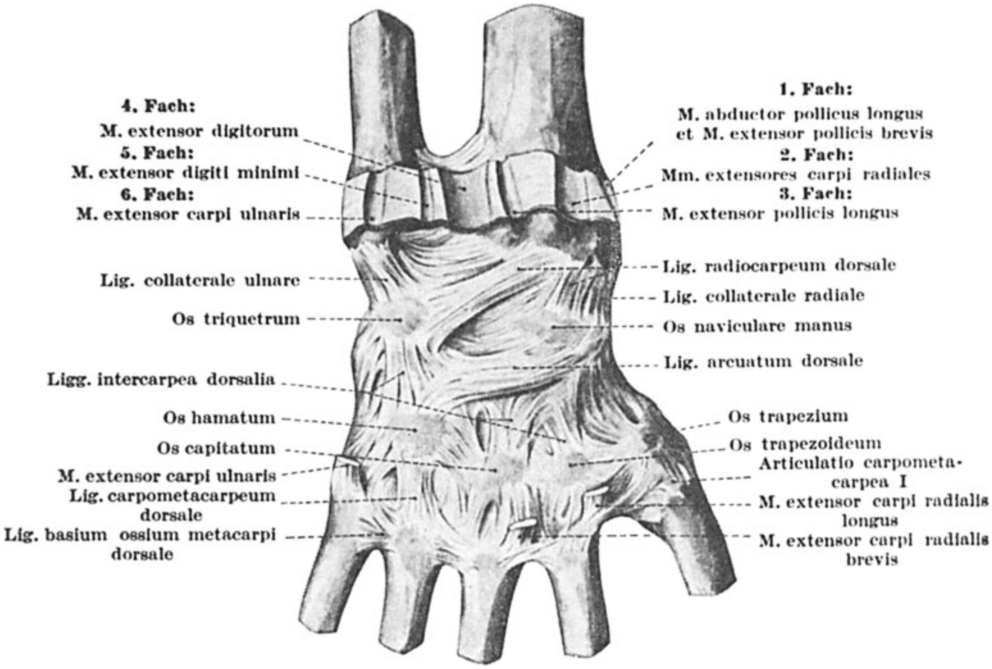

Fig. 2. Dorsal aspect of the wrist. After von Lanz & Wachsmuth (1959).

and the carpal bones; the radio-carpal capsule is reinforced by ligaments running distally from both the radius and the ulna, while ligaments also run between the distal ends of these bones.

There is a collateral ligament attached to the styloid process of the radius and another attached to the styloid process of the ulna (cf. Figs. 1 and 2). The former is short and strong, extending to the scaphoid bone; the latter is longer but weaker and fixes to the triquetral and pisiform bones. The dorsal and volar ligaments to the central part of the carpus issue mainly from the distal part of the radius; only the volar ones occur regularly (von Lanz & Wachsmuth, 1959). The dorsal radio-carpal ligament, which is not always present, is largely fixed to the triquetral bone, a few fibres running to the lunate and scaphoid bones; the volar radio-carpal ligament, which is constantly found, has a strong band attaching to the scaphoid and triquetral bones, while weaker fibres extend to the capitate bone. From the styloid process on the ulna, the corresponding structure or volar ulnar-carpal ligament combines with the volar radio-carpal ligament to form an arch-shaped band sometimes known as the volar arcuate ligament, which runs in a loop round the head of the capitate bone and round the lunate bone. A dorsal ulnar-carpal ligament does not occur regularly.

The distal radio-ulnar joint is reinforced by transverse bands forming the volar and dorsal radio-ulnar ligaments, which are not particularly strong. They intermingle along the border of the articular disc but are separated proximally by a synovial pouch (*recessus sacciformis*) that runs up between the radius and the ulna (cf. Fig. 3).

The broad base of the articular disc in the distal radio-ulnar joint attaches to the distal edge of the ulnar notch on the radius, from where the disc converges onto its insertion on the ulnar styloid process. The distal surface of the disc accounts for about one-quarter of the proximal articular surface of the radio-carpal joint, the other three-quarters being formed by the radius. In shape the disc resembles an equilateral triangle. Its insertion on the ulna may vary: Schinz (1922) has described two sites, one more radially on the head of the ulna, the other at the tip of the styloid process; a further variant is a twin insertion at the foot and tip of the ulnar styloid process.

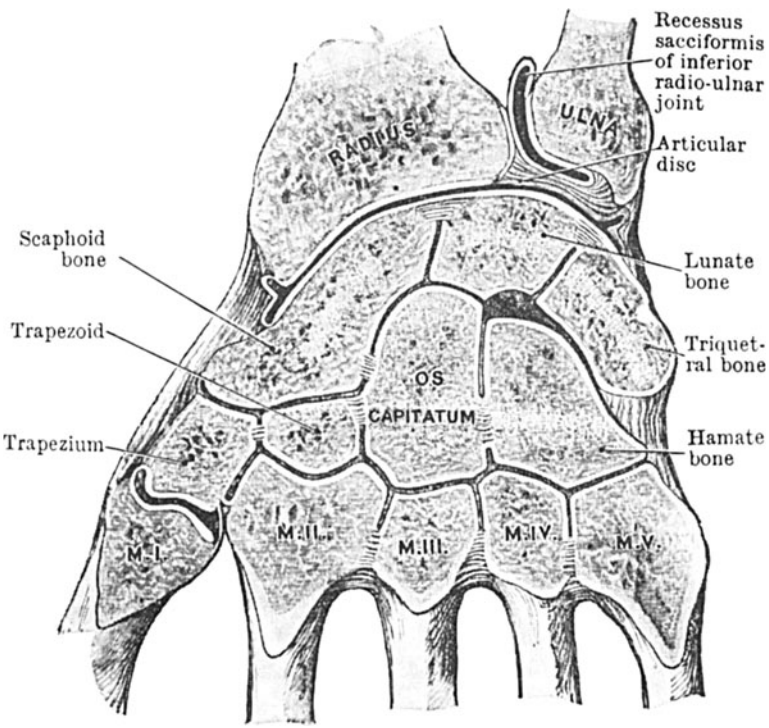

Fig. 3. Coronal section through the radiocarpal, carpal, carpometacarpal and intermetacarpal joints, to show joint-cavities and interosseous ligaments (diagrammatic). After *Cunningham's Anatomy* (1943).

The disc is quite frequently perforated at its insertion on the ulnar notch of the radius, thereby connecting the radio-carpal and radio-ulnar joint cavities. The incidence of this communication is reported to be about 25 % (von Lanz & Wachsmuth, 1935). The degenerative changes in the disc increase with age, frequently leading to a perforation in the middle of the disc as well (Lang, 1942; von Lanz & Wachsmuth, 1959).

In addition to the ligaments described above, attention should be drawn to the following soft tissues in the vicinity of the carpal bones: the pronator quadratus muscle, the volar and dorsal carpal ligaments and the transverse carpal ligament, which lies distal of the volar carpal ligament. Nor should one forget the tendons, nerves and vessels in the volar and dorsal parts of the carpal region; these may incur a variety of injuries in conjunction with or following fracture of the radius. The extensor tendons thus lie dorsally in their tunnels deep to the extensor retinaculum, while the flexor tendons are to some extent protected from the usual site of fracture by the pronator quadratus muscle.

The median nerve and the flexor tendons run in the carpal tunnel. The nerve may be exposed to various types of injury as a result of constriction when the distal radius fractures. Anatomically, the ulnar nerve and artery are less vulnerable than the median nerve, since they lie under superficial parts of the volar carpal ligament on the radial side of the flexor carpi ulnaris muscle, which affords them some protection. They may nevertheless be in danger when the distal radius and ulna are fractured, partly because the volar carpal ligament inserts on the ulna.

The pronator quadratus muscle, finally, has a stabilizing effect on the distal radio-ulnar joint, as have the interosseous membrane, the articular capsule in the distal radio-ulnar joint, the volar and dorsal radio-ulnar ligaments, the triangular disc, the ulnar-carpal ligament and the dorsal and volar superficial carpal ligaments.

CHAPTER II

MECHANISM OF INJURY

Fracture of the distal part of the radius is generally thought to be caused by a fall onto the outstretched arm, the hand being in dorsal flexion or volar flexion to break the fall. Depending on the position of the hand at the time, the fracture will involve dorsal or volar displacement of the distal fragment (i.e. Colles' or Smith's fracture respectively). This simple conception of the mechanism of injury appears to be the one most widely accepted in the literature, possibly because the considerable effort devoted to this question has failed to produce any more definitive account.

In studying the mechanism of injury, many authors have based their theories on experiments with cadavers (Nelaton, 1844; Lecomte, 1861; Hönigschmied, 1878; Hahleyss, 1897; Roberts, 1897; Cotton, 1900; Rosenbach, 1902; Lilienfeldt, 1907, 1908; Pilcher, 1917; Kleinschmith, 1929; Mayer, 1940; Lewis, 1950). In general, however, they do not seem to have produced any very remarkable findings, though Lilienfeldt is an exception. As Lindström (1959) points out, Lilienfeldt's (1907, 1908) results have to some extent shaped the accepted conception of the fracture mechanism in wrist injuries. He demonstrated that the type of injury could be varied at will by manipulating two factors, namely the position of the hand and the angle between the forearm and the surface of impact. Lilienfeldt's experimental design was extremely simple. The specimen was exarticulated at the shoulder and suspended in such a way that the position of the hand and forearm could be adjusted. In each position the investigator fell onto the arm with the weight of his body. With this technique, Lilienfeldt was able to produce fractures of the distal radius provided that the angle between the forearm and the surface of impact was between 60° and 90°. If at the same time the hand was in ulnar deviation, the fracture ran through the radial styloid process, whereas the ulnar styloid process fractured if the hand was in radial deviation. Lilienfeldt managed to reproduce a Smith fracture in one case, the trauma being directed against the back of the hand; from this he concluded that the dislocation is a direct result of the direction of the traumatic force. The scaphoid bone fractured if the angle between the forearm and the surface of impact was at least 90° and the hand was in dorsal flexion and radial deviation. Radial deviation seemed to be necessary for this type of fracture to occur separately. Lilienfeldt also showed that a vertical force against the hand in ulnar deviation and dorsal flexion resulted in distal dislocation of the ulna combined with fracture of the scaphoid bone. In one specimen he even managed to produce an ulnar dislocation indirectly, by loading the hand in dorsal flexion and ulnar deviation from the forearm, which was held vertically and midway between pronation and supination.

It would seem that the chief value of Lilienfeldt's studies is that he appears to have demonstrated that the direction of the traumatic force determines the type of wrist injury. In passing it may be mentioned that Lilienfeldt thought that distal fractures of the radius are caused by a sudden blow.

It may be said that there are three main theories in the literature concerning the mechanism of injury in distal fractures of the radius:

1. *The blow and counter-blow theory.* This theory, first advanced by Dupuytren (1834), suggests that the body's weight generates a counter-blow from the surface of impact and is thereby transmitted through the carpal bones directly to the distal radius. The fracture produced is often typically located where the cortex of the bone is thinnest. Nelaton (1844) and Malgaigne (1847) subsequently adopted this theory, as did Destot & Gallois (1896). The latter demonstrated roentgenographically that, when the hand is in dorsal flexion, the carpal bones come up against the surface of impact at the moment of fracture at the same time as the head of the radius is pressed against the humerus, thus causing the force to be transmitted directly to the lower part of the radius. They also asserted that avulsion fractures (see below) were probably extremely rare.

2. *The avulsion theory.* First suggested by Linhart (1852), this theory was analysed more closely by Lecomte (1861), who pointed out that the design of the olecranon gives the ulna much more intimate contact than the radius with the humerus and that consequently the ulna is probably alone in absorbing the impact of a fall on the hand. The force must be transmitted in some way to the radius. According to Lecomte, this must occur via the interosseous membrane and, more importantly, the ligaments, particularly the strong volar apparatus. The resultant fracture is then produced by avulsion due to traction in the strong volar radio-carpal ligament.

This theory was subsequently criticized. Löbker (1885) and Bähr (1894) argued that, if avulsion is the primary mechanism, one would expect the fracture line to run a volar-proximal—dorsal-distal course, whereas in fact it generally does the opposite. While this criticism seemed to rule out the avulsion theory as a separate fracture mechanism, Löbker in his turn objected to the blow and counter-blow theory as the sole explanation of the fracture because, in that case, comminution of the joint surface of the radius should be more common than it is. He therefore concluded that a combination of both mechanisms was most likely, an opinion that has since been supported by e.g. Pilcher (1917) and Rotter (1920).

3. *The bending fracture theory.* This mechanism was suggested by Meyer (1925), who definitely rejected the avulsion theory. He argued that the course of the fracture in the individual case is determined by three factors: the position of the hand, the surface of impact and the magnitude of the force. If tension simultaneously arose in the ulnar collateral ligament, the radial fracture would for instance always be accompanied by a fracture in the ulnar styloid process. The bending fracture theory was later supported by Lewis (1950), who pointed out that if in fact a fall on the outstretched hand was sufficient to elicit a distal fracture of the radius, gymnasts would surely incur such an injury by doing handstands. Having experimented with cadavers, Lewis envisaged the bending fracture mechanism as follows: the absence of skin abrasions on the palm suggests that at the moment of fracture the hand stays put on the surface of impact; the kinetic energy causes the forward movement of the body to continue, the wrist becomes hyperextended and the patient falls *over* the hand; this loads the volar ligament and the radius is pressed against the carpal articular surface, the force being stopped by the scaphoid and lunate bones; it is then transmitted to the radius, which fractures at its weakest point in the same manner as a beam that is loaded beyond the limit of its elasticity. Interpreted thus, Lewis considered it obvious that a fracture of the distal radius is to be regarded as a bending fracture.

CHAPTER III

BIOMECHANICAL INVESTIGATIONS

As mentioned in the last chapter, numerous studies have been published concerning the experimental production of fractures in the distal radius. Various techniques have been employed. As a rule, the aim has simply been to reproduce the type of fracture met with in clinical practice, without specifically studying the forces required to produce the fracture. The results generally show that a particular technique was successful in producing such types of fracture, but only in a limited proportion of the series.

The incompleteness of earlier series of fracture experiments seems to have been remedied to a considerable extent by the use of special apparatus. This has been demonstrated in recent years for experimentally produced fractures of the neck of the femur (C. Hirsch & Frankel, 1960), of the calcaneum (Thorén, 1964), of the knee-joint (G. Hirsch & Sullivan, 1965) and of the ankle-joint (C. Hirsch & Lewis, 1965). The results published by these authors were obtained with two types of biomechanical fracture investigations. All except Thorén employed a *static* variant and determined the fracture resulting from a known, controllable force (kp). The experiments were made with a hydraulic apparatus (Amsler universal testing machine) to which an automatic writer was attached, giving the size of the load in kp. Thorén's study, on the other hand, involved *dynamic* experiments to determine the fracture resulting from varying degrees of external violence (amount of energy). The apparatus used was an Amsler pendulum-type impact machine; strain gauges fitted to the head of the pendulum and connected to an oscilloscope made it possible to obtain a photographic record of the forces occurring at the moment of fracture.

No such biomechanical fracture experiments have been published for the distal radius. Consequently it seemed well worth conducting a series of experiments with these two types of apparatus with the aim of reproducing distal fractures of the radius in forearm specimens under static and dynamic loading. Such experiments should indicate the amount of the forces producing the fracture and might also indicate suitable conditions for reproducing clinical types of distal radius fractures with greater regularity than has been achieved in previous investigations.

The size of a biomechanical experimental series of this type will naturally be limited by the relative scarcity of forearm specimens. The uneven supply of such specimens led to the dynamic series of experiments being smaller than the static in the present study. This must of course be born in mind when assessing the results.

Specimens

The forearm specimens used in the experiments came from autopsies and surgical operations on 23 women and 25 men. In the majority (36) of the 48 specimens the forearm had been resected just below the elbow; in the other 12 it had been resected about 10 cm above the wrist. Two of the women from whom the specimens came were 46 and 56 years old respectively; all the others were between 65 and 78 years. Most of the men were between 58 and 79 years, though five specimens came from men aged 19–50 years. None of the above persons had skeletal diseases involving the forearm or hand, nor had they any roentgenological signs of osteoporosis.

Distal fractures of the radius were produced in 32 of the 48 experiments. (Details of these 32 are given in Table 1 at the end of this chapter.)

The specimens were either used the same day as they were resected or else stored at −20°C. until the day of the experiment, when they were thawed at room temperature. In both the static and the dynamic experiments the specimen was first freed from soft tissue within a region of about 5 cm from the proximal end, after which the fatty tissue in this region was also removed. The prepared specimen could then be fixed in a metal holder (C. Hirsch, 1964) with the aid of a cast compound (Plastic Padding) that hardened at room temperature, the forearm being held vertical.

Apparatus

Static experiments were conducted with an *Amsler universal testing machine.* A kymograph coupled to this machine recorded the size of the load in kp during the course of the experiment, together with changes in the distance between the ends of the specimen. The testing machine is hydraulically powered and can generate a constant rate of loading. In the present experiments this rate was ca. 100 kp/min. The metal holder into which the specimen had been cast was fixed to the loading head of the machine as indicated in Fig. 4. The specimen thus hung vertically, the palm resting against a wooden block placed on the machine's supporting head. Several different wooden blocks were used in the experiments, their upper surface sloping at different angles. This made it possible to vary the angle of the wrist as required. In the earliest experiments the hand was screwed onto the

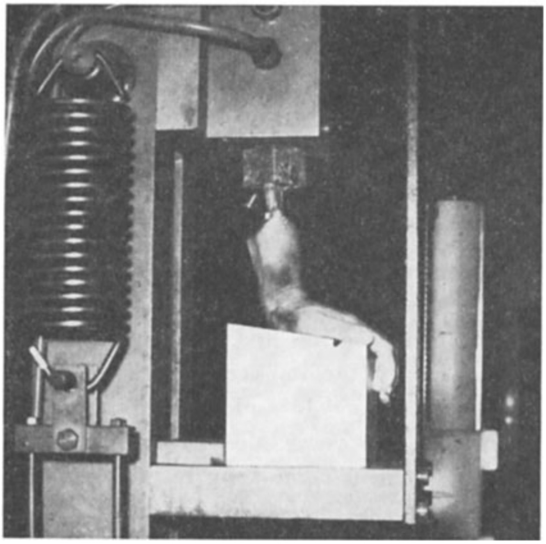

Fig. 4. A specimen fixed in the Amsler universal testing machine.

block. This technique was abandoned, however, since the hand of the specimen rested firmly on this type of support without any special fixation.

Dynamic experiments were conducted with an *Amsler pendulum-type impact machine*, the hammer of which was fitted (as described by Thorén, 1964) with a tube having a duraluminium plate at one end. The metal holder with the specimen was fixed to a large wooden block resting on a steel stand designed in much the same way as that used by Thorén (1964) (Fig. 5). The stand was loaded with a given weight, resulting in a total weight for the entire apparatus of 75 kg (cf. also Fig. 6: 4, 5, 6). The loaded stand with the specimen attached rested on a level floor covered with varnished linoleum. In view of the conditions being studied, nothing was done to eliminate any movement of the stand that might occur during these dynamic experiments. The position of the specimen's wrist was varied in a dorsal or volar direction with the aid of a strong nylon string tied between the hand and the stand. The specimen and the pendulum were aligned so that, on impact, the surface of the pendulum plate lay flat against the surface of the palm or the back of the hand (cf. Fig. 5).

The dynamic experiments comprised two series. The first was only concerned with the apparatus's ability to produce the intended fractures, no attempt being made to measure or record the course of the experiment. The fracturing force was consequently not determined, which naturally detracts from the value of this series. However, several relevant observations during these experiments seem to justify their inclusion in the following discussion.

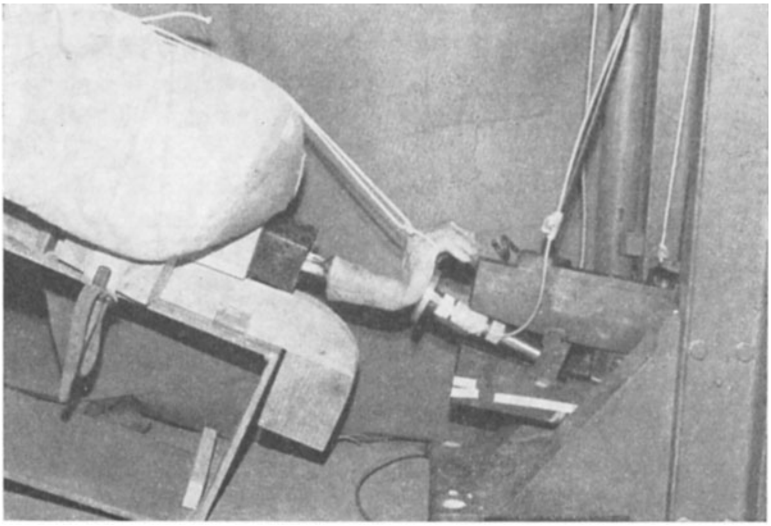

Fig. 5. The apparatus used in the dynamic experiments.

In the second series of dynamic experiments, equipment was included for measuring and recording the force of impact of the pendulum as follows (cf. Fig. 6). The part of the pendulum (9) carrying the metal plate (8) which delivers the blow to the specimen (5) was designed as a long, thin-walled tube. To this were attached four strain gauges, which were coupled via a long, screened cable to a balancing unit (3). The out-signal of this unit was led to the y-axis amplifier of an oscilloscope (2). This apparatus could be calibrated by subjecting the pendulum head (8) to a known load and measuring the deflection on the y-axis of the oscilloscope. The x-axis of the oscilloscope was coupled to a variable time generator. The generator could be triggered by a special signal from a triggering unit (1) coupled in its turn to a microswitch (7). The microswitch was placed so that it was actuated a few milliseconds before the impact plate reached the specimen. This ensured that the time generator had started when the blow fell, besides providing a well-defined zero level for the measurements.

With this apparatus the curve of the impact force (force in kp versus time in ms) could be read directly from the oscilloscope. It could also be recorded with a Polaroid camera attached to the oscilloscope. Evaluation of the results was facilitated by introducing a screen through double exposure. The apparatus had a total error of measurement of $\pm$ 15 kp at 400 kp max. deflection on the y-axis and $\pm$ 0.5 ms at 10 ms max. deflection on the x-axis.

———

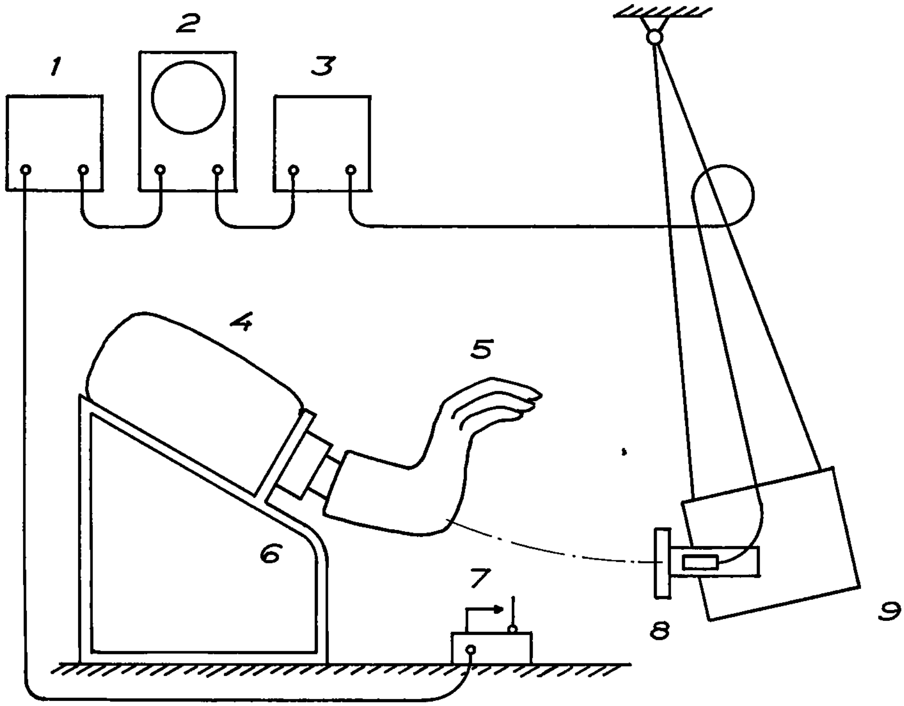

Fig. 6. The experimental set-up of the second series of dynamic experiments. 1, Triggering unit; 2, Oscilloscope; 3, Balancing unit; 4, Counter-weight on specimen stand; 5, Specimen; 6, Specimen stand; 7, Trigger; 8, Impact force gauge; 9, Pendulum.

In both the static and the dynamic experiments, x-rays were first taken of the wrist of the specimen in two projections. This was also done immediately after each experiment. The specimen was then dissected and photographs were taken of the exposed fracture.

Results of static experiments

A total of 37 static fracture experiments were performed, clinical types of distal radius fractures being obtained in 22. The other 15 experiments produced the following injuries: fracture of proximal radius-ulna (5), proximal radius fracture and distal ulnar dislocation (2), proximal radius fracture (1), distal ulna fracture (1), scaphoid fracture (2), scaphoid and capitate fracture (1), pisiform, hamate and capitate fracture (1), triquetral fracture (1) and volar dislocation of the lunate bone with volar fracture in this (1).

The following account is chiefly concerned with the fractures of the distal radius obtained in this series.

The 22 experimental fractures of the distal radius, classified in the same way as in the follow-up series (cf. Chapter IV, p. 30) comprised the following types (I–VIII):

I	II	III	IV	V	VI	VII	VIII
2	1	5	—	1	—	7	6

No less than 19 of them were thus intra-articular fractures. Six were also accompanied by a fracture somewhere in the caput ulnae, usually at the base of the ulnar styloid process (4). An apparently fresh rupture in the triangular disc in the distal radio-ulnar joint was also found in 5 of the 19 specimens. In three of these the rupture was located in the radial part of the disc. One specimen with a vertical intra-articular fracture in the radio-carpal joint also had a ruptured radial collateral ligament.

X-rays of different types of fracture obtained in these experiments are reproduced in Figs. 7—13. The fracture shown in Fig. 10 was produced in one of the dynamic experiments.

Only fractures with dorsal displacement were obtained in the static experiments, probably because only the dorsal flexion and lateral deviation of the wrist were varied in this series.

The tensile strength of the skeleton did not differ markedly between specimens taken from individuals of different ages but the same sex. A clear difference was found, on the other hand, between the tensile strengths of distal radius in specimens from men compared with women. The fracture load for male specimens ranged from 140 to 440 kp (mean 282 kp), while the load for female specimens ranged from 105 to 320 kp (mean 195 kp), see Table 1. It may be noted that, under similar experimental conditions, no essential difference in tensile strength was found between the short and the long specimens. Nor was there any difference in the types of fracture produced that could be ascribed to the length of the specimens.

Distal fractures of the radius were obtained in the static series when the specimen was loaded with the wrist in 40°–90° dorsal flexion and 0°–35° radial or ulnar deviation. In general, it seems that the greater the degree of dorsal flexion, the larger the force required to produce a fracture.

With more than 90° dorsal flexion in the wrist, however, injuries occurred in the carpal bones (see above), usually involving the scaphoid bone. Fracture of the scaphoid alone was obtained only when the hand was also in radial deviation; multiple injuries to the carpal bones occurred when the hand was midway between radial and ulnar deviation or else in ulnar deviation. Injuries to the carpal skeleton also accompanied four of the fractures in the distal radius (only the scaphoid bone in one experiment, multiple carpal injuries in the other three). In these four experiments the course of events followed a particular sequence. The fracture in the distal radius seemed to occur first, followed by the injury to the carpal bones as the dorsal bending of the specimen increased before the loading could be discontinued. The lateral angulation of the hand in these experiments also resembled the conditions that seemed to apply in other experiments in which carpal injuries occurred without fracture of the distal radius.

The loads which led to carpal injuries—from 265 and 510 kp (mean 396 kp)—were considerably higher than those which produced fractures of the distal radius. Furthermore, the loads which resulted in a combination of distal radius fracture and carpal injuries were generally higher than those which produced a distal radius fracture alone.

As already mentioned, eight of the static experiments resulted in proximal fractures in the radius and ulna, or only in the radius, in one case combined with distal dislocation of the ulna. Although these experiments did not result in the type of fracture aimed at, certain features seem worth mentioning here. They started in the same way as all the other static experiments—with the specimen resting against a wooden block, the surface of which sloped to varying degrees, thereby producing a dorsal flexion of 40–70° in the wrist. Loading of the specimen caused the block—and hence the hand—to slide, with the result that the angle between the forearm and the hand gradually straightened out. When the dorsal flexion in the wrist had dropped to 20–35°, the proximal forearm fractures arose at loads between 60 and 190 kp (mean 120 kp). This is considerably less than the loads at which distal radius fractures occurred in the static series.

Discussion. The results of the static fracture experiments seem to justify the following conclusions.

(1) Clinical types of distal radius fractures can be obtained with great regularity on static loading provided the dorsal flexion in the wrist is not less than 40° and not more than 90°.

(2) The degree of dorsal flexion in the wrist also seems to be related to the occurrence of fractures in the carpal bones and in the proximal forearm. Fractures of the carpal bones occurred when the dorsal flexion in the wrist was more than 90°, proximal forearm fractures when it was less than 40°.

(3) Considerable force appears to be required to produce a distal fracture of the radius. The force required would seem to be related to the degree of dorsal flexion in the wrist, since less force produced a fracture when the dorsal flexion was relatively slight. Another finding in keeping with this observation is that all the proximal forearm fractures in the series occurred at a lower load than the distal radius fractures, at the same time as the dorsal flexion of the wrist in the former was less than 40°. Furthermore, the carpal bone fractures in this series occurred at considerably higher loads, at the same time as the dorsal flexion of the wrist in these experiments was greater than 90°.

(4) A greater amount of force was required to produce distal radius fractures in specimens from male individuals compared with female.

(5) The results thus clearly suggest that the extent of the injury depends on the amount and direction of the static force.

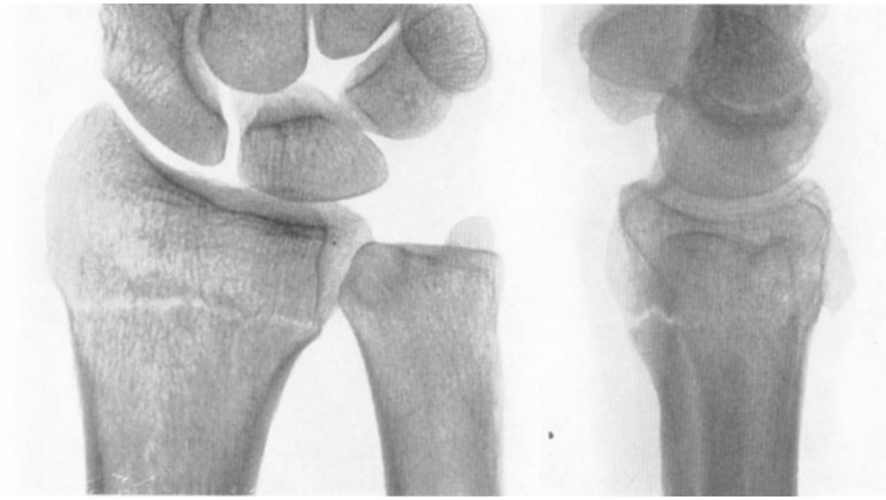

Fig. 7. Experimental fracture type I.

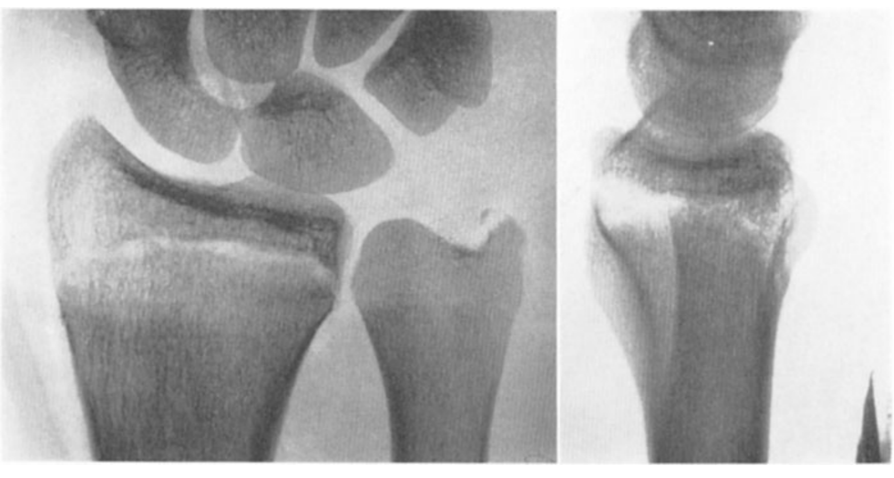

Fig. 8. Experimental fracture type II.

Fig. 9. Experimental fracture type III.

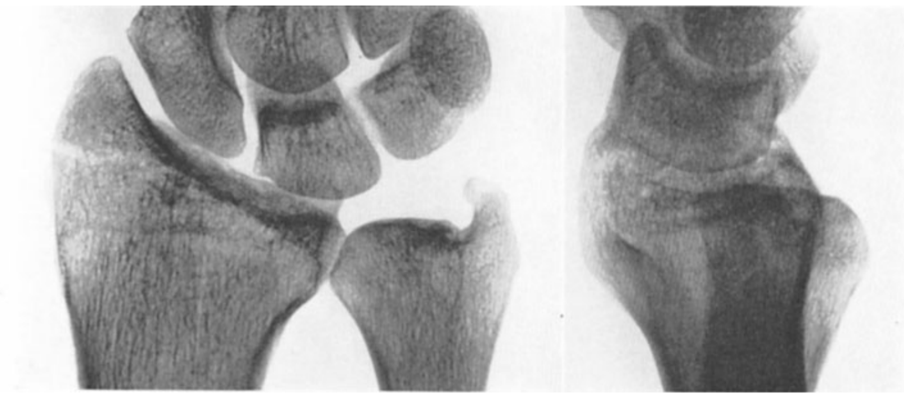

Fig. 10. Experimental fracture type IV.

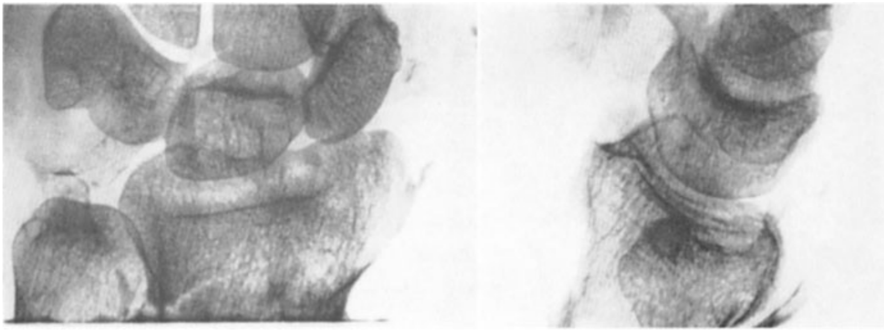

Fig. 11. Experimental fracture type V.

Fig. 12. Experimental fracture type VII.

Fig. 13. Experimental fracture type VIII.

Results of dynamic experiments

The dynamic fracture experiments were performed in two series (see above). The first series comprised seven experiments, the second four. Only in the second series was the course of events measured and recorded. For this reason the results are treated in separate sections below.

The 11 dynamic experiments in the two series resulted in clinical types of distal radius fractures in 10 cases. One experiment in the second series produced multiple injuries in the carpal bones instead.

The ten distal radius fractures were of the following types (I–VIII):

I	II	III	IV	V	VI	VII	VIII
—	1	3	2	—	—	2	2

Nine of them were thus intra-articular fractures. Half of the radius fractures were accompanied by fractures in the distal ulna, in three cases immediately proximal to the caput ulnae. As in the static experiments, a fresh rupture of the triangular disc was observed after three of the dynamic experiments. In two of these specimens the rupture was in the ulnar part of the disc, combined with a fracture through the base of the ulnar styloid process. In the third, the rupture was in the radial part of the disc.

Dynamic series I

This was the series in which the course of the experiment was not recorded. Consequently, no direct data are available for the force producing the fracture. The series was undertaken to test the ability of the impact machine to produce distal radius fractures. It represents a preparatory study for the second series of dynamic experiments.

The Amsler pendulum-type impact machine used for these experiments can be pre-set by hooking up the pendulum in different positions. Given the weight of the pendulum, the minimum height of the centre of gravity above the floor and the increment to this height for the different settings of the pendulum, it is possible to calculate approximately the kinetic energy of the pendulum at the moment of impact as well as its speed on impact.

Prior to this series, trials had shown that only the fifth or the sixth setting of the pendulum produced any fractures. The calculated kinetic energy and maximal speed on impact for these settings are as follows:

Pendulum setting	Kinetic energy		Max. speed on impact	
	kpm	kWs	m/s	km/h
5	13.4	131.5	2.66	9.6
6	15.7	153.5	3.12	11.1

Thus, although no direct data on the force acting at the moment of fracture can be quoted for this series, it seems reasonable to assume that the amount of this force was largely the same as in series II (see below), in which the course of the fracture was recorded and the force of impact ranged from 190 to 440 kp (cf. p. 24).

In four of the seven experiments in this series, the wrist was placed in dorsal flexion varying between 60° and 80°, the specimen being arranged so that the pendulum struck the volar surface of the hand. In order to determine whether a blow from the opposite direction, i.e. onto the back of the hand, produced a different type of fracture, the other three experiments were arranged with the wrist in volar flexion between 75° and 80°.

In the experiments with the wrist in dorsal flexion and a blow to the palm of the hand, the external appearance of the specimen clearly resembled the typical dislocation in which the distal radius fracture bayonets distally. On dissection, the fractures in these specimens had the same appearance and tendency to dislocation as those in the static series, i.e. fractures with dorsal dislocation, in some cases with a dorsal fragment. In the experiments with the wrist in volar flexion and a blow to the back of the hand, the specimens displayed deformation of the wrist with volar angulation. On dissection, fractures were found in all these specimens on the volar face of the distal radius. As in the static series, these dynamic experiments were conducted with variations in the lateral position of the hand.

Discussion. The results of these experiments show that clinical types of distal radius fractures can be produced with great regularity under the present conditions for dynamic loading of the specimen. The dynamic experiments also indicate more clearly than the static that the wrist injuries produced are closely related to the direction of the force producing the fracture.

Dynamic series II

The course of the experiments in this series was recorded with the apparatus described on p. 17.

The series comprised four experiments, three of which resulted in fractures of the distal radius. One of these (No. 31) was severely comminuted. The fourth experiment resulted in multiple injuries in the carpal bones. This specimen was subjected to two impact experiments. The first fractured the scaphoid, capitate and triquetral bones, while the second produced further fracturing of these as well as a volar fracture in the lunate bone.

Thorough calibration of the impact force gauge in a reversible tension testing machine before each experiment minimized the error of measurement with the apparatus to the levels reported on p. 17.

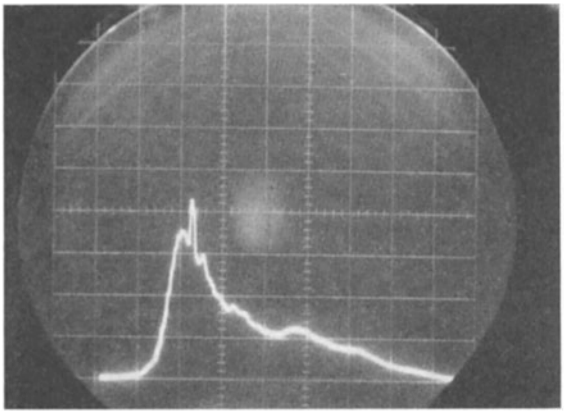

Fig. 14.

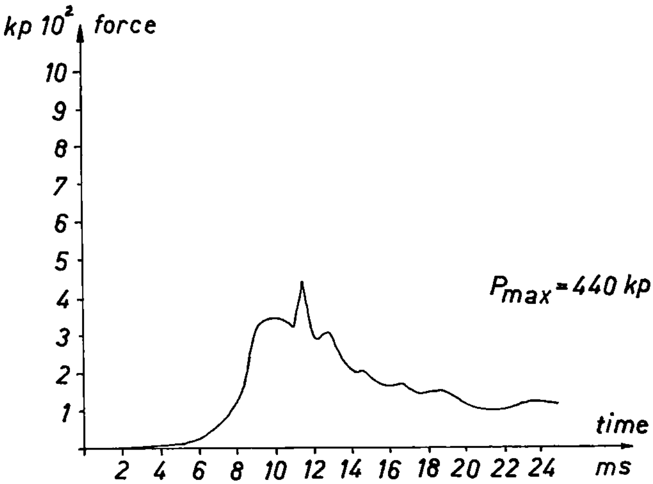

Fig. 15.

The appearance of the impact curve is illustrated in Figs. 14 and 15, which reproduce the original curve as photographed with the Polaroid camera (Fig. 14) and the same curve redrawn (Fig. 15). The curve in question comes from the experiment on specimen no. 32 (cf. Table 1), in which the sweep rate of the oscilloscope was 5 ms/ division and the sensitivity 100 kp/division. As was the case in the other experiments in this series in which distal radius fractures were obtained, the relevant part of the curve spanned 25 ms, while its peak occurred after 8–10 ms. In this experiment, the maximal force when the specimen fractured was calculated to 440 kp. In the other two experiments that resulted in distal radius fractures, the maximal force was calculated to 350 and 190 kp respectively.

The two highest values relate to specimens from men, the lowest to a specimen from a woman.

In the experiment which resulted in multiple injuries to the carpal bones, the maximal force of the first impact was calculated to 440 kp, that of the second to 680 kp.

It should be noted that the maximal load of 350 kp was achieved with the impact pendulum in setting no. 5, while the other experiments were conducted with the pendulum starting from setting no. 6.

The dorsal flexion in the wrist was varied very little between these four dynamic experiments. Two of the specimens were arranged with the hand in slight radial deviation, the other two with the hand in slight ulnar deviation. In view of the small differences in the position of the wrist, as well as the small number of specimens in this series, no conclusions can be drawn about the relationship between the amount of the force and the position of the wrist during the experiment.

All three fractures of the distal radius were of the dorsal dislocation type, no doubt because all these experiments were performed with the wrist in dorsal flexion and the impact striking the volar surface of the hand.

Discussion. This second series of dynamic experiments also produced clinical types of distal radius fractures with satisfactory regularity. The position of the wrist in these experiments corresponded to the conditions in the series discussed above. Once again, the direction of the force of impact determined the direction of displacement in the fracture. The amount of the force measured at the moment of impact was very considerable in this series, as it was in the static experiments, though the values were inside the limits obtained in the static series.

Summary of results from the biomechanical experiments

It is clear that both static and dynamic force can produce clinical types of distal radius fractures with great regularity provided the wrist of the specimen is positioned in a certain angle. The direction of the blow then appears to determine the direction of the resultant fracture's displacement. Thus in the static experiments—in which only the dorsal flexion and lateral deviation of the wrist were varied—all the fractures displayed dorsal displacement. It was shown in some of the dynamic experiments that when instead a hand in volar flexion was loaded from the dorsal side, volar fractures were produced with volar displacement.

In both the static and some of the dynamic experiments, approximate calculations could be made of the amount of the force producing the fracture. It was considerable in both types of experiment. The static experiments in particular showed that considerably less violence was required to produce distal radius fractures in specimens from women than in specimens from men. The amount of the force producing the fracture in the static experiments seems to be related to the degree of dorsal flexion in the wrist, less force being required in moderate compared with pronounced dorsal flexion. (The degree of dorsal flexion also seems to be relevant in that, when it was very slight, diaphysial fractures in the radius and ulna were obtained with much less force than was required for fractures of the distal radius. On the other hand, very pronounced dorsal flexion and a much greater force produced various types of injury to the carpal bones in several static experiments.)

The results of these experiments undoubtedly come up to the aims set out in the beginning of this chapter. In addition, they suggest that the type of wrist injury produced in such experiments will depend on the following factors: (1) Position of the wrist, (2) Direction of the violence, and (3) Magnitude of the violence.

It is conceivable that these factors determine the nature of wrist injuries in clinical practice, although the general conditions in the biomechanical experiments do not of course correspond at all closely to the conditions under which the clinical injuries occur.

These biomechanical studies do not claim to have explained the fracture mechanism in distal radius fractures. Since, however, this question is a natural one in the present context, it may be pointed out that both the static and the dynamic experiments seem to lend support to two of the fracture mechanisms most frequently discussed, namely the blow and counter-blow theory and the bending fracture theory (cf. Chapter II).

TABLE 1. *Factors of interest by the production of the fractures of the distal radius.*

Specimen No.	Sex	Age	Position of the hand in degrees: Dorsal flexion	Volar flexion	Radial deviation	Ulnar deviation	Resultant fracture: Dorsal	Volar	Type of fracture	Maximum force (kp)	Simultanous carpal bone fracture	Lesion of the triangular disc
Static type of experiment												
1	F	56	80				+		VIII	240	+	—
2	M	59	70				+		VII	440	—	—
3	F	67	45			15	+		III	260	—	—
4	F	78	65		10		+		III	145	—	+
5	F	65	60		20		+		VII	180	—	+
6	F	65	65		15		+		V	105	—	—
7	F	78	55			20	+		III	150	—	—
8	F	78	45		30		+		VIII	130	—	+
9	F	67	65			15	+		VIII	130	—	+
10	F	67	60			20	+		VII	320	—	—
11	M	72	65		10		+		VII	440	+ (620 kp)	—
12	M	68	90		20		+		III	440	+ (530 kp)	—
13	M	66	75		15		+		VII	300	—	—
14	M	66	85			5	+		I	170	—	—
15	F	78	60		15		+		III	250	+	—
16	M	72	75			10	+		VII	170	—	—
17	M	19	80				+		II	170	—	—
18	F	78	90		20		+		VIII	220	—	—
19	F	46	40			30	+		VII	160	—	—
20	M	50	90			10	+		VIII	270	+	—
21	F	72	80		35		+		VIII	250	—	+
22	M	61	80				+		I	140	—	—
Dynamic type of experiment												
23	F	78	100				+		III	?	—	—
24	F	78		75				+	III	?	—	—
25	M	61	60			15	+		VII	?	—	—
26	M	61	80		15		+		VIII	?	—	—
27	F	68		85		10		+	III	?	—	—
28	F	68		80		15		+	VIII	?	—	—
29	F	65	80			10	+		IV	?	—	+
30	M	58	80		15		+		VII	350	—	—
31	F	69	70			10	+		II	190	—	+
32	M	31	60		10		+		IV	440	—	+

CHAPTER IV

TYPES OF FRACTURE

Considerable interest and effort have been expended on the systematic classification of these fractures. The use of different clinical factors as a basis for these systems has unfortunately resulted in the publication of such a wide variety of classifications that some authors (e.g. Chandler, 1950) have warned of the dangers of confusion. Most authors (e.g. Kotrnetz & Geiringer, 1937; Arbeitlang & Boeckl, 1963; van Trappen, 1964) point to the value of arranging fractures of the distal radius in separate groups because different types present different problems of treatment and may even have a different prognosis. Similarly, Wiklund & Müllern-Aspegren (1956) hold that one cannot compare the results of different methods of treatment unless one first defines the different types of fracture.

As Lidström (1959) points out, most of the numerous systems for classifying fractures of the distal radius appear to have been used in practice only by their authors (Kahleyss, 1897; Hitzrot & Murray, 1921; Ghormley & Mroz, 1932; Cornell, 1935; Ehalt, 1935; Kotrnetz & Geiringer, 1937). One reason for this is probably the extremely detailed nature of these classifications, particularly that published by Ehalt (1935) with no less than thirty-four different groups for such fractures in adults. Only four published classifications have been at all widely accepted, namely those by Destot (1923), Taylor & Parsons (1938), Nissen-Lie (1939) and Gartland & Werley (1951). Before commenting on these, here is a brief review of the various primary factors upon which published classifications have been based.

The *site of the fracture in relation to the wrist joint* is usually noted by distinguishing between extra- and intra-articular fractures of the distal radius. In general, no notice is taken of whether an intra-articular fracture involves only the radio-carpal or only the distal radio-ulnar joint, or both. On the other hand, attention is often paid to the *degree of joint involvement* as a result of any comminution of the distal fragment. Some authors have even distinguished between *T*- and *Y*-shaped fractures involving comminution, with a further category for fractures causing disruption of an ulnar fragment.

The *direction of displacement* has also been used both separately and, more commonly, in combination with the factors mentioned above for classifying fractures of the distal radius. Practically all the known forms of displacement of the distal radius fragment have been noted—with or without compression or widening—and serve as distinguishing characteristics in several classifications, particularly those of Pilcher (1917), Humphries (1948), Key (1954) and Arbeitlang & Boeckl (1963). In general, however, complicated divisions on this basis have been avoided by considering only two groups, those with dorsal and those with volar displacement. The *degree of displacement* is also frequently used as a basis for classification, fissure fractures and fractures without displacement commonly forming a single group, while the dislocated fractures are usually subdivided according to the degree of displacement.

Some authors regard *injury to the distal radio-ulnar joint* as such an important factor in the clinical picture that they base their systems upon its presence or absence.

Some systems have been based on the *mechanism of injury*, the distinction being between avulsion fractures and those occasioned by a blow and counterblow. In this context the position of the hand at the moment of injury has given rise to different groups for extension, flexion, abduction and adduction fractures, for which different fracture lines have been observed (Cornell, 1935).

As already mentioned, only four systems of classification based on some of these factors have won any general acceptance. These will now be considered separately.

Destot (1923) used the direction of displacement as his basic principle, distinguishing between anterior and posterior fractures. The former are subdivided into fractures of the radial styloid process, fractures of the volar margin and Smith's fracture, while the latter comprise Colles' fracture and fracture of the dorsal margin (Barton's fracture). This system has also been employed by Platt (1931) and Hoffman (1953).

Taylor & Parsons (1938) also had only two main groups, based upon the presence or absence of disc injury in the distal radio-ulnar joint. Only the group with disc injury is subdivided, partly according to whether or not the distal radius has a comminuted fracture. Mayer (1940) and Manges, Jr. (1941) have subsequently adopted this system.

Nissen-Lie (1939) took several factors into account in his classification, including the site of the fracture in relation to the joint surface, the degree of joint involvement, the direction and the degree of displacement. Fractures in adults were thus divided into five groups: 1. Fissure fractures with little or no displacement. 2. Extra-articular fractures with dorsal and radial displacement. 3. Comminuted fractures with one or several fracture lines involving the joint and considerable displacement of the fragment. 4. Fractures of the radial styloid process. 5. Fractures with volar displacement. Several authors in Scandinavia have adopted Nissen-Lie's system, e.g. Rosen (1947), E. Madsen (1949), Wiklund & Müllern-Aspegren (1956) and Djorup (1962).

Fig. 16. Fracture type I.

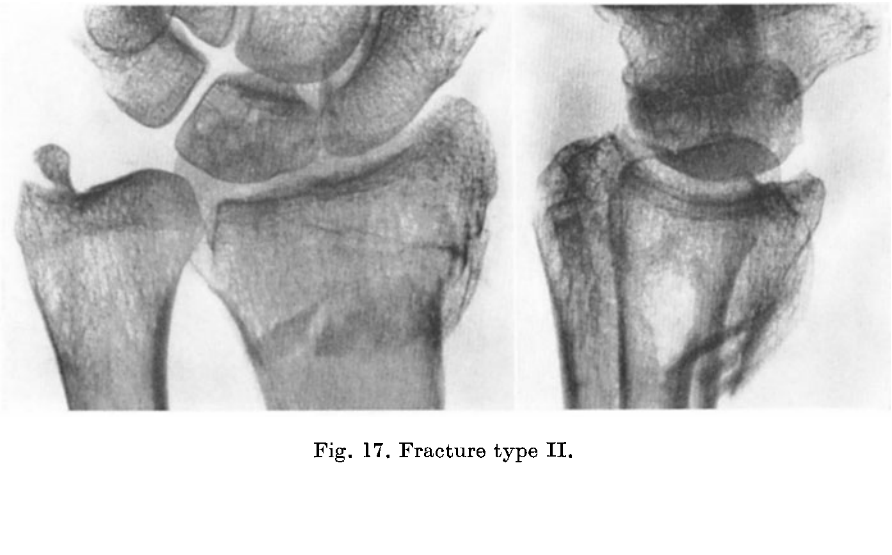

Fig. 17. Fracture type II.

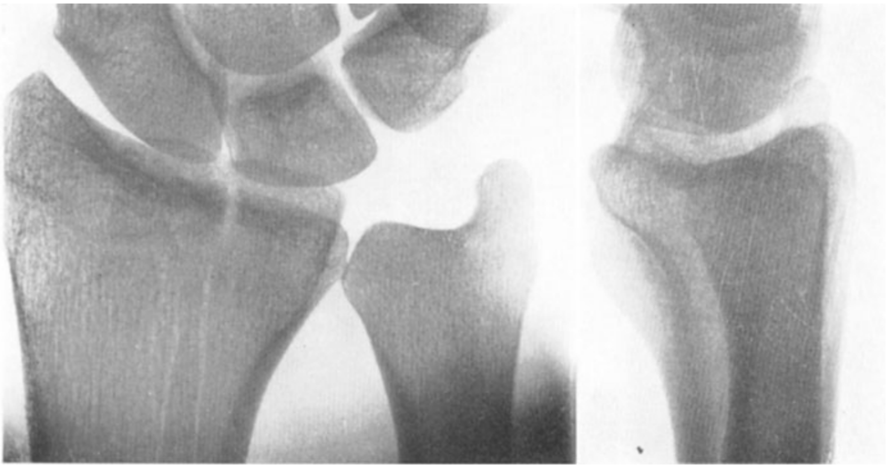

Fig. 18. Fracture type III.

Fig. 19. Fracture type IV.

Fig. 20. Fracture type V.

Fig. 21. Fracture type VI.

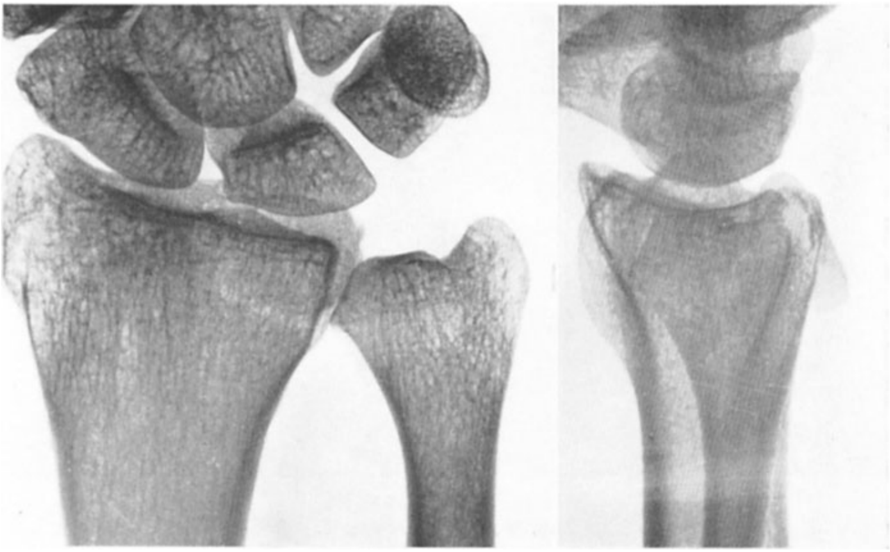

Fig. 22. Fracture type VII.

Fig. 23. Fracture type VIII.

Gartland & Werley (1951), finally, distinguished between three groups according to the fracture's position in relation to the radial articular surface, the degree of joint involvement and the degree of displacement: 1. Simple Colles' fracture not involving the radial joint surface. 2. Comminuted Colles' fracture involving the joint surface but without displacement in this. 3. Comminuted Colles' fracture involving the joint surface and with displacement of the fragments. Those who have subsequently followed this division include de Palma (1952) and K. P. Madsen (1959).

Lidström (1959) adopted the principle that only the factors which tend to elucidate certain clinical problems should be included in a system of classification. His system largely followed that drawn up by Kotrnetz & Geiringer (1937), which took into account the degree and direction of displacement, joint involvement and the degree of comminution. By modifying this system, Lidström rendered it simpler and probably enhanced its clinical value. The resultant arrangement comprised three main groups: I. Fissure fractures and fractures with no appreciable displacement. II. Fractures with posterior displacement. III. Fractures with volar displacement. The fractures in group I were held not to pose any clinical problems, excellent results being generally obtained irrespective of the treatment. A distinction was made between the fractures of groups II and III because the mechanism behind them differs and consequently they require different techniques of reduction. In view of the factors mentioned above, fractures with posterior displacement had to be subdivided and Lidström's complete classification appeared as follows:

I. Fissure fractures and fractures with no appreciable displacement.

II. Fractures with posterior displacement:
   - A. Fractures with merely dorsal angulation, not involving the joint surface.
   - B. Fractures with merely dorsal angulation, involving the joint but without comminution of the articular surface.
   - C. Fractures with complete displacement, not involving the joint surface.
   - D. Fractures with complete displacement, involving the joint but without comminution of the articular surface.
   - E. Fractures with complete displacement and comminution of the joint surface.

III. Fractures with volar displacement.

Commenting on this system, Lidström notes that fractures of the radial styloid process with displacement are included in group II E, while other fractures with displacement belong to groups II C, II D or II E, depending on the degree of joint involvement. Further, group II corresponds to Nissen-Lie's groups 2 and 3 (simple fracture-dislocations without joint involvement and comminuted fractures), the two types of fracture most often discussed in the Scandinavian literature.

Classification used in the present study

In the present study, in keeping with the principles adopted at the Department of Bone and Joint Surgery at Sahlgrenska Sjukhuset, it was not considered that the primary displacement should constitute an important factor in the system of classification. This is because the degree of primary displacement as measured on roentgenograms is hardly even an approximate indication of the actual displacement at the time of the fracture. It therefore seems worthless as a criterion. Nor, judging from the literature, does it seem that the direction of displacement is sufficiently important to necessitate consideration in this context. For the same reason, the degree of comminution in the distal fragment of the radius has been deemed irrelevant in a classification system; this factor impairs the prognosis only if the fracture reaches and causes displacement in the articular surfaces on the radius. Since instead it is presumably valuable—both for the prognosis and to some extent for treatment—primarily to determine the extent of involvement of the fracture in both the radiocarpal and the distal radio-ulnar joint, this has been adopted as the guiding principle for the classification of fractures in the present series. This principle largely corresponds to that published by Gartland & Werley (1951), i.e. the system subsequently accepted by e.g. de Palma (1952) and K. P. Madsen (1959).

The basic distinction in this system is between extra- and intra-articular fractures of the distal radius. In addition, consideration is paid to whether or not there is also a fracture of the distal ulna, the reason for this being the deleterious effect which such fractures have on the prognosis for the fractures of the distal radius in this series. The complete system of classification used here is as follows:

I. Extra-articular fractures without fracture of the distal ulna (Fig. 16).
II. Extra-articular fractures accompanied by fracture of the distal ulna (Fig. 17).
III. Intra-articular fractures involving the radio-carpal joint but without fracture of the distal ulna (Fig. 18).
IV. Intra-articular fractures involving the radio-carpal joint and accompanied by fracture of the distal ulna (Fig. 19).
V. Intra-articular fractures involving the distal radio-ulnar joint but without fracture of the distal ulna (Fig. 20).
VI. Intra-articular fractures involving the distal radio-ulnar joint and accompanied by fracture of the distal ulna (Fig. 21).

VII. Intra-articular fractures involving both the radio-carpal and the distal radio-ulnar joint but without fracture of the distal ulna (Fig. 22).

VIII. Intra-articular fractures involving both the radio-carpal and the distal radio-ulnar joint and accompanied by fracture in the distal ulna (Fig. 23).

Discussion

This classification has been applied consistently throughout the series regardless of whether the case involved a fissure fracture, fracture with only slight displacement or fracture with considerable displacement. Nor, as already mentioned, has primary consideration been paid to the direction of displacement (as for instance in Lidström's (1959) series, in which a distinction was made between fractures with dorsal and volar displacement). Although no conclusive reasons for making such a distinction could be found in the literature, a separate study has however been made of the functional end results for fractures with volar displacement in order to assess any difference that may exist in the results for fractures with this type of displacement. Similar special studies have also been made of the results for fissure fractures, fractures with only slight displacement and fractures with more pronounced displacement (fissure fractures, unreduced fractures and reduced fractures). Any significance discovered for these factors will be discussed in a subsequent chapter.

CHAPTER V

PRESENT SERIES

The cases included in the present study came from the series of fractures of the distal end of the radius treated at the Department of Bone and Joint Surgery of Sahlgrenska Sjukhuset, Gothenburg, from October 1956 to October 1959 (when the Department was located at Ekmanska Sjukhuset in Gothenburg). The series includes cases admitted to hospital for treatment and subsequently handled as out-patients, as well as cases treated entirely as out-patients. All the patients had been registered at the Department's out-patient reception. This register was inspected for the period in question and a selection was made of all records concerning fractures of the distal radius. The complete series comprised 516 fractures in 509 patients (7 fractures being bilateral). The follow-up examinations were conducted between December 1960 and June 1961, the mean interval from the accident being 2 years and 7 months.

The series does not include any individuals below 16 years of age because such cases are treated at the Children's Hospital in accordance with the local regulations for the City of Gothenburg's hospitals; nor does it seem disadvantageous to omit such cases: previous authors have noted that the type of distal fracture of the radius incurred by children differs as a rule from that in adults; the location is usually more proximal and the fracture is not infrequently of the greenstick type. In some cases there are also epiphyseal injuries (Lidström, 1959). Moreover the prognosis is considerably better than in adult fractures (Önne & Sandblom, 1949).

No upper age limit was set, though this has been done in some of the series published previously. Lidström (1959), for instance, excluded patients above the age of 75 because their physical and mental health was generally considered to be so poor that it was difficult to assess their performance. In the present series, however, there seemed to be no such difficulty in evaluating the total activity of these patients.

A separate analysis showed that the results for fissure fractures in the distal radius and fractures with no or only slight displacement were not as generally satisfactory in the present series as they have been reported to be by previous authors (e.g. Kotrnetz & Geiringer, 1937; Rosen, 1947; Wiklund & Müllern-Aspegren, 1956; Lidström, 1959). Unlike Lidström (1959), therefore, I could find no justification for excluding these cases.

Of the 509 patients in the original series, 22 (4.3%) had died between the time of their accident and the follow-up examination, while 30 (5.9%) had either only been visiting Gothenburg or had moved elsewhere and could not be traced for lack of a proper address. Moreover, 33 (6.5%) of the patients were for various reasons unwilling to submit to a follow-up examination, most of them reporting that they had completely recovered and saw no necessity for a further check-up; others stated that their work prevented them from attending a follow-up examination, while a few pleaded old age. None of the above 85 patients who were not examined had bilateral fractures. Altogether, therefore, 424 patients or 87.0% of the 487 survivors were examined at the follow-up, representing 431 fractures or 83.5% of the 516 in the complete series. To avoid misunderstanding and unless otherwise indicated, *only the number of fractures will be discussed below*, not the number of patients.

The distributions by sex and age for the complete series of 516 fractures (see Table 2) follows roughly the same pattern as in other published series of fractures of the distal radius (e.g. Kotrnetz & Geiringer, 1937; Nissen-Lie, 1939; Rosen, 1947; E. Madsen, 1949; Wiklund & Müllern-Aspegren, 1956; Hölund, 1957; Lidström, 1959; Baitsch & Heller 1959; Djorup, 1962; Waugh, 1963; Smaill, 1965). The maximum incidence for women is thus between 56 and 65 years and for men somewhat earlier, between 36 and 45 years. It is noteworthy that even though the present series includes only a few fractures in military conscripts (whereas Lidström's (1959), for instance, contained a considerable number), there is a high incidence of men aged 16–25 years.

As already mentioned, the 431 cases available for the follow-up investigation comprised 83.5% of the original series. Owing to serious discomfort after the fracture in the distal radius, an arthrodesis was performed in the radiocarpal joint in one of these 431 cases seven months after the fracture. The status of this case was thus not comparable with that of the others at the time of

TABLE 2. *Distribution by age and sex (total series).*

	Age								
	16–25	26–35	36–45	46–55	56–65	66–75	76–85	86–95	Total
Men	22	17	22	21	19	11	1	—	113 21.9%
Women	10	16	23	75	135	111	26	7	403 78.1%
Total	32 6.2%	33 6.4%	45 8.7%	96 18.6%	154 29.9%	122 23.6%	27 5.2%	7 1.4%	516
No. followed-up	23/32 72%	21/33 64%	40/45 89%	85/96 89%	142/154 92%	105/122 86%	14/27 52%	1/7 14%	431/516 83.5%

the follow-up examination and consequently it has been omitted. Accordingly, *the calculations presented below refer to the remaining 430 cases in the follow-up series.*

The sex distribution in the follow-up series agrees fairly well with that for the complete series and for other series published earlier (see above). The proportions are thus 80.9% women and 19.1% men, compared with 78.1 and 21.9% in the complete series and 81.1 and 18.9% in Lidström's.

While the age distribution in the follow-up series is also much the same as in the complete series (see Table 3), there are some exceptions. Both the youngest and, in particular, the oldest age groups have become smaller. The reduction in the youngest groups is chiefly due to unwillingness to take part in the examination but partly because the patients had left Gothenburg and could not be traced. The smaller size of the older age groups is due to all the deaths having occurred here as well as to the patients' unwillingness to participate for reasons of age. The maximum incidence among the women is still between 56 and 65 years. Among the men it is in the lower age groups, though both 36–45 years and 46–55 years now have a high incidence. There is still a high incidence of men in the lowest age group. No definite explanation could be found for this circumstance. A possible factor may be the inclusion of radius fractures without displacement (i.e. without reduction) in the series. While the predominace of men in the youngest age groups applies to both the reduced and the un-reduced cases, it is most marked in the latter (cf. Tables 4 and 5).

The 430 cases in the follow-up series are arranged by type of fracture, sex and age groups in Table 6. There is a remarkable predominance of intra-articular fractures, which account for about two-thirds of the series. This is most unlike the pattern usually reported in the literature, where the extra-articular fractures account for two-thirds or more of published series (Nissen-Lie, 1939; Lidström, 1959; van Trappen, 1964). This discrepancy cannot be explained by the inclusion of both reduced and un-reduced fractures since, as shown

TABLE 3. *Distribution by age and sex (follow-up series).*

	Age								
	16–25	26–35	36–45	46–55	56–65	66–75	76–85	86–95	Total
Men	15	8	17	18	16	8	—	—	82 19.1%
Women	8	13	22	67	126	97	14	1	348 80.9%
Total	23 5.3%	21 4.9%	39 9.1%	85 19.8%	142 33.0%	105 24.4%	14 3.3%	1 0.2%	430

TABLE 4. *Distribution of age groups by type of fracture and sex (295 reduced cases).*

	Type of fracture																Total		
	I		II		III		IV		V		VI		VII		VIII				
Age	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	Total
16–25	—	1	3	2	—	—	—	1	—	1	3	1	—	1	—	2	6	9	15
																	2.0%	3.1%	5.1%
26–35	—	—	4	—	1	1	1	1	2	—	2	—	—	—	1	—	11	2	13
																	3.7%	0.7%	4.4%
36–45	—	1	3	1	1	2	1	3	1	—	6	1	—	1	1	1	13	10	23
																	4.4%	3.4%	7.8%
46–55	1	—	11	1	1	5	5	3	3	1	14	4	2	—	10	1	47	15	62
																	15.9%	5.1%	21.0%
56–65	9	—	12	2	5	—	11	1	7	2	18	—	6	—	17	2	85	7	92
																	28.8%	2.4%	31.2%
66–75	13	—	15	—	1	—	12	—	2	—	11	—	2	—	19	1	75	1	76
																	25.4%	0.3%	25.7%
76–85	4	—	4	—	2	—	—	—	—	—	2	—	—	—	1	—	13	—	13
																	4.4%	—	4.4%
86–95	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	1
																	0.3%	—	0.3%
Total	27	2	52	6	11	8	30	9	15	4	57	6	10	2	49	7	251	44	295
																	85.0%	15.0%	
	29		58		19		39		19		63		12		56		295		
	9.8%		19.7%		6.4%		13.2%		6.4%		21.4%		4.1%		19.0%				

TABLE 5. *Distribution of age groups by type of fracture and sex (135 un-reduced cases).*

Age	Type of fracture I ♀	I ♂	II ♀	II ♂	III ♀	III ♂	IV ♀	IV ♂	V ♀	V ♂	VI ♀	VI ♂	VII ♀	VII ♂	VIII ♀	VIII ♂	Total ♀	Total ♂	Total
16–25	—	3	1	1	—	1	1	—	—	1	—	—	—	—	—	—	2	6	8
																	1.5%	4.4%	5.9%
26–35	2	2	—	—	—	2	—	—	—	2	—	—	—	—	—	—	2	6	8
																	1.5%	4.4%	5.9%
36–45	5	2	2	1	1	3	—	1	1	—	—	—	—	—	—	—	9	7	16
																	6.7%	5.2%	11.9%
46–55	7	1	3	—	3	1	2	—	1	—	2	—	1	—	1	1	20	3	23
																	14.8%	2.2%	17.0%
56–65	15	3	6	2	8	2	4	1	3	—	3	1	—	—	1	—	40	9	49
																	29.6%	6.7%	36.3%
66–75	6	1	4	1	3	1	5	1	3	1	1	1	—	1	1	—	23	7	30
																	17.0%	5.2%	22.2%
76–85	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
																	0.7%	—	0.7%
86–95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
																	—	—	—
Total	36	12	16	5	15	10	12	3	8	4	6	2	1	1	3	1	97	38	135
																	71.9%	28.1%	
	48		21		25		15		12		8		2		4		135		
	35.6%		15.5%		18.5%		11.1%		8.9%		5.9%		1.5%		3.0%				

TABLE 6. *Distribution of age groups by type of fracture and sex in follow-up series.*

	Type of fracture																Total		
	I		II		III		IV		V		VI		VII		VIII				
Age	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	Total
16–25	—	4	4	3	—	1	1	1	—	2	3	1	—	1	—	2	8	15	23
																	1.9%	3.4%	5.3%
26–35	2	2	4	—	1	3	1	1	2	2	2	—	—	—	1	—	13	8	21
																	3.0%	1.9%	4.9%
36–45	5	3	5	2	2	5	1	4	2	—	6	1	—	1	1	1	22	17	39
																	5.1%	4.0%	9.1%
46–55	8	1	14	1	4	6	7	3	4	1	16	4	3	—	11	2	67	18	85
																	15.6%	4.2%	19.8%
56–65	25	3	18	4	13	2	15	2	10	2	21	1	6	—	18	2	126	16	142
																	29.3%	3.7%	33.0%
66–75	18	1	19	1	4	1	17	1	5	1	12	1	2	1	20	1	97	8	105
																	22.5%	1.9%	24.4%
76–85	5	—	4	—	2	—	—	—	—	—	2	—	—	—	1	—	14	—	14
																	3.3%	—	3.3%
86–95	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	1
																	0.2%	—	0.2%
	63	14	68	11	26	18	42	12	23	8	63	8	11	3	52	8	348	82	430
Total	14.6%	3.3%	15.8%	2.6%	6.0%	4.2%	9.7%	2.8%	5.3%	1.9%	14.6%	1.9%	2.6%	0.7%	12.1%	1.9%	80.9%	19.1%	
	77		79		44		54		31		71		14		60		430		
	17.9%		18.4%		10.2%		12.5%		7.2%		16.5%		3.3%		14.0%				

by Tables 4 and 5, the intra-articular fractures do not predominate among the cases not subjected to reduction. Instead, I should like to put forward a different explanation.

In reports on these fractures in the literature it is usual to record the presence of joint involvement in the distal radius. This is generally taken to mean just the fracture's involvement of the distal articular surface of the radius and it is only exceptionally that mention is made of the ulnar articular surface in this context (Fagge, 1929; Lang, 1942; Chandler, 1950). Although many authors have studied injuries to the soft tissues in the distal radio-ulnar joint in connection with distal fractures of the radius, *no one appears to have drawn attention to this fracture's solitary involvement of the distal radio-ulnar joint*, in my opinion a common and clinically important variant of this fracture. I suspect that a large proportion of the fractures described in the literature as extra-articular and affecting the distal end of the radius were in fact intra-articular in the distal radio-ulnar joint. This opinion is supported by the following simple calculation: if the 102 fractures in the present series with intra-articular involvement of only the distal radio-ulnar joint are transferred to the group of extra-articular fractures, the latter will comprise 60% of the series, i.e. much the same incidence as that usually reported for extraarticular fractures in the literature.

The age distribution shown in Table 6 also largely corresponds to that generally reported in the literature. The present study gave no indication that the distribution by type of fracture is influenced by the age factor.

There are 19 fissure fractures among the 430 cases in the follow-up series and their distribution by age, sex and type of fracture is shown in Table 7. It may be noted that the number of intra-articular fractures in this group amounts to considerably less than 50%, in contrast to the proportion in the rest of the follow-up series. There are more fissure cases in the youngest age groups and they are relatively more common among the men.

The follow-up series also includes 17 cases with volar displacement in the radius fracture. Their distribution by age, sex and type of fracture is given in Table 8. In relation to the total follow-up series there is a higher proportion of men in this group, which is also somewhat over-represented in the youngest age groups.

Both the fissure fractures and the volar fractures will be discussed separately in a subsequent chapter.

Discussion

Out of the complete series of 516 cases between 16 and 95 years of age, follow-up examination was originally performed on 431 or 83.5%. This is a

TABLE 7. *Distribution of fissure fractures by type of fracture, sex and age.*

Age	Type of fracture I ♀	♂	II ♀	♂	III ♀	♂	IV ♀	♂	V ♀	♂	VI ♀	♂	VII ♀	♂	VIII ♀	♂	Total ♀	♂	Total
16–25	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	4	4
26–35	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2
36–45	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
46–55	1	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	3	—	3
56–65	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	1	4
66–75	—	—	—	—	2	—	1	—	1	—	—		—	—	—	—	4	—	4
76–85	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
86–95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	8	3	—	1	4	1	1	—	1	—	—	—	—	—	—	—	14	5	19
																	73.7%	26.3%	
	11		1		5		1		1		—		—		—		19		

TABLE 8. *Distribution of fractures with volar displacement by type of fracture, sex and age.*

	Type of fracture																		
	I		II		III		IV		V		VI		VII		VIII		Total		
Age	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	Total
16–25	—	1	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	3	3
26–35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
36–45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
46–55	—	—	1	—	—	2	1	2	—	—	—	—	—	—	—	—	2	4	6
56–65	—	—	1	—	—	—	2	—	—	—	—	—	1	—	1	—	5	—	5
66–75	—	—	2	—	—	—	—	—	—	—	—	—	—	—	1	—	3	—	3
76–85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
86–95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
																	10	7	17
Total	—	1	4	—	—	2	3	3	—	—	—	—	1	1	2	—	59%	41%	
	1		4		2		6		—		—		2		2		17		

relatively high figure compared with, for instance, *Lidström's* (1959) series with 68%. Lidström was unable to determine whether his 68% were representative of the total series but he did find good agreement in the distribution by age and type of fracture between those who were examined and those who were not. He therefore concluded that, since the treatment had been uniform, there was good reason to suppose that the follow-up series was in fact representative of the total series. Moreover, a questionnaire was sent to some of the unexamined patients, asking about their recovery; 58% of these replied that they were completely free from discomfort. In the follow-up series, the same subjective opinion had been given by 54%.

Turning to the distribution by age, sex and type of fracture for the unexamined cases in the present series (Table 9), it will be seen that the youngest and oldest age groups account for a larger proportion than they do with respect to the follow-up series (Table 6). This is explained both by the difficulty of interesting the youngest individuals in a follow-up examination, since they considered themselves entirely recovered, and by the fact that all the deaths occurred in the highest age groups. On a sex basis, most of the unexamined cases among the women were in high age groups, while most of those among the men were in low age groups. Deaths and a reluctance induced by age explain the drop-out among the women, while many of the young men were unwilling to participate because they considered themselves recovered. Concerning the distribution of those not included in the follow-up by type of fracture, somewhat more had extra-articular injury than in the follow-up group. Moreover, the intra-articular fractures have fewer complicated cases in the group not included in the follow-up than in the follow-up series. This agrees to some extent with the findings reported by Lidström (1959). It could possibly be explained by the fact that the incidence of severe fractures is lower in the younger age groups than in the older, an effect which would be heightened by the over-representation of individuals in the younger groups.

A skewness of this sort in the series not included in the follow-up may of course detract from the value of the results of this series and make it less representative of the complete series. The discrepancies, however, chiefly favour the younger age groups and the simpler types of fracture, both of which are known to be favourable prognostic factors. Thus an increased participation by the patients not included in the follow-up could be expected to produce a generally better functional end result.

Only in the case of minor differences, therefore, will discrepancies in the composition of the total series and the follow-up series introduce an element of uncertainty. In other respects the follow-up series must be regarded as representative (cf. also the distribution of the total and the follow-up series by type of fracture and age groups in Tables 10 and 6).

TABLE 9. *Distribution of cases not followed up by type of fracture, sex and age.*

Age	I ♀	I ♂	II ♀	II ♂	III ♀	III ♂	IV ♀	IV ♂	V ♀	V ♂	VI ♀	VI ♂	VII ♀	VII ♂	VIII ♀	VIII ♂	Total ♀	Total ♂	Total
16–25	1	1	—	2	1	2	—	2	—	—	—	—	—	—	—	—	2 2.4%	7 8.2%	9 10.6%
26–35	—	4	2	1	1	—	—	2	—	—	—	—	—	1	—	1	3 3.5%	9 10.6%	12 14.1%
36–45	—	—	1	—	—	1	—	2	—	—	—	—	—	—	—	1	1 1.2%	4 4.7%	5 5.9%
46–55	2	—	2	—	1	2	1	1	—	—	1	—	—	—	1	—	8 9.4%	3 3.5%	11 12.9%
56–65	2	—	2	—	—	2	—	1	—	—	3	—	—	—	2	—	9 10.6%	3 3.5%	12 14.1%
66–75	3	—	3	1	—	1	3	—	3	—	2	1	—	—	—	—	14 16.5%	3 3.5%	17 20.0%
76–85	3	—	6	—	—	—	—	1	—	—	3	—	—	—	—	—	12 14.1%	1 1.2%	13 15.3%
86–95	—	—	1	—	—	—	3	—	—	—	—	—	—	—	2	—	6 7.1%	— —	6 7.1%
Total	11	5	17	4	3	8	7	9	3	—	9	1	—	1	5	2	55 64.7%	30 35.3%	85
	16 18.8%		21 24.7%		11 12.9%		16 18.8%		3 3.5%		10 11.8%		1 1.2%		7 8.2%			85	

TABLE 10. *Distribution of age groups by type of fracture and sex in total series.*

	Type of fracture																Total		
	I		II		III		IV		V		VI		VII		VIII		Total		
Age	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	Total
16–25	1	5	4	5	1	3	1	3	—	2	3	1	—	1	—	2	10	22	32
																	1.9%	4.3%	6.2%
26–35	2	6	6	1	2	3	1	3	2	2	2	—	—	1	1	1	16	17	33
																	3.1%	3.3%	6.4%
36–45	5	3	6	2	2	6	1	6	2	—	6	1	—	1	1	3	23	22	45
																	4.5%	4.2%	8.7%
46–55	10	1	16	1	5	8	8	4	4	1	17	4	3	—	12	2	75	21	96
																	14.5%	4.1%	18.6%
56–65	27	3	20	4	13	4	15	3	10	2	24	1	6	—	20	2	135	19	154
																	26.2%	3.7%	29.9%
66–75	21	1	22	2	4	2	20	1	8	1	14	2	2	1	20	1	111	11	122
																	21.5%	2.1%	23.6%
76–85	8	—	10	—	2	—	—	1	—	—	5	—	—	—	1	—	26	1	27
																	5.0%	0.2%	5.2%
86–95	—	—	1	—	—	—	3	—	—	—	1	—	—	—	2	—	7	—	7
																	1.4%	—	1.4%
	74	19	85	15	29	26	49	21	26	8	72	9	11	4	57	11	403	113	516
Total	14.3%	3.7%	16.5%	2.9%	5.6%	5.0%	9.5%	4.1%	5.0%	1.6%	14.0%	1.7%	2.1%	0.8%	11.1%	2.1%	78.1%	21.9%	
	93		100		55		70		34		81		15		68		516		
	18.0%		19.4%		10.6%		13.6%		6.6%		15.7%		2.9%		13.2%				

CHAPTER VI

GENERAL ASPECTS OF TREATMENT, WITH SPECIAL REFERENCE TO THE PRESENT SERIES

Considerable space has been devoted to the subject of treatment in many previous reports on the clinical aspects of distal radius fractures. The account which I have found most complete in this respect is that published by Lidström (1959), in which the problem is approached from the following angles: (1) Technique of reduction, (2) Appropriate time for reduction, (3) Method of anaesthesia, (4) Technique of immobilization, (5) Duration of immobilization, (6) Position of the hand during immobilization, and (7) Physical therapy. In view of the completeness of this account, I feel it would be unnecessarily repetitive to present a further review of the relevant literature here. Instead, the reader is referred to Lidström's monograph for reference to literature up to 1959. The following account, based on the headings listed above, is a brief review of more recent publications in this field, coupled with the related information arising out of the present follow-up investigation.

Technique of reduction

The reduction technique described by Böhler (1923) still seems to be most widely used (Lidström, 1959; Hamsa, 1962; Guttman, 1964; Older, Stabler & Cassebaum, 1965; Soren, 1965) though some authors still refer to the technique described by Robert Jones (1915), which now appears to be practised largely in Anglo-Saxon countries (Sponsel, 1964). Kane (1964), however, has emphasised the importance of allowing for the primary displacement in the individual fracture when reducing this.

Authors continue to point out that Böhler's technique requires rather a large staff, and attempts have been made to apply new forms of extension apparatus instead of manual traction during reduction (Grath, 1956) or else the use of finger traction with the help of Chinese finger stalls (Older, Stabler & Cassebaum, 1965). The extension apparatus described by Grath (used in several cases in the present series) can be employed for fractures of the distal radius as well as for forearm fractures, while a slight modification makes it suitable for fractures of the lower leg as well. The apparatus is easy to apply on an ordinary operating table and the extension is achieved by traction on all the fingers, but not the thumb, the former being fixed midway up the proximal phalanges by an adjustable, rubberized cuff. A system of springs makes it possible to adjust the traction to the desired number of kilograms.

Own cases. There were 295 cases among the 430 in the present follow-up series in which the primary treatment involved *closed reduction.* Böhler's technique had been used in all these cases, though in 31 of them, manual traction had been replaced by traction with the extension apparatus described by Grath (1956). The dorsal or volar displacement had been corrected by volar or dorsal flexion of the hand as well as by direct pressure against the distal fragment. Secondary *open reduction* had been performed in 7 cases at various intervals after the primary reduction in order to correct a persistent displacement, the fracture being fixated either with a loop of steel wire passed through the bone or with a Kirschner wire implanted subcutaneously.

Appropriate time for reduction

Little of importance has been contributed to this topic since Lidström's monograph (1959). Immediate reduction is still generally considered preferable to any delay (Guttman, 1959; K. P. Madsen, 1959), though Golden (1963) is of the opinion, previously put forward by e.g. Kotrnetz & Geiringer (1937), that the reduction should not be carried out until at least 24 hours after the accident. This is believed to reduce the risk of renewed haemorrhage in the fracture region, thereby diminishing the post-traumatic swelling and the number of early circulatory disturbances. An intermediate position has been adopted by Sponsel (1965), who prefers to delay reduction except in cases of open fracture or pronounced dorsal dislocation.

Own cases. Reduction was performed only a few hours after the injury in the great majority of the 295 cases given this treatment in the present series. The result was checked by X-ray examination and a renewed attempt was made if the previous one proved unsatisfactory.

There were 29 cases in which the reduction had not been performed immediately, because the patients waited before applying for treatment. In 15 of these cases, however, no more than 12–24 hours elapsed between the accident and the time of reduction. More than 24 hours (in one case as much as a week) elapsed before reduction in the remaining 14 cases. Even so, the post-reduction course in these cases did not differ significantly from that in the cases in which reduction could be performed without delay.

The 7 cases in which open reduction was performed as a secondary measure constitute a special group among the reduced cases. Primary closed reduction had been attempted in all these cases but had either failed or soon been followed by re-dislocation in the fracture, whereupon it was decided that surgical treatment was indicated. In these cases, the open reduction was undertaken between 1 and 7 days after the accident.

As already indicated, the follow-up series includes 135 cases in which reduction was not performed. The two types of extra-articular fractures accounted for 69 of these, while 40 of the remaining 66 were intra-articular only in the radio-carpal joint, 20 occurring only in the distal radio-ulnar joint and 6 in both these joints. The dorsal angulation amounted to less than 10° in 83 of these 135 cases, to between 10° and 20° in 50 cases and to between 20° and 30° in 2 cases. One of the last two cases was a re-fracture and, since it was considered that part of the displacement was probably residual from the first fracture, reduction was not attempted after the present injury. In the other case, reduction was not performed on account of the patient's advanced age.

Method of anaesthesia

Judging from publications on fractures of the distal radius in recent years, complete agreement still seems to be lacking as to which form of anaesthesia is most suitable for obtaining the best results from reduction. Local anaesthesia still seems to be the method most generally used (Schwetlick, 1962; Sponsel, 1964; Soren, 1965) while some authors recommend general anaesthesia only (e.g. Miller, 1960) and others are not so categorical. Thus, Mack (1959) and Gambier & Venturini (1964) recommend local anaesthesia for elderly patients and general anaesthesia or brachial block for younger, while van Trappen (1964) and Older, Stabler & Cassebaum (1965) recommend local anaesthesia for simple types of fracture and general anaesthesia or brachial block for more complicated.

In Lidström's (1959) series, local anaesthesia had been used at reduction in 388 out of 486 cases. Lidström points out that more than a quarter of these patients stated at the follow-up examination that they would have preferred a general anaesthesia on account of the severe pains which they experienced during the manipulations for reduction. There were 98 patients in Lidström's series who received a general anaesthesia, reduction having first been attempted under a local anaesthesia in 14. In a further 6 cases in which an initial attempt at reduction under local anaesthesia had failed, a brachial block was used for the final reduction.

Own cases. Of the 295 reduction cases in the present series, local anaesthesia was given in 247, brachial block in 20, general anaesthesia in 16 and no anaesthesia in 10. In the remaining 2 cases, a local anaesthesia proved insufficient to ensure a satisfactory reduction, whereupon a brachial block was administered in one case and a general anaesthesia in the other.

Of the 31 cases in which Grath's (1956) extension apparatus was used for the primary reduction, local anaesthesia was administered in 19, brachial block in 6, general anaesthesia in 2 and no anaesthesia in 4. Of the seven cases in which open reduction was performed (see above), this was done with a brachial block in six and a general anaesthesia in one. There was one case in which brachial block was used for transfixation, after closed reduction and immobilization in plaster had proved unsuccessful. Brachial block was also used as a rule in the limited number of cases in which closed reduction was re-attempted following re-dislocation shortly after the primary reduction.

Discussion. There is no justification for using the results of reduction as an indication of the superiority of a particular form of anaesthesia. The choice of anaesthesia should be dictated by the individual circumstances. *In general, it seems that satisfactory reduction of a fracture in the distal radius can be obtained in local anaesthesia.* The analgesic effect of a local anaesthesia in this type of fracture has been discussed, for instance, by Lidström (1959). As already mentioned, a good 25 per cent of the patients in his series who underwent reduction in local anaesthesia, spontaneously complained of having suffered severe pains during the manipulations. In the present series, in which 247 out of 295 cases were reduced in local anaesthesia alone, only ten patients reported such complaints spontaneously. A further indication that the analgesic effect is sufficient can be derived from the fact that local anaesthesia was usually employed even for relatively complicated manipulations such as reduction with an extension apparatus. The other types of anaesthesia—brachial block and general anaesthesia—obviously have advantages in respect of analgesia and muscular relaxation, but their use is to some extent limited by the fact that these fractures are generally treated as out-patient cases.

Technique of immobilization

Lidström (1959) found that the technique of immobilization "is undoubtedly the most controversial detail in the management of fractures of the distal radius". The available literature contained a wide range of recommendations, from a complete absence of fixation to large circular plaster bandages enclosing the whole arm. In general, however, the aim was to devise a means of fixation that ensures satisfactory immobilization without preventing active movements of the fingers at an early stage. In Lidström's own series the standard procedure was a dorsal plaster splint; a circular plaster was used in only 12 cases, with the elbow included in no more than two.

Even in later publications there does not seem to be complete agreement about the ideal way of immobilizing fractures in the distal radius. By and large, however, the dorsal plaster splint advocated by Böhler (1919, 1923) still seems to be most common, at least in Europe (Rehn, 1965; Smaill, 1965). At the same time, there are still many authors who question this simple immobilization technique's effectiveness in preventing re-dislocation. Instead, they propose the use of a circular plaster on the forearm (Guttman, 1959; Schwetlick, 1962; Soren, 1965). Others go further and recommend the general use of a circular plaster extending above the elbow (Schnek, 1962; Kudelka, 1963; Sponsel, 1964). Several authors wish to take the patient's age and the extent of the injury into consideration, a circular forearm plaster being used for younger individuals with simple types of fracture and a plaster that also encloses the elbow for others. Several American authors recommend a sugar-tong plaster, some of them together with a circular plaster bandage (Kenney, 1960; Miller, 1960; Kane, 1964; Older, Stabler & Cassebaum, 1965).

Various methods of transfixation still seem to be in common use and are recommended in both the English and the German literature (Mack, 1959; Kenney, 1960; Miller, 1960; Schnek, 1962; Brady, 1963; Kane, 1964; Scott, 1964). This is also true of fixation with Kirschner wires, particularly for comminuted fractures (Willenegger & Guggenbühl, 1959; Boutin, 1960; Older, Stabler & Cassebaum, Raschle, 1965; Rehn, 1965). Some authors indicate a preference for embedded Steinman pins, which are introduced through the ulna in the direction of the radial styloid process (K. P. Madsen, 1959; Dowling & Sawyer, 1961).

Elaborate methods for osteosynthesis appear to be recommended only for fractures that are particularly difficult to reduce and fixate. Several authors mostly use a technique for closed reduction and fixation with Rush pins (Rush & Rush, 1949), good results being reported with this treatment (Thornton & Warner, 1955; Edwards, 1959; Mack, 1959). Other authors find it valuable in such cases to use open reduction and crossed Kirschner wires for fixation of the fragments (e.g. Jung & Heineman, 1961).

Irrespective of the technique proposed for promoting fixation, these authors generally use some form of immobilization with plaster as well. Rush & Rush (1949), however, state that their technique for osteosynthesis imparts sufficient stability for immediate functional exercise.

Own cases. Some form of plaster support was used for fixation of the fracture in all but two of the 430 cases in the follow-up examination. No fixation at all was used in one case without reduction, while in one reduced case fixation was achieved simply with an elastic bandage.

A dorsal plaster splint was applied in the unreduced cases as well as in 174 of those in which reduction was performed, a circular plaster being fitted in the other 120 cases. It may be noted that closed reduction had been performed in the case in which only an elastic bandage was used for fixation, while plaster was used in all the seven cases of open reduction as well as in the only case of transfixation. The elbow was included in the circular plaster in six of the 120 cases given this treatment, the reason in each case being that the position of reduction was judged to be so unstable that forearm rotation had to be prevented in order to reduce the risk of re-dislocation.

Duration of immobilization

In Lidström's (1959) series the period of immobilization lasted an average of 34.8 days, simpler types of fracture generally having the shortest periods, comminuted fractures and Smith's fractures the longest. The majority of authors who have subsequently touched on this subject recommend a period of five or six weeks (Mack, 1959; Kenney, 1960; Hamsa, 1962; Kudelka, 1963; Waugh, 1963) and recommendations to prolong the period of immobilization are also common (Guttman, 1959; K. P. Madsen, 1959; Drill, 1963; Sponsel, 1964; Older, Stabler & Cassebaum, 1965). Only occasionally are reasons given for shortening this period to three (van Trappen, 1964) or four weeks (Smaill, 1965). Extreme proposals such as not using any immobilization at all (Lucas-

Championnière, 1886; Petersen, 1894) do not appear to have been put forward in the literature in recent years.

Own cases. Immobilization lasted an average of 28 days for the entire follow-up series. Most of the fractures with or without dislocation were kept immobilized for four to five weeks, fissure cases generally not more than two to three weeks, while a few comminuted fractures were immobilized for as much as twelve weeks.

These figures refer to the duration of continuous fixation. A dorsal plaster splint was used in a few cases as a support during the night for the first week after the regular plaster had been removed.

Position of the hand during immobilization

Lively interest used to be aroused by this subject, as noted by Lidström (1959) in his review. The chief questions were whether it is necessary to immobilize the hand in volar flexion and whether fixation in this position in fact involves a direct risk for the injured hand during the post-traumatic course. Lidström reported that in his series the wrist was immobilized as a rule in a neutral position, if possible combined with ulnar deviation. In only a few cases had the wrist been placed in a position of palmar flexion after the fracture had been reduced, generally because it had been difficult to eliminate the dorsal angulation. In all Lidström's cases the position of volar flexion was changed to one of extension after 10–14 days. In keeping with Böhler (1919), several authors have recently condemned fixation in palmar flexion and ulnar deviation, especially in such extreme forms as Cotton-Loder's position. In particular, this position is considered to involve a considerable risk of compression of the median nerve as a result of constriction of the carpal tunnel (Abbot & Saunders, 1933; Meadoff, 1949; Robbins, 1963). The position of fixation described by Böhler—with the extended wrist midway between pronation and supination, combined with moderate ulnar deviation—still seems to be the one most generally accepted (Hamsa, 1962; Kudelka, 1963; Mandell, 1965; Rehn, 1965). Several authors, however, prefer a completely neutral position for the wrist, i.e. midway between extension and flexion, ulnar and radial deviation and pronation and supination (e.g. Soren, 1965). Guttman (1959) and Mack (1959) also recommended a neutral position between extension and flexion for the wrist, but in combination with ulnar deviation; in other words, the position for immobilization that was most common in Lidström's (1959) series.

Own cases. As already mentioned, reduction was not performed in 135 cases in the present series. One of these cases had no fixation in plaster at all, while a dorsal plaster splint had been used in the other 134. In these cases, the wrist was immobilized in slight dorsal flexion and ulnar deviation.

All but one of the 295 reduced fractures in the series were immobilized with some type of plaster, the exception being the case in which only an elastic bandage was used. Of the 294 cases treated with plaster, 195 had the wrist placed in a neutral position, 82 had the wrist in volar flexion and 17 in dorsal flexion; these positions were combined with ulnar deviation. Volar flexion, when used, was moderate and never more than 30°, the indication in all cases being a clear risk of dorsal re-dislocation; the position was maintained for not more than 10–14 days, after which the wrist was placed midway between flexion and extension. In the case of immobilization in dorsal flexion, all 17 cases had had primary volar dislocation of the fracture.

Physical therapy

There seems to have been a gradual decline in the popularity of the early, intensive physical therapy—with passive exercises, massage and heat—that was frequently practised at the beginning of this century. Such therapy has in fact been used in more recent series, though generally on special indications only (Lidström, 1959). Such indications were present in a good 25 per cent of Lidström's series and this group displayed considerably less satisfactory functional end results than the rest of the series. According to Lidström, no conclusion could be reached about the value of the physical therapy in his series, except that it had no appreciable influence on the end result in the group in which it was used. Otherwise there are only a few authors who discuss the justification for physical therapy in connection with fractures of the distal radius. Older, Stabler & Cassebaum (1965) and Smaill (1965) state that they use it only if the patient so wishes or under special circumstances such as when the fracture is complicated by a shoulder-hand-finger syndrome.

The gradual abandonment of routine physical therapy for fractures of the distal radius occurred after Böhler (1919) stressed the value of active functional training. In recent years there have thus been many authors who have indicated the desirability of carefully instructing the patient about active finger movements at the start of treatment, strongly emphasizing the value of using the hand as much as possible for normal everyday tasks during the period of healing (Guttman, 1959; K. P. Madsen, 1959; Kenney, 1960; Djorup, 1962; Hamsa, 1962; Schwetlick, 1962; Golden, 1963; Kudelka, 1963; Kane, 1964; Sponsel, 1964; van Trappen, 1964; Older, Stabler & Cassebaum, 1965; Raschle, 1965; Rehn, 1965; Smaill, 1965; Soren, 1965).

Active arm and shoulder movements in the form of daily exercises have previously not been ascribed the same importance as active finger exercises for avoiding complications during the treatment of fractures of the distal radius. A sling is still widely used, at least during the first week of immobilization. More recently, Moberg (1955) and others have pointed out the value of active arm movements for counteracting stiffness of the shoulder and swelling of the fingers after such fractures and this has subsequently been emphasized by several authors (Guttman, 1959; Hamsa, 1962; Golden, 1963; Kane, 1964; Sponsel, 1964; Raschle, 1965; Rehn, 1965; Soren, 1965).

Own cases. All the patients in the present series were instructed at the start of treatment about intensive active exercises in the form of movements of the shoulder and fingers. The use of a sling was generally forbidden. Instead, the patients were advised to perform *active elevation of both arms simultaneously to full extension at least 50 or 100 times a day.* It is my opinion that this consistent regimen kept the need of physical therapy to a minimum in this series, as witness the data provided in subsequent chapters and the separate review of the small number of cases with a shoulder-hand-finger syndrome.

Physical therapy in the form of *active* exercises *supervised by a physical therapist* and limited to finger, wrist and shoulder movements was given to only 11 patients in the present series. Nine of these developed swelling of the fingers and a tendency to stiffness of the shoulder at an early stage of treatment; the physical therapy was consequently introduced while the patient was still in plaster, mainly as a prophylaxis against the shoulder-hand-finger syndrome. In the other two cases, physical therapy was given after the end of immobilization to counter a loss of mobility in both the wrist and the forearm.

As will be seen from the separate review of the shoulder-hand-finger syndrome, only three of the nine cases given early physical therapy had a residual loss of function, with impaired finger mobility and poor mobility in the wrist. In the other six cases the active physical therapy may be said to have had a certain prophylactic effect. Once again, it should be pointed out that this therapy only involved active exercises and not passive movements, massage or any form of heat treatment.

CHAPTER VII

CASE REPORTS AND INVESTIGATION TECHNIQUES

Case reports

Written reports were available on all the patients in the follow-up series. They generally included a brief account of the accident as well as a report on the patient's condition at the time of admission to the hospital, including the appearance of the wrist and any signs of disturbance in the innervation fields of the median, ulnar and radial nerves. Information was also provided on the post-traumatic course, including any subsequent neurological symptoms, symptoms of the shoulder-hand-finger syndrome, swelling of the wrist or fingers from other causes, tendon injury and the like. Furthermore, the records showed how long immobilization in plaster had lasted and generally gave fairly exact information on when the patient resumed half or full-time work. Any persistent discomfort or disability had been recorded and copies were available of any certificate of disability, providing valuable information about the patient's condition at the end of the treatment.

Data at follow-up

At the follow-up interview, great importance was attached to ascertaining the patient's condition in the interval between the end of treatment and the time of the interview. A note was made of any *aches and pains* during this period as well as any *neurological symptoms.* In order to check the data in the case reports, the patient was also asked whether neurological symptoms had appeared in conjunction with the trauma or early on during treatment and, if so, whether they had subsequently disappeared or persisted. An accurate note was made of the time when such symptoms first appeared and whether they occured periodically. Similar questions were asked about *symptoms of tendon rupture* in the long extensor to the thumb. The patient's *present discomfort* was recorded, with questions about the presence of *resting pain,* the degree of this and any diurnal variation. If pains were reported, the patient was asked about their intensity, location and spread. Particular care was taken to determine whether any type of movement in the wrist elicited the pain, or just rotation. In this context, the relation between pain on rotation and the size of a simultaneous load on the wrist was also studied.

The patient was asked about *loss of mobility*, i.e. whether stiffness of the wrist, impaired forearm rotation or reduced mobility of the fingers, was regarded as being a result of the injury. The patient's subjective opinion about the *strength of the injured hand* was noted. All patients were asked whether they were *right or left-handed*.

The patient's *working conditions* were gone into thoroughly. Any transfer to a different type of work was noted, special attention being paid to the tasks in the previous occupation that could not be performed on account of the persistent disability after the present injury.

Clinical examination

The final assessment of the functional end results in the present series is based on a thorough clinical examination carried out in accordance with a pre-determined plan. In some cases, however, the examination was of an even more specialised nature (see below). The clinical examination comprised the following:

1. *Inspection.* Any swelling was noted. The cosmetic appearance of the wrist was assessed and graded according to any visible dorso-volar or radio-ulnar displacement. The two wrists were compared to evaluate the size of any increased prominence of the caput ulnae. The appearance of the skin over the wrist and fingers was considered, particular attention being paid to any scars after a compound fracture or surgery. A note was made of any atrophy or other changes in the skin of the fingers in conjunction with impaired sudomotor function. At the same time, attention was paid to any signs of wear or work calluses on the injured hand in relation to the condition of the uninjured hand.

2. *Palpation.* Any tenderness was noted, with particular reference to its relation to the radio-carpal or the distal radio-ulnar joint. The latter joint was examined in each patient as follows: The patient sat at a table opposite the investigator, with the elbow resting on the table and the forearm held vertically in a relaxed position. During manual compression of the distal radio-ulnar joint, the investigator executed passive supination and pronation. In the extreme positions, the loading pains described by the patient (especially those on rotation in the wrist) are clearly elicited. Any crepitations in the distal radio-ulnar joint were also noted during this examination (cf. Moberg, 1959).

In connection with the above examination, the stability of the distal radio-ulnar joint was tested with the technique described by Lidström (1959): The distal end of the radius was gripped between the thumb and forefinger of one hand, while the thumb and forefinger of the other hand were used to grasp the end of the ulna and try to move this to and fro in a dorso-volar direction. Any increase in the mobility of the distal end of the ulna on the injured side was registered.

During palpation an attempt was also made to assess the degree of any persistent deviation that had escaped notice in the outward appearance of the wrist. In addition, a note was made of any large callus formation.

3. *Active mobility of the wrist.* The range of motion was measured with an ordinary goniometer and compared with the opposite hand. In accordance with Cave & Roberts (1936), the neutral point was taken to be the position of the extended hand mid-way between pronation and supination and with the palm flat against the palm of the other hand. Mobility was measured with respect to dorsal flexion, volar flexion, ulnar deviation and radial deviation, the same measurements in the uninjured hand being taken as the normal values. In cases with bilateral fractures, the values were compared with normal figures reported in the literature (Broman, 1934): volar flexion 70°, dorsal flexion 60°, ulnar deviation 45° and radial deviation 20°. The range of pro- and supination in the forearm was also tested, the upper arm with the forearm at right-angles to it always being adducted into the body in order to avoid accompanying rotation at the shoulder. Normal values were obtained in the same way as for the wrist (the total range of rotation being 150° according to Broman, 1934).

As pointed out by Cobe (1928), the normal range of motion in the wrist varies between the sexes (greater in women) as well as within the same sex. It may also differ between the wrists (greater in the left). Furthermore, Cobe suggested that a single measurement cannot provide an adequate indication of the range of motion because active movements usually fall short of the joint's true capacity. In addition, comparisons with the opposite hand may be vitiated by earlier injuries in this which the patient has forgotten at the time of the examination. On the other hand, as Lidström (1959) pointed out, even though this method of examination unquestionably has several sources of error, it has to be accepted for practical reasons for lack of more exact methods of measurement on clinical series of this size.

In view of these considerations, the *passive range of motion* was measured as well, in both the wrist and the forearm. The results did not differ substantially from those obtained for the active movements. In several cases this investigation elicited the same pain on motion as the patient had reported experiencing.

4. *Strength of the grip* was measured with a Collin's dynamometer. At least three measurements were made with each hand, the average value being taken as a measure of the muscle power. As many authors have pointed out, the use of this dynamometer introduces considerable sources of error (Whipple,

1914; Brahme, 1936; Lidström, 1959; Mannerfelt, 1966). Some of these were avoided as far as possible in the present investigation. Thus the time factor between two consecutive measurements was reduced by having the investigator hold the manometer and place it in the patient's hand. Since hardly any of the patients in this series had any pain in the hand itself, there was little risk of the results being too low on this account. The hand was dried with alcohol and ether before the measurement if there was a tendency to perspire strongly. Even so, one is of course left with the possibility that the dynamometer will be gripped incorrectly, partly because the Collin's dynamometer does not automatically fit into the correct position. This method of measurement may nevertheless be considered acceptable if one simply requires a rough estimate of the strength of the injured hand in relation to the sound one. At all events, no other method for determining the total strength of the hand is definitely known to be more exact.

5. *Neurologic examination.* The function of the musculature that is innervated by the median and ulnar nerves was tested as part of the routine examination, as were the sensibility to pain and touch and the palpable sudomotor function in the areas of the hand that are innervated by the median, ulnar and radial nerves. A ninhydrin test was made in all cases, using the technique described by Moberg (1958). This test added nothing of diagnostic interest to the findings on palpation but it did of course serve as a valuable objective indicator of loss of sudomotor function. In the cases in which neurologic disturbances were noted in the innervation field of either the median or the ulnar nerve, tactile gnosis was further examined with the aid of Moberg's (1958) picking-up test and Weber's two-point discrimination test.

Roentgen examination

Primary roentgenograms were available for all the cases in the present series of 516 patients, i.e. including those not treated by reduction. In a few cases, no roentgenograms had been taken before the reduction, but the result of this had been checked roentgenographically. In all cases, therefore, the type of fracture could be determined from primary roentgenograms taken before and immediately after reduction.

A roentgen investigation was conducted at the follow-up examination in 125 of the 430 cases included in this. In most instances, roentgenograms were taken of both the injured and the uninjured wrist, using a uniform focus-film distance. This made it possible to measure the shortening in the healed fracture of the radius as described by Lidström (1959): the degree of shortening is estimated by comparing the distance between a plane through the tip of the radial styloid process and a plane through the articular surface of the caput ulnae in the injured hand with the corresponding distance in the uninjured hand. In the follow-up series, roentgenograms taken at the end of treatment or later and showing a picture of healing in the fractures, were available for a further 99 patients. In these cases there was little possibility of comparing with the roentgen picture of the sound wrist. However, in order to gain some idea of the extent of shortening after the fracture had healed, a similar comparison to that above was made between the first roentgenogram of the accepted reduction and the final pictures. This procedure is not of course as accurate as Lidström's but it does give an approximate idea of the degree and the incidence of shortening when the fracture has healed.

The total number of cases examined roentgenographically in the follow-up series is thus 224. Their distribution by age, sex and type of fracture was analysed to find out whether these cases were representative of the total follow-up series (Table 11). A comparison with Table 6 p. 37 (which gives the same distributions for the total follow-up series) shows that there is good agreement on both counts. This conclusion was supported by a statistical analysis of age and type of fracture as well as other factors of clinical importance. The roentgen series has therefore been regarded as being representative of the total follow-up series.

The existence of any residual deformity in a volar or dorsal direction was determined from lateral-view roentgenograms in the usual way. A 10° volar angulation was taken as the normal position of the radial articular surface. Deformities in a radial or ulnar direction were also measured, using the decrease in the angle between the distal articular surface and the long axis of the radius in the frontal view.

The distal radio-ulnar joint was accorded particular attention in the roentgenological investigation, especially in cases with clinical symptoms from this joint. The roentgen examination comprised frontal projections in pronation and supination as well as lateral projections. In order to permit measurement of the distance between the radius and the ulna in the distal radio-ulnar joint, the central ray in the frontal projection must be tangential to the articular surface of the radius in this joint. To be sure of this, it was necessary in most cases to angle the roentgen tube 2°-6° in an ulnar or radial direction in the frontal projections. Besides making it possible to assess the distance between the radius and the ulna, this procedure gave a better picture of the independently projected articular surfaces in the distal radio-ulnar joint (Frykman & Scheller, 1962, 1963).

Any post-traumatic articular changes in the radio-carpal and distal radioulnar joints were registered from both the general roentgenograms of the wrist and the specific roentgenograms of the distal radio-ulnar joint. In some cases (4 % of the roentgen series) such changes were also registered in other parts of the carpal skeleton.

TABLE 11. *Distribution of age groups by type of fracture and sex in X-ray series.*

Age	Type of fracture I ♀	I ♂	II ♀	II ♂	III ♀	III ♂	IV ♀	IV ♂	V ♀	V ♂	VI ♀	VI ♂	VII ♀	VII ♂	VIII ♀	VIII ♂	Total ♀	Total ♂	Total
16–25	—	3	2	1	—	—	—	1	—	—	2	—	—	—	—	1	4	6	10
																	1.8%	2.7%	4.5%
26–35	—	1	3	—	1	2	1	1	—	1	1	—	—	—	1	—	7	5	12
																	3.1%	2.2%	5.3%
36–45	2	2	3	—	1	2	1	2	1	—	3	1	—	1	—	1	11	9	20
																	4.9%	4.0%	8.9%
46–55	5	1	6	—	3	4	1	2	4	1	11	2	—	—	6	1	36	11	47
																	16.1%	4.9%	21.0%
56–65	7	—	11	3	5	—	7	1	6	2	13	1	6	—	14	2	69	9	78
																	30.8%	4.0%	34.8%
66–75	13	1	8	1	2	1	9	1	1	—	4	—	—	—	10	1	47	5	52
																	21.0%	2.2%	23.2%
76–85	1	—	3	—	—	—	—	—	—	—	—	—	—	—	1	—	5	—	5
																	2.2%		2.2%
86–95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	28	8	36	5	12	9	19	8	12	4	34	4	6	1	32	6	179	45	224
	12.5%	3.6%	16.1%	2.2%	5.3%	4.0%	8.5%	3.6%	5.3%	1.8%	15.2%	1.8%	2.7%	0.4%	14.3%	2.7%	79.9%	20.1%	
	36		41		21		27		16		38		7		38		224		
	16.1%		18.3%		9.3%		12.1%		7.1%		17.0%		3.1%		17.0%				

CHAPTER VIII

THE FOLLOW-UP STUDY

In my follow-up study I found it suitable to consider the patient's subjective symptoms and the following objective factors (cf. Lidström, 1959): anatomical and cosmetic results, loss of mobility, loss of strength, neurologic signs and disturbance in the distal radio-ulnar joint.

The examinations were conducted according to the general methodological principles outlined in the preceding chapter. Any special basis for assessments is reported below in the account of the objective findings.

Subjective symptoms

Some kind of subjective symptom from the injured wrist or hand was reported in 225 of the 430 cases (52.3%) in the follow-up study. The symptoms were slight and scarcely affected function in rather more than half (122) of these cases. They were reported more frequently by the women in the series (189 of 348, 54.3%) than by the men (36 of 82, 43.9%).

Discussion. Only a few of the published reports discuss the incidence of subjective symptoms after fractures of the distal radius. Edwards & Clayton (1929) found that in a series of 321 patients interviewed by questionnaire, 73.2% reported no symptoms, 23.1% moderate discomfort and 3.7% such pronounced discomfort that the function of the wrist was definitely impaired. Lidström (1959) reported that 236 of the 515 patients (45.8%) in his follow-up series had subjective symptoms from the injured wrist, and that 133 of these regarded their symptoms as negligible. Arbeitlang & Boeckl (1963), in a series of 251 cases, reported subjective symptoms in 5.6% at the follow-up examination. Some cases had been examined after one year's observation, the others after three years. The incidence of subjective discomfort was said to be almost four times as high for the cases with the shorter observation period.

There is thus a considerable variation in these incidences of subjective symptoms from different series. I have not been able to find any explanation for this and can simply note that the incidence in the present series is similar to that in Lidström's, both of which were selected in a similar manner and have much the same composition by age and sex.

Weakness. The most frequent symptom in the present series was *weakness of the hand and wrist,* which was reported in 154 of the 225 cases with subjective symptoms. The loss of strength was not as a rule particularly inconvenient, but made itself felt when the patients tried to carry heavy loads or exerted the hand and wrist, e.g. when opening a tin, screw-top jar or the like. Many found it particularly troublesome when the hand was loaded with the forearm horizontal, particularly if the forearm had to be rotated at the same time. For example, many housewives found it difficult to handle a frying pan or a saucepan with the injured hand. Craftsmen (carpenters, electricians) had similar difficulties in handling a screwdriver.

Pain. The next most frequent symptom was *pain in the wrist on loading.* This was reported in 61 of the 225 cases. The pain usually appeared as soon as the hand was loaded and rapidly disappeared when the load was removed. In a few cases the pain was so intense that the object grasped by the hand had to be released.

Another common subjective symptom was *pain on rotation* (59 of the 225 cases). This type of pain was generally moderate if the wrist and hand were not loaded but it increased at once when rotation was combined with weight bearing. (This symptom was particularly frequent—49 out of 80 cases—in a group of patients having subjective symptoms as well as objective signs of disturbance in the distal radio-ulnar joint.)

An equally common symptom was *pain after exertion,* which occurred in 58 cases with varying intensity and duration. *Pain on a change in the weather* was reported in 23 cases. Two cases of *continuous pain* were noted independent of any external factor (the pain being described as so severe that analgesics were required daily).

Excessive fatigability. There were 10 cases with complaints of excessive fatigability of the hand and wrist unaccompanied by any other symptoms. Strains on the wrist which had been tolerated before the injury, now elicited a sensation of fatigue in the arm.

Loss of mobility in the wrist was reported in 12 cases, ten of the patients having noticed a dorso-volar impairment and two a less satisfactory rotation in the forearm and wrist. This low incidence of 12 cases with subjective reduction of the range of movements in the wrist contrasts strongly with the objective findings for the series—impaired mobility of the wrist in 332 cases.

Swelling after exertion was reported in six cases, though this could not be verified at the objective examination.

Neurological symptoms were indicated in 14 cases in the form of reduced sensibility to pain and touch or tingling in the innervation field of the median or the ulnar nerve. A feeling of clumsiness in the injured hand accompanied this impaired sensibility in three of the cases.

Locking. None of the patients reported symptoms of *locking in the wrist during pronation or supination.* This seems remarkable in view of the fact that no less than 80 cases had objective signs of disturbance in the distal radio-ulnar joint.

Discussion

My series presents a wide range of subjective symptoms. The most common was weakness of the hand and wrist. This was the most common symptom in Lidström's (1959) series too, and the incidences of the other symptoms are also much the same in both studies.

Objective findings

Anatomical end results

In keeping with Lidström (1959), I have assessed the anatomical end results as follows:

(1) No or insignificant deformity: dorsal angulation not exceeding 90°, or shortening of less than 3 mm.

(2) Slight deformity: dorsal angulation of 91–100° and/or shortening of 3–6 mm.

(3) Moderate deformity: dorsal angulation of 101–114° and/or shortening of 7–11 mm.

(4) Severe deformity: dorsal angulation of at least 115° and/or shortening of at least 12 mm.

Only 224 of the 430 cases in the present series were given an x-ray examination at a time when the fracture could be considered healed (cf. Chapter VII, p. 56). These 224 cases have been shown to constitute a representative sample of the follow-up series and consequently the following assessment of their anatomical end results may be held to apply to the entire series.

The anatomical end results for the series are given in Table 12. Cases without residual deformity make up 25% of the series and cases with severe deformity 5%.

The table also shows the anatomical end results in relation to type of fracture. The only definite conclusion to be drawn from this is that less satisfactory anatomical end results are obtained, regardless of the nature of the distal radius fracture, when there is also a fracture in the distal ulna. Thus the anatomical end result (angulation and shortening) does not seem to be influenced by whether the fracture is intra-articular or extra-articular.

The 80 cases with disturbance in the distal radio-ulnar joint are analyzed in Chapter XI in the same way as the total series. It is nevertheless interesting to consider here the anatomical end results for the 70 cases in this group that

TABLE 12. *Anatomical end results in relation to type of fracture (total X-ray series).*

	Type of fracture																
	I		II		III		IV		V		VI		VII		VIII		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Total
No deformity	13	36	13	32	7	33	5	18	5	31	8	21	1	14	5	13	57 25%
Slight deformity	16	45	15	36	12	57	11	41	7	44	14	37	3	43	16	42	94 42%
Moderate deformity	7	19	11	27	2	10	10	37	4	25	12	32	3	43	13	34	62 28%
Severe deformity	—	—	2	5	—	—	1	4	—	—	4	10	—	—	4	11	11 5%
Total	36	100	41	100	21	100	27	100	16	100	38	100	7	100	38	100	224

had been given a final x-ray examination. These results are shown in Table 13 for the group as a whole as well as in relation to type of fracture. Compared with the total x-ray series above, there is a smaller proportion of cases without residual deformity and almost double the proportion of cases with severe deformity. The tendency for anatomical end results to be less satisfactory if the distal radius fracture is accompanied by fracture in the distal ulna is also evident in this group.

Discussion. The anatomical end results in this series largely agree with those reported by Lidström (1959). The distributions by degree of deformity are thus approximately the same, and the anatomical end results are less satisfactory for the types of distal radius fracture that include fracture in the distal ulna. The reason for the poorer results for these types of fracture is that the primary dislocation was probably more pronounced and the tendency to re-dislocation greater.

Cosmetic end results

The cosmetic end results in the present follow-up series were assessed in relation to the four groups used by Lidström (1959):

(1) Normal appearance.

(2) Normal appearance except for prominence of the capitulum (caput) ulnae.

(3) Slight radial deviation.

(4) Moderate to pronounced radial deviation, silver fork deformity.

The cosmetic end results assessed in this way are given in Table 14 for the follow-up series. A normal appearance was found in 49% of the cases and pronounced deformity in 5%. In general, the cosmetic results appear to to be worse if the distal radius fracture is accompanied by a fracture in the distal ulna. The cosmetic results are also clearly inferior for the intra-articular types of fracture compared with the extra-articular. The degree of intra-articular involvement also seems to have some negative effect on the cosmetic results.

Since an important point in the present series is the relationship between the cosmetic and the anatomical results, the former are given in Table 15 for the 224 cases in which a final x-ray examination was performed. The cosmetic results are here worse than in the follow-up series, e.g. the proportion of cases with a normal appearance is 11% lower, although the proportion of cases with pronounced deformity is much the same. The deleterious effect of an accompanying fracture in the distal ulna is even more marked in the x-ray group. On the other hand, intra-articular involvement does not appear to affect the cosmetic result in this group, in contrast to the results for the total follow-up series.

TABLE 13. *Anatomicals end results in relation to type of fracture (cases with disturbance in the distal radio-ulnar joint).*

	Type of fracture																
	I		II		III		IV		V		VI		VII		VIII		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Total
No deformity	1	50	3	50	—	—	—	—	2	25	6	27	—	—	—	—	12 17%
Slight deformity	1	50	3	50	5	100	1	25	3	37.5	5	23	2	50	9	47	29 41%
Moderate deformity	—	—	—	—	—	—	2	50	3	37.5	8	36	2	50	8	42	23 33%
Severe deformity	—	—	—	—	—	—	1	25	—	—	3	14	—	—	2	11	6 9%
Total	2	100	6	100	5	100	4	100	8	100	22	100	4	100	19	100	70

TABLE 14. *Cosmetic end results in relation to type of fracture (follow-up series).*

	Type of fracture																
	I		II		III		IV		V		VI		VII		VIII		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Total
Normal appearance	56	73	37	47	27	61	21	39	16	52	28	39	3	22	21	35	209 49%
Prominent cap. ulnae	8	10	5	6	4	9	6	11	3	10	5	7	1	7	2	3	34 8%
Slight radial deviation	13	17	33	42	13	30	24	44	11	35	29	41	9	64	31	52	163 38%
Silver fork deformity	—	—	4	5	—	—	3	6	1	3	9	13	1	7	6	10	24 5%
Total	77	100	79	100	44	100	54	100	31	100	71	100	14	100	60	100	430

TABLE 15. *Cosmetic end results in relation to type of fracture (total X-ray series).*

	Type of fracture																Total
	I		II		III		IV		V		VI		VII		VIII		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Normal appearance	24	67	13	32	12	57	8	30	5	31	11	28	1	14	11	30	85 38%
Prominent cap. ulnae	2	5	4	10	2	10	4	15	2	13	3	8	—	—	2	5	19 9%
Slight radial deviation	10	28	22	53	7	33	13	48	9	56	18	46	5	72	20	54	104 46%
Silver fork deformity	—	—	2	5	—	—	2	7	—	—	7	18	1	14	4	11	16 7%
Total	36	100	41	100	21	100	27	100	16	100	39	100	7	100	37	100	224

TABLE 16. *Cosmetic end results in relation to type of fracture (cases with disturbance in the distal radio-ulnar joint of X-ray series).*

	Type of fracture																Total
	I		II		III		IV		V		VI		VII		VIII		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Normal appearance	1	50	2	33	1	20	2	50	1	12.5	5	22	—	—	5	28	17 24%
Prominent cap. ulnae	—	—	1	17	—	—	—	—	1	12.5	1	4	—	—	1	5	4 6%
Slight radial deviation	1	50	3	50	4	80	1	25	6	75	10	44	4	100	9	50	38 54%
Silver fork deformity	—	—	—	—	—	—	1	25	—	—	7	30	—	—	3	17	11 16%
Total	2	100	6	100	5	100	4	100	8	100	23	100	4	100	18	100	70

Table 16 gives the cosmetic results for the 70 cases out of the 80 with disturbance in the distal radio-ulnar joint that were given a final x-ray examination (i.e. the group considered separately under Anatomical end results). In general, the cosmetic results were considerably inferior to those for the total group given a final x-ray examination. There is no indication that an ulna fracture or an intra-articular involvement of the distal radius fracture has an unfavourable effect on the cosmetic end results.

Discussion. With the criteria used here, the only direct comparison that can be made between the anatomical and the cosmetic end results is in respect of severe deformity. While there is good agreement between the two for the total group given a final x-ray examination, the smaller group with disturbance in the distal radio-ulnar joint has less satisfactory cosmetic results compared with the anatomical in this respect. This relationship in the smaller group probably reflects the fact that, under certain conditions, even moderate anatomical deformity is liable to produce the appearance of a silver-fork deformity. In both groups, however, the cosmetic results as a whole are inferior to the anatomical results, even though both have more cases with excellent cosmetic results than with excellent anatomical results. This is certainly due to the frequency with which, in particular, minor anatomical deformity with slight shortening impairs the cosmetic result through a prominent caput ulnae or, more often, a slight radial deviation. On the other hand, the greater number of excellent cosmetic results compared with excellent anatomical results in both groups indicates that even relatively severe anatomical deformity is often not apparent from the cosmetic appearance.

Even though there are apparently some minor differences between the cosmetic and the anatomical end results in this series, there is considerable agreement between them in general. The cosmetic results, like the anatomical, seem to be adversely affected by the combination of the distal radius fracture with a fracture of the distal ulna. The explanation for this is no doubt the same for both types of result and has been discussed in connection with the anatomical results above.

The cosmetic results in my series were assessed, as already mentioned, with the same criteria as in Lidström's (1959) study. His findings were more favourable than those reported here, with normal appearance in 60% of the cases and silver-fork deformity in 11%.

Lidström, too, reported general agreement between the anatomical and the cosmetic results, even though many cases of considerable anatomical deformity had no corresponding cosmetic impairment. He considered that this partly depended upon the amount of soft tissues, but chiefly upon the type of deformity which dominated the roentgenogram. Thus he found that "Dorsal angulation not exceeding 105°, if it was the sole residual deformity, often did not cause any clinical signs. Mere telescopic shortening of the radius without significant radial deviation of the articular surface similarly caused extremely slight cosmetic changes. In some cases, on the other hand, where the roentgenograms bore evidence of a perfect anatomical result, the cosmetic result was marred by a prominent capitulum ulnae. In many cases this was due to a soft-tissue injury in the distal radio-ulnar joint causing the end of the ulna to displace ulnarwards and palmarwards."

Information about cosmetic results in earlier series is provided in different ways in the relatively few reports in which it is included. Rosenbach (1902) found no deformity in 70% of his cases and 10% severe deformity. Kotrnetz & Geiringer (1937) report perfect cosmetic results in 58.6%, good in 24.6%, acceptable in 12.5% and poor in 4.3%. Hoffmann (1953) found good cosmetic results in 43% and poor in 26%, while Mason (1953) only reports that 70% had satisfactory results. These figures thus appear to correspond to those reported for my series or by Lidström.

Loss of mobility

Loss of mobility was registered in my series if it exceeded 10° in any direction at the wrist. As shown in Table 17, no less than 77% of the cases had a loss of at least this magnitude. The incidence is clearly higher for the distal radius fractures accompanied by fracture of the distal ulna, regardless of whether the former fracture was extra-articular or intra-articular. There is no substantial difference between the incidences for extra-articular and intra-articular types of fracture, except that loss of mobility tends to be more common if the fracture involves both the radio-carpal and the distal radio-ulnar joint.

It will be seen from Table 18. that the most common form of impaired mobility was reduced volar flexion (52%), followed by reduced ulnar deviation (40%). Impaired supination was almost four times as frequent as impaired pronation.

TABLE 17. *Incidence of impaired mobility in relation to type of fracture. (Follow-up series.)*

	Type of fracture								
	I	II	III	IV	V	VI	VII	VIII	Total
Incidence of cases with impaired mobility	51/77 66%	63/79 80%	34/44 77%	43/54 80%	20/31 64.5%	58/71 82%	11/14 79%	52/60 87%	332/430 77%

TABLE 18. *Loss of mobility (follow-up series).*

Loss of	10–19°	20–29°	30–39°	40–49°	50–59°	Total	
	No. of cases					No.	%
Volar flexion	132	68	20	3	—	223	52
Dorsiflexion	97	18	5	—	2	122	28
Ulnar deviation	127	44	1	1	—	173	40
Radial deviation	76	12	2	—	—	90	21
Pronation	13	4	1	—	1	19	4
Supination	49	11	4	1	1	66	15

The different forms of impaired mobility were present together in the majority of cases, only a small proportion having simply impaired palmar flexion or impaired dorsal flexion.

As reported in the table, the loss of mobility was found to be generally moderate, i.e. less than 20°.

Three of the 430 cases (0.7%) in the series presented *loss of mobility in the fingers*. In each case this was due to shortening of the collateral ligaments in the metacarpophalangeal and interphalangeal joints. All three cases represented residual symptoms after a shoulder-hand-finger syndrome. They all presented some diastasis between the finger-tips and palm at maximal clenching of the fist. (Partly owing to these defective movements, all three cases were classified under poor functional result.)

No cases in the present series displayed impaired shoulder mobility as a sequela of the distal radius fracture or a shoulder-hand-finger syndrome, if present.

Discussion. Previous authors differ somewhat over the degree of restricted mobility that is compatible with a satisfactory functional result. In general, however, less than 10° loss of mobility is not registered (Wiklund & Müllern-Aspegren, 1956; Lidström, 1959; Arbeitlang & Boeckl, 1963; van Trappen, 1964). The incidences reported for loss of mobility after distal fractures of the radius vary a great deal. Graham (1938) found 50% with impaired volar flexion and 17% with impaired supination. Bacorn & Kurtzke (1953), in a large series of compensation cases, found impaired palmar flexion in 94.5% of the cases and limited pronation and supination in one-third. Lidström (1959) reported loss of mobility in 48.5% of his cases but Arbeitlang & Boeckl (1963) in only 21.9% of theirs. The incidence in my series is thus higher than that generally reported previously. While there is no apparent explanation for this difference, it may of course reflect differences in the technique of examination.

In Lidström's series, about one-fifth of the patients had observed the loss of mobility themselves. In this respect there is a further discrepancy in my series, in which only 12 of the 332 cases concerned patients who had themselves noticed the loss of mobility.

Lidström found that the incidence of impaired mobility was lower for simple fractures of the distal radius, while the group with comminuted fractures had an incidence of about 80%. No direct comparison in this respect can be made with my results because the fractures are classified differently.

Only 0.7% of my series had loss of finger mobility that could be attributed to the distal radius fracture or its sequelae. The figure in Lidström's series was 4%, though the impairment was relatively slight in most cases. Since some of these cases also presented clinical signs of rheumatoid arthritis, Lidström questioned whether the loss of finger mobility was due to the distal radius fracture in every case. Whatever the cause, the present incidence must be considered unusually low compared with those in other series, e.g. 20% in Graham's (1938).

Loss of strength

The strength of the grip was in my series determined with a Collin's dynamometer. Three consecutive measurements were made, their mean being taken as the strength of the grip. Several authors have pointed out that the use of this type of dynamometer is subject to considerable sources of error (Whipple, 1914; Brahme, 1936; Lidström, 1959; Mannerfelt, 1966). As mentioned in a previous chapter, some of the disadvantages indicated by Mannerfelt were avoided as far as possible in the present study—the interval between measurements was minimized by the investigator himself placing the manometer in the patient's hand, and the hand was dried with alcohol or ether if there was a pronounced tendency to perspire.

The strength of the injured hand was compared with that of the other, i.e. the "healthy" hand. Seven patients, however, had bilateral fractures. Four of them had a definite loss of strength in the leading hand, whereas the strength of their non-leading hand could be accepted as quite normal. Since it was possible to make this assessment, these four cases have been included in the results for the total series. The other three patients with bilateral fractures had no signs of impaired strength in either hand. Nor were there any cases with previous injuries that might render the other hand invalid for such a comparison.

The criteria used in the present study for loss of strength were (1) *Strength in an injured leading hand less than that in the non-leading hand*, and (2) *Strength in an injured non-leading hand less than half that in the leading hand.*

On this basis, loss of strength was found in 102 of the 430 cases (24%) in the total follow-up series. Table 19 shows the results in relation to age and type of fracture. It will be seen that loss of strength appears to be less frequent after extra-articular fractures than after intra-articular, while among the latter the frequency is approximately the same irrespective of the type or degree of the intra-articular involvement. The youngest and oldest age groups have the lowest incidences for loss of strength, while the incidence is somewhat higher and much the same in the middle age groups (46–55 and 56–65 years).

The incidence of loss of strength shows no difference between the sexes. The incidence for fractures in the left wrist was 12%, whereas that for the right wrist was 41%. This difference is hardly surprising, however, since 417 of the cases (97%) concerned right-handed patients.

Functional disturbance in the distal radio-ulnar joint clearly contributed to loss of strength in the hand. This is shown by Table 20, which relates loss of strength to age and type of fracture for the 80 cases with such disturbance. The incidence here is 45% compared with loss of strength in 24% of the total follow-up series. Again there is a higher incidence among the intra-articular compared with the extra-articular fractures, though the difference is not so pronounced as in the total series.

Nor do these 80 cases show any sex difference in the incidence of loss of strength. The difference between the hands, however, is still more pronounced, the incidence of loss of strength after fractures in the left hand being 24% and after fractures in the right hand 68%.

TABLE 19. *Incidence of impaired grip strength in relation to age and type of fracture. (Follow-up series.)*

Age	Type of fracture								Total	
	I	II	III	IV	V	VI	VII	VIII	Inci-dence	%
16–25	—	2	—	—	—	1	—	1	4/23	17
26–35	—	—	2	—	—	—	—	—	2/21	9.5
36–45	4	—	1	1	1	1	—	—	8/39	20.5
46–55	4	2	3	1	4	8	1	3	26/85	31
56–65	3	5	4	6	2	8	2	7	37/142	26
66–75	4	2	2	4	1	5	1	3	22/105	21
76–85	1	1	—	—	—	—	—	—	2/14	14
86–95	—	—	—	—	—	1	—	—	1/1	(100)
Total incidence	16/77	12/79	12/44	12/54	8/31	24/71	4/14	14/60	102/430	
%	21	15	27	22	26	34	28	23	24	

TABLE 20. *Incidence of impaired grip strength in relation to age and type of fracture.* (*Cases with disturbance of the distal radio-ulnar joint.*)

Age	Type of fracture								Total	
	I	II	III	IV	V	VI	VII	VIII	Inci-dence	%
16–25	—	—	—	—	—	1	—	1	2/2	100
26–35	—	—	—	—	—	—	—	—	0/2	0
36–45	—	—	—	—	—	1	—	—	1/3	33
46–55	—	1	—	—	2	5	—	2	10/19	53
56–65	1	1	2	1	1	4	1	7	18/38	47
66–75	—	—	—	—	—	3	—	2	5/14	36
76–85	—	—	—	—	—	—	—	—	0/2	0
86–95	—	—	—	—	—	—	—	—	—	—
Total incidence	1/3	2/6	2/6	1/4	3/9	14/25	1/5	12/22	36/80	
%	33	33	33	25	33	56	20	54	45	

Discussion. Only Lidström (1959) appears to have reported any direct figures for the incidence of loss of strength in the hand after fractures of the distal radius. Since he used much the same examination technique and similar criteria for assessing the loss of strength, his results appear suitable for a comparison with those reported here.

Compared with an incidence of 24% in my series, Lidström reports loss of strength in 17.5% of his series. My series displayed a good correlation between subjective symptoms of loss of strength and the results of objective measurement. No less than 65 of the 102 cases (64%) with a measurable loss of strength also had subjective symptoms of this. In Lidström's series, on the other hand, only 16 out of 84 patients had themselves noticed that the strength of the injured hand was impaired. Lidström found a higher incidence of impaired strength among fractures with complete displacement, the highest figure referring to the group with comminuted fractures. No such relationship could be discerned in my series. On the other hand, a higher incidence was found for intra-articular types of fracture compared with extra-articular. It is also interesting that the cases with symptoms of disturbance in the distal radio-ulnar joint have a considerably higher incidence of impaired strength than those without such symptoms.

Neurologic signs

As already mentioned, all the cases in the present follow-up series were examined with particular care for any neurologic symptoms that might be related in some way with the fracture of the radius, either as a direct result of the accident or as sequelae.

Subjective symptoms of loss of sensibility in the innervation field of the median nerve were reported in 10 cases, eight of which also presented objective signs of impaired sensory function of this nerve. In three of the cases there was also atrophy and loss of strength in the thenar muscles.

In all eight cases in which the subjective symptoms were confirmed objectively, the hand function was impaired to such an extent that it adversely affected the functional end result.

Subjective symptoms of loss of sensibility in the innervation field of the ulnar nerve were reported in 4 cases, three of which also presented objective signs of impaired sensory function. None of these cases, however, showed signs of impaired motor activity of the ulnar nerve.

The three cases with subjective symptoms and objective signs of injury to the ulnar nerve all displayed an inferior functional end result, partly as a consequence of the impaired function of this nerve.

The cases with primary and late injuries to the median and ulnar nerves are discussed in a separate section in Chapter XI.

Tendon injuries

Injury to the tendon of the extensor pollicis longus muscle was found in three of the 430 cases (0.7%) in the follow-up series. The subcutaneous tendon rupture occurred within about two months of the accident in two cases and later than this interval in one case.

One of these cases was treated surgically, with satisfactory function at the follow-up examination. In one of the other two, the rupture was discovered before the end of treatment for the fracture but the patient refused surgical treatment. In the third case the patient had not applied for treatment of the rupture, although impaired extension of the thumb of the injured hand had been noticed. In both the last two cases, the tendon rupture clearly caused the patient difficulty through impaired pinching power and impaired gripping capacity. The rupture definitely contributed to the unsatisfactory functional end result in these cases.

The subcutaneous rupture of the tendon to extensor pollicis longus in this series is considered in a separate section in Chapter XI.

Disturbance in the distal radio-ulnar joint

Several references have already been made to the 80 cases (18.6%) in my series in which there were clinical signs of disturbance in the distal radio-ulnar joint. This group is also discussed in detail in Chapter XI.

CHAPTER IX

CRITERIA FOR EVALUATION OF THE FUNCTIONAL END RESULTS

Considering that distal fracture of the radius is a relatively well-defined type of fracture and that, except for a few minor deviations, its treatment is fairly uniform, one would hardly expect to find large differences between the results of treatment in published series. And yet such differences do exist. Some authors regard this type of fracture as difficult to treat, with a rather poor prognosis (Miller, 1960; Golden, 1963; Rehn, 1965; and others). Grasby & Trick (1929), for instance, found poor results in 62.5 % of their series of patients with primary dislocated fractures. In a series of compensation cases, Bacorn & Kurtzke (1953) reported a 24 % average disability (range 0–100 %), with only 2 % of the cases displaying entirely satisfactory results. In contrast to these discouraging figures, other published series are reported to have a satisfactory functional result in considerably more than 90 % of the cases (e.g. Krantz, 1910; Eskelund, 1927; Platt, 1932; Kotrnetz & Geiringer, 1937; Cassebaum, 1950; Mason, 1953; Djorup, 1962; and Schnek, 1962). Outstandingly favourable figures have been reported by Ehalt (1935) from Böhler's clinic, with satisfactory function in almost 100 % of the cases.

Lidström (1959) is one of those who have discussed the reasons for the large differences between the results in published series. He considers, no doubt correctly, that the explanation has less to do with variations in and the quality of the treatment than with the use of different criteria for evaluation of the residual symptoms and clinical findings at the follow-up. For one thing, no significant correlations can be demonstrated between variations in the result of treatment and different therapeutic techniques, whereas one soon finds that very slight modifications of the criteria used to assess the end result may produce very considerable changes in the analysis of results. As an example of this, Lidström cites two authors' different criteria for evaluating the residual loss of mobility in the wrist. One of them (E. Madsen, 1949) considered a 15° loss of palmar flexion incompatible with a satisfactory functional result, whereas the other (Cassebaum, 1950) accepted the same loss in his requirements for an excellent result. In most publications, moreover, both the objective findings and the patient's subjective evaluation contribute to the assessment of the functional end result, which will consequently vary with the interpretation of the patient's statements. It is well known from Lidström's monograph—and is clear from the present study—that some patients tend to minimize their subjective complaints, ignoring quite considerable cosmetic defects as well as loss of mobility provided that their wrist does not prevent them from doing the same tasks as before the injury. Nor does Lidström find this surprising, since many unskilled tasks, including household work, do not require the full range of motion of the wrist. While pointing out that a serious loss of mobility, even though unnoticed by the patient, should lead to the case being classified as unsatisfactory, Lidström warns against grading the functional end result too strictly in accordance with a moderate loss of motion. Thus, he considers that a 25° loss of palmar flexion does not necessarily constitute an unsatisfactory end result in a patient with no other objective findings and no subjective symptoms. In conclusion, Lidström remarks that "any final evaluation of the functional end result must inevitably represent a compromise".

Lidström classified his end results under four headings, namely *Excellent*, *Good*, *Fair* and *Poor* (see below), and found that in his series of 515 cases 41.5 % had Excellent results, 38 % Good, 12 % Fair and 8.5 % Poor.

The end results in the present follow-up series of 430 cases were assessed with much the same criteria as Lidström used. The four headings and their criteria are given below, with the additions to Lidström's criteria shown in italics:

1. *Excellent results:* Function of the wrist unimpaired. No subjective symptoms. No deformity. Loss of dorsiflexion or palmar flexion not exceeding 15° accepted. *No loss of strength.*

2. *Good results.* Function of the wrist unimpaired. Negligible subjective symptoms. Deformity accepted if not producing subjective symptoms. *Moderate loss of motion, i.e. up to 20°, though a loss of 25° accepted as a solitary symptom. Slight to moderate loss of strength accepted, i.e. if leading hand, only slightly weaker than other hand, if non-leading hand, not less than half of leading hand.*

3. *Fair results.* Function of the wrist less satisfactory for activities requiring special strength or extreme movements, which must be avoided. Most pre-injury activities possible. Loss of motion, even if marked, accepted if not associated with subjective symptoms. *Moderate loss of strength accepted, i.e. if leading hand, definitely weaker than other hand, if non-leading hand, less than half of leading hand.*

4. *Poor results:* Working capacity diminished or general way of life affected. Cases with continuous pain. *Considerable loss of strength, i.e. if leading hand, considerably weaker than other hand, if non-leading hand, considerably less than half of leading hand.*

In the series reported in the literature, the systems used for classifying the end results have not included any of the special subjective and objective symptoms associated with sequelae of a fracture in the distal radius, i.e. disturbance of the distal radio-ulnar joint, nerve injuries, the shoulder-hand-finger syndrome and tendon injuries. While this seems reasonable in general, since these symptoms are any way incorporated in the criteria, there are cases in which they occur separately, with a clear effect upon the end result. In the present series, special consideration was paid to this point (cf. Chapter X).

CHAPTER X

FUNCTIONAL END RESULTS

Judged by the criteria presented in Chapter IX, the present series displayed the end results compiled in Table 21.

Discussion

These end results show more residual disability than those presented by for instance Lidström (1959). This is remarkable, considering that the present series includes a number of cases of fracture without primary dislocation. According to the current opinion in the literature, one would rather expect their presence to increase the number of satisfactory end results. That this was not the case is partly due to the use of a somewhat different classification compared to other published series, but more especially to the fact that in certain cases, special consideration was paid to symptoms occasioned by the sequelae as specified in Chapter IX. This aspect will be discussed at greater length in Chapter XI in connection with the analysis of the factors that are significant for the end results.

Here it may be noted that the present results, like those in for instance Lidström's series, occupy an intermediate position between the best and the worst in the literature. In Lidström's series there were only a few cases in which the fracture resulted in permanent disability, while in about 10 % of the cases the loss of function did not impair the individual's ability

TABLE 21. *End results in the total follow-up series.*

Result		No.of cases	%
Excellent		105	24
Good		218	51
Fair		81	19
Poor		26	6
	Total	430	100

to work after the injury had healed. In the present series there was a somewhat smaller proportion of cases with permanent disability but almost 20 % of the individuals had fairly considerable subjective discomfort and impeded function. Even so, I consider that the end results in the present series may be regarded as relatively good.

It should be strongly emphasised that, even though the number of cases with a poor functional end result may not appear very large in a series of this type, the high incidence of fractures in the distal end of the radius means that every year a large number of patients are disabled to a greater or lesser extent as a result of this injury.

CHAPTER XI

END RESULTS AND THEIR DEPENDENCE ON CERTAIN CLINICAL VARIABLES

Distal fracture of the radius in adults is generally considered to have an incidence of 10–20% of all clinical forms of fracture (M. Hirsch, 1914; Böhler, 1919; Hilgenfeldt, 1950; Robbins, 1950; Wiklund & Müllern-Aspegren, 1956, and others). The annual incidence of such fractures in Sweden has been estimated to 5000 (Lidström, 1959), a figure that agrees quite well with a reported incidence of between 2500 and 3000 for Finland (Valtonen, 1949). On the other hand, both these figures are low in relation to the findings of Alffram & Bauer (1962): in a five-year series in Malmö (pop. c. 200,000), there were about 300 cases annually of distal fractures of the radius in adults. Raised to a total population of 7½ million, this gives an incidence of about 12,000 cases annually in Sweden.

From the present study and other published series of consecutive cases it seems that unsatisfactory end results are generally found in 20 to 25% of fractures of the distal radius. The common occurrence of this type of fracture thus means that a considerable number of cases annually incur practical social consequences as a result of varying degrees of permanent invalidity. Several factors contribute to this. *Those which I consider most important will be subjected to a clinical analysis in this chapter.*

Of the 430 cases in the follow-up series, 295 had the fracture reduced, after which the wrist was immobilized either with a dorsal plaster splint or with a circular forearm plaster, usually in the 180° position (i.e. in line with the forearm) and in slight ulnar deviation. In 6 cases the elbow was included in the circular plaster. The reduction technique was more or less uniform throughout, with the exception of 7 cases in which open reduction was performed. Nor was there any large variation in the duration of immobilization. The principles of treatment in the reduced and un-reduced cases were otherwise the same. Minor variations in this respect had no demonstrable influence on the end results and are consequently not considered in the clinical analysis below.

The factors that seem to call for an analysis in relation to the end results are as follows:

A. *General factors.* (1) Age. (2) Sex. (3) Type of fracture. (4) Fracture of caput ulnae or ulnar styloid process. (5) Anatomical end result. (6) Interval between accident and follow-up study.

B. *Special factors* (including sequelae). (1) Injuries to the distal radio-ulnar joint. (2) Nerve injuries. (3) Shoulder-hand-finger syndrome. (4) Rupture of the extensor pollicis longus tendon.

A1. Age

Some authors consider that between the ages of 40 and 70 the results are largely independent of age but that below the age of 40 they are better and above the age of 70 they are worse (Rosenbach, 1902; White, 1940; van Trappen, 1964; Older, Stabler & Cassebaum, 1965). Hitzrot & Murray (1921) found that the results deteriorated above the age of 50, while Golden (1963) reported that age affected the end results only in patients of 70 or over. Better end results in younger age groups are reported by Eskelund (1927), while Ehalt (1935) found similar results regardless of the patient's age, though the period of treatment was shorter among younger individuals.

Bacorn & Kurtzke (1953) provide the interesting finding that, in their compensation cases, the degree of invalidity rose by 4% per 10-year age group. Glock, Mackel & Brown (1957) also state that residual invalidity is directly proportional to the patient's age. Although Lidström (1959) found that the results in his series were better in the under-thirties and worse in the over-seventies, he could not detect any definite trend towards a variation with age. Moreover, the differences between the age groups in his series were generally small. In view of the fact that the majority of his patients were in the age group 50–70 years, Lidström drew the conclusion that the age factor was of minor importance for the ultimate function of the wrist. The number of redisplacements did, however, increase with age, leading to somewhat less satisfactory anatomical results. Somewhat surprisingly, this did not give rise to less satisfactory end results in the higher age groups. According to Lidström, this was partly because the redisplacement was slight in most cases and partly because demands on the function of the wrist are lower in elderly people, who consequently report fewer subjective symptoms.

Own cases. Table 22 and Fig. 24 give the relations between the functional end results and the patients' age at the time of injury. The functional results are fairly uniform in the age groups under 45, though the youngest age group has relatively fewer unsatisfactory results. Nor are there any major differences between the three middle age groups, from 45 to 75 years. In the two highest age groups the number of unsatisfactory results is somewhat greater than in the others. In general, though, the differences in functional end results between the age groups are rather slight. The only possible age-dependent trend is

TABLE 22 *End results in relation to age (follow-up series).*

Result	Age in years 16–25 No.	%	26–35 No.	%	36–45 No.	%	46–55 No.	%	56–65 No.	%	66–75 No.	%	76–85 No.	%	86–95 No.	%	Total no. of cases No.	%
Excellent	10	43	8	38	16	41	16	19	30	21	25	24	—	—	—	—	105	24
Good	11	48	10	47	18	46	47	55	67	47	55	52	10	71	—	—	218	51
Fair	2	9	2	10	3	8	16	19	33	23	20	19	4	29	1	100	81	19
Poor	—	—	1	5	2	5	6	7	12	9	5	5	—	—	—	—	26	6
Total	23	100	21	100	39	100	85	100	142	100	105	100	14	100	1	100	430	100

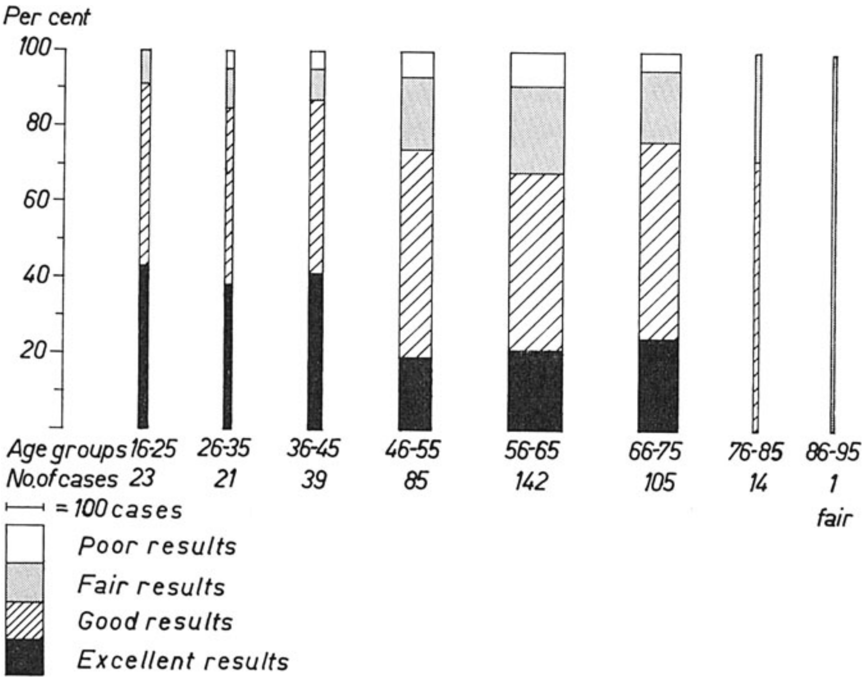

Fig. 24. End results in relation to age.

that for all three age groups under 45 in relation to the three between 46 and 75 years. The top two groups are so small, however, that no definite conclusions can be drawn concerning these.

Discussion. As indicated above, the functional end results in the present series are uniform and somewhat better in the age groups under 45. However, the differences in relation to the age groups between 46 and 75 are not particularly marked. The results for the latter age groups are similar to one another and these groups constitute the greater part of the series. In view of this and the absence of any substantial differences in functional end results between the age groups, it is concluded that *the importance of the age factor for the functional end result is slight.*

A 2. Sex

There is general agreement in the literature that no sex differences can be demonstrated for functional end results after these fractures. This was confirmed in Lidström's (1959) series.

TABLE 23. *End results in relation to sex (follow-up series).*

Result		♀ No.	♀ %	♂ No.	♂ %	Total no. of cases
Excellent		82	24	23	28	105
Good		177	51	41	50	218
Fair		68	19	13	16	81
Poor		21	6	5	6	26
	Total	348	100	82	100	430

Own cases. The incidence of satisfactory results was somewhat higher in the male group compared with the female in the present series, cf. Table 23. This difference, however, is not statistically significant. Thus in this series, too, no difference between men and women can be determined in the functional end results after fracture of the distal radius.

Discussion. The agreement between the functional end results of the men and women in this series is somewhat surprising in view of the fact that the male group had a higher proportion of intra-articular fractures, which the present study ascribes a less favourable prognosis. This is no doubt compensated, however, by almost half the men (40 of 82) in the series being between 16 and 45 years of age, which is the range for which somewhat better end results were obtained.

A 3. Type of fracture

In publications in which the degree of comminution and any intra-articular involvement are included in the classification of the fractures, it is just these factors that are reported to have a definite influence on the functional end result (Gartland & Werley, 1951; Glock, Mackel & Brown, 1957; van Trappen, 1964; Older, Stabler & Cassebaum, 1965). Lidström (1959), too, found less satisfactory end results after comminuted fractures with joint involvement. He did not consider, on the other hand, that the degree of primary dorsal dislocation was particularly relevant in this respect. The fractures with primary volar dislocation did, however, present inferior functional end results. A few authors (e.g. Ehalt, 1935) have reported satisfactory results even for severely comminuted fractures that were treated in the same way as uncomminuted fractures. There are also several authors who report that their special techniques for reduction and fixation have produced good results even after comminuted fractures (Geckeler, 1953; Saikku, 1953; de Palma, 1952, Dowling & Sawyer, 1961; Kane, 1964; Sponsel, 1964). It is occasionally reported that cosmetic end results are less satisfactory after comminuted fractures with severe joint involvement, but that the functional end results are nevertheless satisfactory (Kotrnetz & Geiringer, 1937).

Own cases. The classification of the fractures in this series is based upon whether the fracture was extra-articular or intra-articular and also upon the degree of intra-articular involvement. Furthermore, consideration was paid to the presence of fracture in the caput ulnae or the ulnar styloid process.

Table 24 and Fig. 25 give the functional end results in relation to type of fracture.

It is clear that these results are better after the extra-articular fractures than after the intra-articular. For the former there is no substantial difference between the fractures accompanied and unaccompanied by fracture in the distal ulna. For the latter the results are also quite similar for the types of fracture unaccompanied by fracture of the distal ulna, i.e. those types in which the primary displacement cannot have been particularly pronounced. Among the three types of fracture accompanied by fracture of the distal ulna, the one in which the fracture was intra-articular only in the radio-carpal

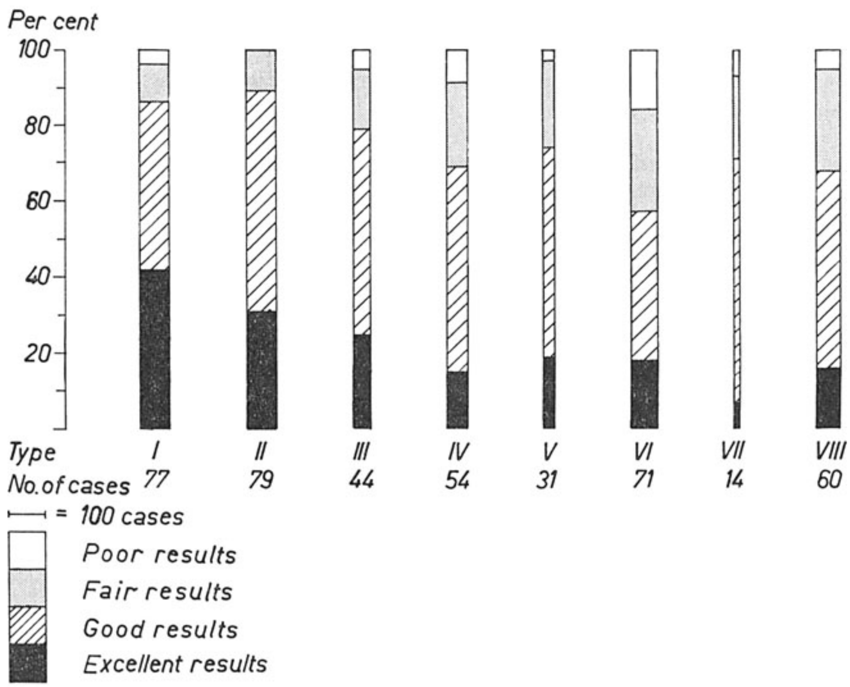

Fig. 25. End results i relation to type of fracture.

TABLE 24. *End results in relation to type of fracture (follow-up series).*

Result	Type of fracture I		II		III		IV		V		VI		VII		VIII		Total no. of cases
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Excellent	32	42	24	31	11	25	8	15	6	19	13	18	1	7	10	16	105
Good	34	44	46	58	24	54	29	54	17	55	28	39	9	64	31	52	218
Fair	8	10	9	11	7	16	12	22	7	23	19	27	3	22	16	27	81
Poor	3	4	—	—	2	5	5	9	1	3	11	16	1	7	3	5	26
Total	77	100	79	100	44	100	54	100	31	100	71	100	14	100	60	100	430

joint displays the best results. The results are less satisfactory for involvement of both the radio-carpal and the distal radio-ulnar joints. They are least satisfactory, however, for involvement of only the distal radio-ulnar joint.

Discussion. It is not surprising that the extra-articular fractures display better functional results than the intra-articular, since the latter always involve a risk of deformative changes in the joint surfaces and hence a deleterious effect on function. It is somewhat remarkable that, among the extra-articular fractures, there is no substantial difference in functional end results between cases with and without fracture in the distal ulna, the presence of which implies a greater chance of displacement. Among the intra-articular fractures, on the other hand, the results are less satisfactory when the distal ulna is also involved. Furthermore, it is striking that among the intra-articular fractures, those with involvement of the distal radio-ulnar joint plus fracture of the distal ulna have much less satisfactory end results than those in which the radio-carpal joint is involved as well. The only explanation afforded by the present study is that it is just the fractures with involvement of the distal radio-ulnar joint that have a greater number of sequelae with functional impairment in this joint or injury to the median nerve.

From the present results it may be concluded that *the type of fracture clearly influences the functional end results*, which are less satisfactory after intra-articular than after extra-articular fractures. In particular, *involvement of the distal radio-ulnar joint* seems to be *unfavourable for the prognosis*. It is also clear that, in intra-articular fractures of the radius, the addition of a fracture in the distal ulna leads to a deterioration of the functional end result.

A 4. Fracture of caput ulnae or ulnar styloid process

Many authors report an incidence of 50–75% for fractures in the ulnar styloid process among fractures of the distal radius. Although a large proportion of the fractures in the ulnar styloid process do not heal, most authors do not consider that this complication had an important effect on the end results in their series (Kahleyss, 1897; Schinz, 1922; Eskelund, 1927; Grasby & Trick, 1929; Cornell, 1935; Bacorn & Kurtzke, 1953; Lidström, 1959). Others, however, report that this combination may prolong the period of treatment after fractures of the distal radius (Haglund, 1914) and lead to instability in the distal radio-ulnar joint with loss of function (Bange, 1921). Ghormley & Mroz (1932) considered that fracture of the ulnar styloid process was often the cause of late complaints with tenderness. They also divided their cases according to whether the ulnar styloid process was fractured or not. Mac Ausland (1937) has also reported that persistent symptoms were frequently due to tenderness over the ulnar styloid process, though he ascribed this more to incomplete healing in a ruptured ulnar collateral ligament than to poor healing of the ulnar styloid process.

Similar opinions have been put forward by Reeves (1966), who operated upon a number of cases with persistent tenderness over the ulnar styloid process. At operation he found not only a loose fragment from this process but also a radial displacement of the ulnar collateral ligament. This, in conjunction with the fragment, was assumed to result in painful locking in the ulnar region of the wrist in extreme dorsal extension, volar flexion and ulnar deviation respectively. After the fragment had been removed, these patients' pain disappeared.

Smaill (1965) found that loss of mobility was more frequent after distal fractures of the radius accompanied by fracture of the ulnar styloid process than after distal radius fractures alone. On the other hand, his series did not have a higher frequency of pain in the former group.

Discussion. Opinions therefore differ as to whether fracture of the ulnar styloid process is of any prognostic importance whatsoever, and also whether its presence causes persistent complaints. I find Reeves' (1966) investigations most convincing in this respect. The small number of cases in his study unfortunately precludes any definite conclusions. No data appear to have been published about the importance of other fractures in the distal ulna.

Own cases. In the present series of 430 fractures of the distal radius, 264 (61.4%) cases also had a fracture in the caput ulnae or the ulnar styloid process.[1] The functional end results in these cases are compared with those in the cases without fracture in the distal ulna in Table 25.

TABLE 25. *Comparison of end results in cases with and without fracture of ulnar styloid process, u.s.p.*

		With fracture of u.s.p.		Without fracture of u.s.p.	
Result		No.	%	No.	%
Excellent		55	20.8	50	30.1
Good		134	50.8	84	50.6
Fair		56	21.2	25	15.1
Poor		19	7.2	7	4.2
	Total	264	100	166	100

[1]) A few cases in my series had fractures in both the caput ulnae and the ulnar styloid process, but most cases had a fracture in the latter only. The former group is too small for an analysis of the end results in relation to those for the latter group. In future, therefore, the expression "fracture of the ulnar styloid process" will be used synonymously with "fracture of the distal ulna".

The functional end results are clearly worse after fracture of the distal radius accompanied by fracture of the distal ulna. There are thus 9.1% fewer cases with satisfactory results in this group.

Discussion. In view of this finding, *the presence of a fracture in the distal ulna must be considered to affect the functional end results after fracture of the distal radius.*

It may of course be difficult to specify exactly how this effect manifests itself. It is conceivable, however, that fracture of the distal ulna may impair the function of the distal radio-ulnar joint, possibly though dysfunction in the disc and ligaments. Of the 430 cases in the follow-up series, 80 had disturbances in the distal radio-ulnar joint. In no less than 67 of these 80 cases there was also a fracture in the distal ulna. This aspect is discussed at greater length later on in this chapter.

A 5. Anatomical end results (angulation and shortening)

The relation between the anatomical and the functional end results in fracture of the distal radius is widely discussed in the literature. Several authors, including Lidström (1959), regard this relationship as one of the central problems in the clinical management of this fracture. As with many other factors in the clinical picture of distal radius fractures, authors differ considerably in their opinions. Three main attitudes can be distinguished.

(1) *Deformity and impaired function are largely interdependent.* This opinion is held by the majority. In 1902 Rosenbach reported a series with unsatisfactory functional results in all cases of severe deformity, in half those with moderate deformity and in only 11% of those without deformity. Similar figures have been published by White (1940). Walker (1952) also found unsatisfactory function in one-sixth of his cases without persistent deformity, though in the rest of his series the degree of deformity clearly affected the functional result. In contrast to these authors, Taylor & Parsons (1938) assert that excellent anatomical results can always be expected to give satisfactory function in the wrist. Other authors in this group consider, generally without any reservations, that a poor anatomical result has an unfavourable effect on the prognosis after fractures of the distal radius (Hitzrot & Murray, 1921; Grasby & Trick, 1929; Cornell, 1935; Mac Ausland, 1937; Mayer, 1940; Hobart & Kraft, 1941; Gartland & Werley, 1951; Sirbu & Collof, 1951; Glock, Mackel & Brown, 1957; Djorup, 1962; Mandell, 1965; Rehn, 1965).

Lidström (1959) found that the functional end result was impaired by the degree of deformity but he also stated that even severe deformity does not usually impede a good functional result. His series contained 27 cases with severe deformity, of which no less than 14 had a satisfactory functional result.

Published series of compensation cases also report a close connection between persistent symptoms and the degree of deformity after fracture of the distal radius. Bacorn & Kurtzke (1953), for instance, found that the degree of invalidity increased in direct proportion to the persistent, clinically demonstrable deformity.

(2) *Only in special cases is the deformity of importance for function.* Among the authors subscribing to this opinion, Gurd (1937) considered that the deformity as such need not necessarily involve poor function of the wrist unless it is so pronounced as to include subluxation of the distal ulna. According to Hölund (1957), the functional end result is influenced by persistent deformity only in young and middle-aged patients, those over the age of 60 being unaffected in this way.

(3) *The deformity has no or only limited importance as a contributory factor to poor functional results.* Among the supporters of this view, Böhler (1923) found that only axial displacement with radial shortening had an adverse effect on the cosmetic results, the functional results being unaffected. In Nissen-Lie's (1939) series of fractures with primary displacement, more than five-sixths of the cases had incorrect anatomical relationships; only a few of these cases with deformity had related clinical symptoms. Like Pilcher (1917) and Cox & Meyer (1951), Lidström (1959), as mentioned above, found that in a large number of cases with unsatisfactory anatomical results, these did not impede a satisfactory functional result. Cassebaum's (1950) series of 81 cases also showed largely excellent or good functional results in a number of cases in which the anatomical results were judged to be less satisfactory. Similar opinions are expressed by Older, Stabler & Cassebaum (1965).

Arbeitlang & Boeckl (1963) and Gambier & Venturini (1964) report that in their series the functional end result was not obviously influenced by the anatomical result, since functional impairment appeared just as frequently among cases without deformity as in cases with severe deformity.

Many authors also discuss which type of deformity is to be regarded as most detrimental to function. Some, including Grasby & Trick (1929), ascribe the poor functional result both to residual dorsal rotation of the distal radius fragment and to radial deviation of this, with disalignment of the distal radio-ulnar joint. Edwards & Clayton (1929) found that dorsal angulation and radial deviation of the distal fragment are important, but that a long interval elapsed before the radial deviation elicited symptoms in the distal radio-ulnar joint.

Several authors consider the most important deformity to be either shortening or radial deviation, or a combination of the two, frequently because they are accompanied by disturbances in the distal radio-ulnar joint (Rodgers, 1944; Milch, 1950; Hoffman, 1953; Mason, 1953; Guttman, 1959; Milch, 1963, 1964). Milch (1950, 1963, 1964) in particular has stressed that shortening is the most important deformity. If this is severe, radial deviation develops, followed ultimately by forward dislocation of the carpus with dorsal prominence of the caput ulnae. This condition seriously impedes rotation in the distal radio-ulnar joint, leading to considerable functional impairment of the wrist. Lidström (1959) also found that even a slight radial shortening as the only residual deformity increased the proportion of unsatisfactory functional results, from 9% to 18%. He did not consider dorsal angulation to be of much consequence for the functional result unless it amounted to more than 20°. Above 21°, however, dorsal angulation caused a rapid deterioration of the functional results.

A few authors (e.g. Poulsen, 1906) report that radial deviation does not influence the functional end result.

In some publications, residual dorsal angulation is considered to be the most important cause of a poor functional result (Bankart, 1929; E. Madsen, 1949; Gartland & Werley, 1951; Wiklund & Müllern-Aspegren, 1956). E. Madsen and Wiklund & Müllern-Aspegren are of the opinion that more than 5° dorsal angulation is incompatible with a satisfactory functional end result, while Hobart & Kraft (1941) found no detrimental influence up to 10°, though a greater deformity than this impaired the wrist function. As mentioned above, Lidström (1959) did not find that the functional end result was affected by dorsal angulation up to 20°.

Own cases. As pointed out already, an x-ray examination was not performed in all the cases in the present follow-up series *after* the period of healing. However, the 224 out of 430 cases in which this was done have been shown to be representative for the total series. The following comparison between anatomical and functional end results refers to this limited proportion of the total series.

Table 26 and Fig. 26 give the functional end results in relation to the degree of residual deformity as assessed in the manner described in Chapter VIII.

Table 27 indicates the incidence of unsatisfactory (fair and poor) functional end results in relation to the two types of deformity (dorsal angulation and shortening) discussed in the review of the literature above.

Discussion. Table 26 suggests that the functional end result deteriorates with increasing deformity. There are so few cases of severe deformity that random factors may lie behind the apparently better results in this group. It is nevertheless clear that severe deformity is not compatible with excellent results, though it does not necessarily rule out a good result. This remarkable circumstance has, as mentioned, been reported previously by Pilcher (1917), Cox & Meyer (1951) and Lidström (1959).

TABLE 26. *End results in relation to degree of residual deformity.* *(224 cases in the X-ray group.)*

Result		Degree of residual deformity								Total no. of cases	
		None		Slight		Moderate		Severe			
		No.	%	No.	%	No.	%	No.	%	No.	%
Excellent		20	35	18	19	2	3	0	—	40	18
Good		28	49	51	54	30	48	7	64	116	52
Fair		6	11	22	24	23	37	1	9	52	23
Poor		3	5	3	3	7	12	3	27	16	7
	Total	57	100	94	100	62	100	11	100	224	100

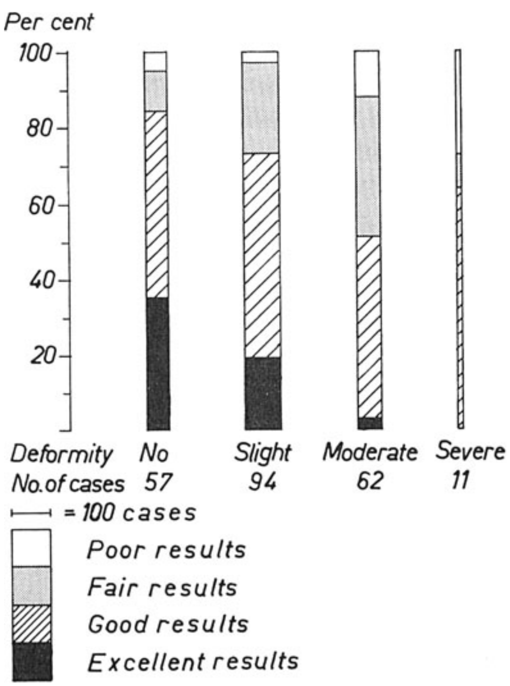

Fig. 26. End results in relation to the degree of residual deformity.

TABLE 27. *Incidence of fair and poor results in relation to dorsal angulation and shortening (224 cases in the X-ray group).*

Shortening	Incidence of fair and poor results			
	No dorsal angulation	Slight dorsal angulation	Moderate dorsal angulation	Severe dorsal angulation
None	9/57(=16%)	5/18(=28%)	1/6 (=17%)	0/0 —
Slight	11/47(=23%)	10/30(=33%)	13/20(=65%)	1/6(= 17%)
Moderate	6/15(=40%)	4/7 (=57%)	5/13(=38%)	1/1(=100%)
Severe	0/0 —	1/2 (=50%)	0/0 —	1/2(= 50%)

From Table 27 it will be seen that the degree of dorsal angulation alone, without any shortening, only slightly increases the incidence of unsatisfactory functional end results.

Table 27 also indicates that radial shortening as the sole residual deformity is a more regular source of a poor functional end result than is residual dorsal angulation by itself. The detrimental effect of radial shortening does not become pronounced, however, until it is combined with a certain degree of dorsal angulation.

With reference to the discussion above, it seems reasonable to conclude that *radial shortening was the deformity that exerted the greatest unfavourable influence on the functional end result.*

From the results presented in Table 26 and Fig. 26, it is clear that *a roentgenologically perfect anatomical result* arising from a satisfactory reduction and immobilization *cannot be taken as a definite guarantee of a satisfactory functional end result.* The table also indicates that *not even severe deformity is a definite obstacle to satisfactory function* of the wrist after fracture of the distal radius.

A 6. Interval between accident and follow-up study

The length of the interval between the accident and the follow-up examination is seldom considered in the literature as a possible influence on the functional end result.

In a series of miners, Magnus (1933) found that 30% had some invalidity when they returned to work at the end of treatment but that after five years the incidence was only 2½%.

Lidström (1959) found in his series that unsatisfactory results were somewhat more common in the group followed-up 2–4 years after the accident than in the groups examined less than 2 years and more than 4 years respectively after the accident. However, no definite tendency could be found towards a variation in the results with the length of this interval. Hence it was concluded that, within the limits concerned, no significant effect existed.

Arbeitlang & Boeckl (1963) report that in their series the number of cases with symptoms one year after the injury was almost four times as high as after three years. Rehn (1965) found that the number of cases granted an annuity fell from 22.6% two years after the accident to 11% after four years.

Own cases. The follow-up examinations in the present series were conducted between December 1960 and June 1961. The interval between the accident and the follow-up examination ranged from one year two months to four years six months, the mean interval being two years seven months.

Table 28 and Fig. 27 show the relation between the functional end result and the length of the interval between the accident and the follow-up examination. It will be seen that the functional result is somewhat better for the group having the longest interval between the accident and the examination. The end results do not, however, vary a great deal between the different lengths of this interval. It is perhaps most remarkable that the group with the longest interval does not have a single case with a poor functional end result. This group is so small, however, that purely random factors may well have produced this result.

Discussion. In this context it should be noted that the cases in the present follow-up series were treated during the period 15 October 1956 to 14 October 1959. An analysis by years shows that the different types of fracture are not distributed uniformly over the whole period. As Table 29 shows, there is a larger proportion of extra-articular fractures among the early cases. The difference seems to be offset by the next earliest group having a considerably smaller proportion of extra-articular fractures in relation to intra-articular fractures. In the two most recent year groups, the distribution between extra-articular and intra-articular fractures is much the same.

The fact that extra-articular fractures, which have a more favourable prognosis, make up a larger proportion of the year group likely to have the

TABLE 28. *End results in relation to the time between injury and follow-up examination.*

Result		Years								Total no. of cases
		$1^1/_6$–2		2–3		3–4		>4		
		No.	%	No.	%	No.	%	No.	%	
Excellent		29	26	38	21	31	28	7	28	105
Good		58	52	97	53	50	45	13	52	218
Fair		17	15	36	20	23	21	5	20	81
Poor		8	7	11	6	7	6	—	—	26
	Total	112	100	182	100	111	100	25	100	430

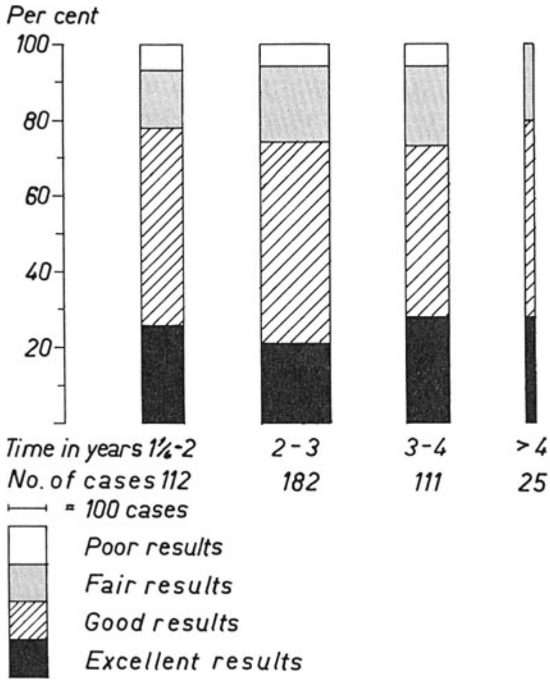

Fig. 27. End results in relation to the interval between accident and follow-up examination.

longest interval between injury and follow-up examination is probably one of the reasons why the functional results are better in the cases for which this interval is longest. It therefore seems reasonable not to ascribe any practical importance to this finding and to draw the general conclusion that *the length of the interval between the injury and the follow-up examination has no significant effect on the functional end results* in this series within the limits indicated above. (This finding is also supported by the lack of significance for this factor in the statistical analysis.)

TABLE 29. *Distribution of each year's cases by extra- and intra-articular fractures.*

Year of accident	Total	Extra-articular	Intra-articular
1956	21	47.6%	52.4%
1957	116	28.5%	71.5%
1958	168	38.6%	61.4%
1959	125	38.4%	61.6%

B 1. *Injuries to the distal radio-ulnar joint*

Review of the literature

Disturbances in the distal radio-ulnar joint as a consequence of fracture of the radius have been extensively discussed in the literature. Only Platt (1932) and Gartland & Werley (1951) consider that such disturbances are of little account.

Opinions differ about the importance of the possible factors behind the disturbances. Some authors place most emphasis on injury to the triangular disc or to other ligaments. Others discuss various forms of malposition in the joint. Only a few point to irregularities in the joint surfaces as a result of an intra-articular fracture. In view of these opinions and the unusual anatomical construction of this joint, it seems suitable to make a distinction between three clinical types of injury to the distal radio-ulnar joint: (*a*) injuries to the ligamentous apparatus, resulting in instability; (*b*) disalignment in the distal radio-ulnar joint, and (*c*) changes in the articular surfaces with incongruity.

(*a*) *Ligamentary injuries*. The head of the ulna is connected with the radius by the interosseus membrane, the distal radio-ulnar articular capsule, the triangular disc, the ulnar collateral ligament, the volar and dorsal radio-ulnar ligaments, the volar and dorsal radio-carpal ligaments and the pronator quadratus muscle.

Mitchell (1922) considered that the triangular disc is of primary importance for joint stability, an observation that has subsequently been confirmed by Lippman (1937) and Lidström (1959) in autopsy specimens. The latter authors found that *damage to the disc is essential for abnormal mobility of the caput ulnae, but that the instability will be pronounced only if one of the radio-ulnar ligaments is also ruptured*. Milch (1942) considered that the essential stabilizing structure is the ulnar collateral ligament, but this seems to be contradicted by the findings of Lidström (1959) and others.

Instability of the joint was noticed already by Colles (1813), who found that the distal ulna was abnormally loose immediately after fracture of the distal radius. Bange (1921) reported that instability of the joint often prevented heavy work. Mitchell (1922), on the other hand, did not consider that abnormal mobility of the head of the ulna necessarily impairs function unless it is so great as to permit recurrent complete dislocation from the ulnar notch of the radius. Lippmann's (1937) series had instability in the distal radio-ulnar joint in every 9th case, with a wide variety of symptoms that often included pain in the ulnar region of the wrist, restricted supination and tenderness in extreme pronation. Injury to the triangular disc with resultant laxity in the distal radio-ulnar joint is considered by some authors to be of such prognostic importance that they use it as a criterion for the classification of these fractures (Taylor & Parsons, 1938; Mayer, 1940; Manges Jr., 1941). Lidström (1959), whose series included about 15% with laxity in the distal radio-ulnar joint, demonstrated that this complication has a detrimental effect on the functional end results after fracture of the distal radius.

Instability in the distal radio-ulnar joint involving recurrent complete dislocation of the distal ulna has been discussed by e.g. Mitchell (1922), Eldridge (1932), Henschen (1938), Hyman & Martin (1939), Birch-Jensen (1951) and Bette (1957). In particular Eldridge, Hyman & Martin and Bette agree in considering that such recurrent dislocation of the caput ulnae is a relatively common complication of distal fracture of the radius.

Cochrane (1929) reported that residual volar dislocation of the caput ulnae is a common cause of poor end results after distal radius fractures. Such a case has been published by Blaimont, Buchin, Geens & Kinnaert (1963). Edwards & Clayton (1929) assert that, when the distal radius fractures, the head of the ulna is dislocated volarly in relation to the radius fragment but that this is corrected as a rule when other components of the fracture are reduced.

(*b*) *Disalignment in the distal radio-ulnar joint.* In a series of 400 normal cases, Hultén (1928) found that physiological differences in the prominence of the caput ulnae lead to variations in the configuration of the distal radio-ulnar joint. The lengths of the radius and the ulna were the same in 61% of the cases, while the ulna was 1 mm shorter in 15%, 2 mm in 5.5%, 3 mm in 2% and 4 mm in 0.3%; the radius was 1 mm shorter in 10%, 2 mm in 4%, 3 mm in 1%, 4 mm in 0.7% and 5 mm in 0.5% of the cases.

Disalignment of the distal radio-ulnar joint as a result of angulation or shortening of the fractured end of the radius has long been regarded as one of the causes of poor functional results after these fractures.

Milch (1942, 1950, 1963) has investigated the causes of residual symptoms after fractures of the distal radius and found that the most important deformity is shortening, which leads to radial deviation and ultimately to forward displacement of the carpus. This gives rise to dorsal prominence of the caput ulnae and a relative lengthening of the ulna. The displacement of the carpus causes the proximal row of carpal bones to impinge upon the ulna, preventing rotation of the radius. Milch distinguished roentgenologically between four types of axial malalignment (lineal, transpositional, angulational and torsional) that may induce what he terms "derangement about the wrist", with symptoms in the form of prominence of the caput ulnae, tenderness over the distal ulna, weakness, pain on motion and sometimes crepitus.

Darrach (1913) noted that cases with loss of contiguity in the distal radio-ulnar joint often present considerable pronation and supination defects. He recommended resection of the caput ulnae in such cases. Subsequently, however, Darrach (1927) reported that patients had fewer complaints when a severe deformity of the distal radius was combined with a complete disruption of the distal radio-ulnar joint than if the joint surfaces remained partly in contact. This apparently correct and important observation has since been confirmed by, for instance, Raschle (1965). Shortening of the radius with partial dislocation of the distal radio-ulnar joint is also discussed by Ehalt (1931), Hammond (1949), Cox & Meyer (1951), Hoffmann (1953) and Mason (1953).

In Lidström's (1959) series, the cases in which shortening was combined with "loss of contiguity" of the distal radio-ulnar joint had a 10–12% higher incidence of unsatisfactory end results than the cases of shortening without such "loss of contiguity".

Impaired forearm rotation is said to be a fairly common symptom in the above-mentioned sequelae of distal radius fracture. Schnek (1929) considered, however, that the restriction of pronation and supination was due to contracture and fibrosis of the pronator quadratus muscle, while Patrick (1946) attributed the impaired rotation to obliteration of the joint space between the triangular disc and the caput ulnae as a result of scar formation after an injury to the joint capsule and the disc. The disc could not slide smoothly over the head of the ulna, hence the loss of rotation.

(*c*) *Changes in the articular surfaces.* Post-traumatic changes in the joint surfaces due to intra-articular fracture or "arthritis" in the distal radio-ulnar joint have attracted relatively little interest. Only a few publications give figures for the incidence of these two forms of articular disturbance.

A number of authors, including Lambrinudi (1938) and Albert, Wohl & Rechtmann (1963) consider that arthritis in the distal radio-ulnar joint is exceptional. Lang (1942) pointed out that infractions in the ulnar notch of the radius are often overlooked and may lead to severe symptoms in the joint. He also emphasized that roentgenological signs of arthritis in this joint appear a long time after the injury, a point which he argued should be borne in mind when assessing patients with symptoms in this joint and a "negative" roentgenogram. Chandler (1950) found that fractures which involved the distal radio-ulnar joint generally gave rise to "arthritis" in this. Grasby & Trick (1929), Watson-Jones (1929) and Mason (1954) are the chief proponents of the view that arthritis in the distal radio-ulnar joint is a common complication of fractures in this. In Lidström's series only 5 of the 515 cases (less than 1%) were reported to have post-traumatic arthritis in the distal radio-ulnar joint. The total incidence of arthritic changes in the wrist amounted to 5.7%. Lidström considered that this figure did not permit any definite conclusions about the effect of this complication on the functional end results.

Discussion. The literature thus presents only sporadic attempts to distinguish between lesions in the ulnar surface of the radius as a result of joint fracture on the one hand and secondary "arthritis" on the other. No-one appears to have attached much importance to the fact that the incidence of intra-articular fractures in the distal radio-ulnar joint is as high as it is—a forgotten joint according to Guillermo (1938).

My findings, summarized on p. 99, indicate that no less than 41% of the cases in the follow-up series had intra-articular fractures in the distal radio-ulnar joint, i.e. were liable to deformation of the radial surface of this joint. This is emphasized by the results of the experimental fracture study (p. 26). It was therefore particularly interesting to undertake the clinical examination described on p. 53 as a means of "isolating" symptoms from the distal radio-ulnar joint.

Own investigations

In the total follow-up series of 430 cases, 80 (18.6%) were found to have distinct pain on compression of the distal radio-ulnar joint, as well as an accentuation of this pain upon compression during rotation. It is notable that *all* these 80 cases had subjective symptoms from the injured region. (Note that very few of the patients could themselves distinguish symptoms ascribable to the radio-carpal or distal radio-ulnar joints from those elsewhere in the carpal region.)

Clinical findings. As in the total series (see p. 59), the most common symptom in this group was weakness in the hand and wrist (56 cases). This was followed by pain in the wrist on rotation (49 out of 80; cf. 58 out of 430 in the total series). Since the presence of subjective symptoms was not considered compatible with an excellent functional end result in the present study, none of the 80 cases could be classified under this heading.

Table 30 indicates the inferiority of the functional end results in the 80 cases with symptoms from the distal radio-ulnar joint compared with the

TABLE 30. *Comparison of end results in cases with and without disturbance of the distal radio-ulnar joint (D.R.U.J.).*

Result	Cases with disturbance in D.R.U.J. %	Cases without disturbance in D.R.U.J. %
Excellent	—	30
Good	45	52
Fair	39	14
Poor	16	4

same results for the other 350 cases in the total follows-up series. In particular the, incidence of "unsatisfactory" results in the former group is more than twice as high as in the total follow-up series (cf. p. 77). (The statistical analysis also shows that this complication has a highly significant influence on the functional end result.)

The 80 cases with disturbance in the distal radio-ulnar joint were subjected to the same clinical analysis as the total follow-up series.

Type of fracture. Table 31 shows the distribution of the 80 cases by type of fracture and sex. Compared with the corresponding table for the total series (Table 32), there is a still greater predominance of intra-articular fractures in the present group. Furthermore, the majority of intra-articular fractures in the 80 cases represent direct involvement of the distal radio-ulnar joint.

Laxity. Only 9 of the 80 cases (11.2%) presented laxity in the distal radio-ulnar joint, which was thus only seldom important as an influence on the functional end result. The low total incidence of laxity in my series (12 out of 430 cases in the total series, 2.8%) is in striking contrast to the figure of 11.1% reported by Lippmann (1937) and Lidström's (1959) 14.9%. There does not seem to be any direct explanation for this. Perhaps it is nevertheless to be found in methodological differences.

Both Lippmann and Lidström concluded that laxity in the distal radio-ulnar joint had a deleterious effect on the functional end results in their series. In view of the results presented above, the chief cause of the unsatisfactory end results in these 80 cases must instead be considered to be primary or secondary deformation of joint surfaces or disalignment of the radius in relation to the ulna.

There has been considerable discussion in the literature as to whether widening of the joint space as demonstrated in roentgenograms can be held to indicate instability in the radio-ulnar joint. Nowhere, however, is there any discussion of what is meant by "joint space", though it is clear that the term refers to the distance between the bone surfaces without allowing for the thickness of the cartilage. The figures reported thus do not refer to the anatomical joint space. To simplify comparisons, the same principle was applied in the present series.

Cornell (1935) reports that in his series of 156 cases of distal radius fractures, 17% presented a diastasis in the radio-ulnar joint. Nothing, however, is said about the degree of instability in these cases. In keeping with Lidström (1959), I question the value of this finding. Lidström, with 77 cases of clinical instability in the distal radio-ulnar joint, found a radiological diastasis in only 18, i.e. 23%. On the other hand, Marthaler (1959) considered that a widening of the joint space by more than 3 mm on the injured side was pathological. In the present total series, a final x-ray examination had been performed on 10 of the 12 cases with instability in the distal radio-ulnar joint. Six of these ten had a widening of more than 3 mm in the distal radio-ulnar joint space. Little clinical importance should be attached to these figures. Thus, of the other 214 cases given

TABLE 31. *Type of fracture in cases with disturbance in the distal radio-ulnar joint.*

	Type of fracture																Total	
	I		II		III		IV		V		VI		VII		VIII			
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
No.	3	—	5	1	5	1	2	2	8	1	21	4	5	—	18	4	67	13
%	3.8	—	6.25	1.25	6.25	1.25	2.5	2.5	10.0	1.25	26.2	5.0	6.25	—	22.5	5.0	83.7	16.3
Total No.	3		6		6		4		9		25		5		22		80	
%	3.8		7.5		7.5		5.0		11.3		31.2		6.2		27.5			

Extra-articular = 11.3%

Intra-articular = 88.7% (76.2% intra-articular in distal radio-ulnar joint or both joints)

TABLE 32. *Type of fracture in follow-up series.*

		Type of fracture																
		I		II		III		IV		V		VI		VII		VIII		Total	
		♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
	No.	63	14	68	11	26	18	42	12	23	8	63	8	11	3	52	8	348	82
	%	14.6	3.3	15.8	2.6	6.0	4.2	9.7	2.8	5.3	1.9	14.6	1.9	2.6	0.7	12.1	1.9	80.9	19.1
Total	No.	77		79		44		54		31		71		14		60		430	
	%	17.9		18.4		10.2		12.5		7.2		16.5		3.3		14.0			

Extra-articular (I–II) = 36.3%

Intra-articular (III–VIII) = 63.7% (41.0% intra-articular in distal radio-ulnar joint or both joints) a final x-ray examination (i.e. those without instability in this joint), no less than 70 presented this degree of radiological widening. The lack of convincing studies of the normal range in this respect is a further reason for attaching little importance to these findings.

Radiological findings. The analysis of changes in the distal radio-ulnar joint would naturally have benefitted if the entire follow-up series had been examined with the special roentgenological technique described on p. 56. For various reasons, however, this could not be done and the special x-ray examination was performed in only 56 of the 80 cases (70%) with a disturbance in the distal radio-ulnar joint plus a control group of 69 cases from the other 350 (19.7%) in the series.

Changes in joint surface. In the group of 56 cases with symptoms in the distal radio-ulnar joint, the special roentgenological technique revealed changes in the joint surface in 42 (75%). A random sample from the control series, matched by type of fracture, displayed such changes in 18 out of 28 cases (64%).

It will be seen from Table 33 that, among the cases with symptoms from this joint, the incidence of changes in the joint surface is clearly higher for intra-articular than for extra-articular fractures. There is admittedly a high incidence even among the extra-articular fractures in the sample from the control group, but this seems to be partly due to chance, since a larger number of cases from the total control group displayed a lower incidence (40%). It therefore appears that the control group, too, in reality has a higher incidence of changes in the joint surfaces for intra-articular compared to extra-articular fractures.

It is interesting that a special roentgenological examination is able to detect such a high percentage of changes in the joint surfaces even among cases in which the clinical examination failed to demonstrate any symptoms from the distal radio-ulnar joint.

TABLE 33. *Incidence of radiological changes in the distal radio-ulnar joint (comparison between cases with and without clinical symptoms).*

		Cases with clinical symptoms		Cases without clinical symptoms	
		Extra-articular	Intra-articular	Extra-articular	Intra-articular
Incidence of radiological changes	No.	1/6	41/50	2/3	16/25
	%	16.7	82.0	66.7	64.0

The present examination has shown that there is a high significance of roentgenological changes in the distal radio-ulnar joint in cases with clinical symptoms from this.

The results indicate that post-traumatic articular changes constitute one of the more important factors behind the genesis of clinical symptoms from this joint.

The analysis also shows that roentgenologically demonstrable changes on the surfaces of the distal radio-ulnar joint are present in as much as 64% of cases that do not have clinical symptoms from this joint. However, this analysis is based on only 28 cases and random factors may have been involved. It is also possible that, since the average length of the follow-up period in these cases was only two years seven months, many of these patients may develop clinical symptoms at a later date.

Shortening and angulation. In the total x-ray series, radial shortening was the deformity with the most frequent deleterious effect on the functional end result (see Table 27, p. 92). The same analysis was performed for the 70 cases in the x-ray series with clinical symptoms from the distal radio-ulnar joint. The findings, presented in Table 34, show that, when neither shortening nor angulation is present, the end results are unsatisfactory in about 50% of the cases. The degree of shortening does not seem to be important, but the results tend to deteriorate somewhat with increasing dorsal angulation.

However, the individual groups are too small for any definite conclusions about the influence of these factors on the end results. It is probable that other factors are more responsible for the poor results in these cases.

Disalignment. Lidström (1959) and others have asserted that radial shortening is related in no small degree to "loss of contiguity of the distal radio-ulnar joint" as a result of distal displacement of the caput ulnae, and that this had an adverse effect on the end result.

TABLE 34. *Incidence of fair and poor results in relation to dorsal angulation and shortening (70 cases with disturbance in the distal radio-ulnar joint in the X-ray group).*

	Incidence of fair and poor results			
Shortening	No dorsal angulation	Slight dorsal angulation	Moderate dorsal angulation	Severe dorsal angulation
None	6/12(=50%)	2/3 (= 67%)	0/3(= 0%)	0/0 —
Slight	5/16(=31%)	8/11(= 73%)	9/9(=100%)	1/1(=100%)
Moderate	2/4 (=50%)	3/3 (=100%)	3/3(=100%)	1/1(=100%)
Severe	0/0 —	1/2 (= 50%)	0/0 —	1/2(= 50%)

In the 224 cases given a final x-ray examination in my series, special attention was paid to the degree of disalignment in the distal radio-ulnar joint in cases with shortening of the radius. In 90 of the cases (40.2%) distal displacement of the caput ulnae amounted to more than 4 mm (cf. the reference to Hultén, 1928, on p. 96 and Lindström, 1959). These 90 cases (among the 224 given a "final" x-ray examination) comprised 40 of the 70 (57.1%) with disturbance in the distal radio-ulnar joint and 50 of the 154 (32.4%) without such disturbance. The difference between these incidences indicates that disalignment in this joint is an important factor behind the disturbances noted.

To test this line of reasoning, the cases with "unsatisfactory results" and shortening of the radius in the two series of 70 and 154 cases were classified according to the *presence of disalignment* in the distal radio-ulnar joint and the degree of residual dorsal angulation. The frequencies are compared in Tables 35 and 36.

In the cases with clinical signs of injury in the distal radio-ulnar joint, the end results are an average of 10% worse for the group with disalignment in this joint, whereas disalignment does not appear to have an unfavourable effect in the cases without clinical signs in this joint. It is difficult to assess

TABLE 35. *Incidence of unsatisfactory functional results in relation to disalignment in the radio-ulnar joint in cases with shortening (70 cases with disturbance of the D.R.U.-joint in the X-ray group).*

	Incidence of unsatisfactory results	
	No or slight dorsal angulation	Moderate or severe dorsal angulation
No disalignment	4/10=40%	2/2 =100%
Disalignment	15/26=58%	13/14= 93%

TABLE 36. *Incidence of unsatisfactory functional results in relation to disalignment in the radio-ulnar joint in cases with shortening (154 cases without disturbance in the D.R.U.-joint in the X-ray group).*

	Incidence of unsatisfactory results	
	No or slight dorsal angulation	Moderate or severe dorsal angulation
No disalignment	9/38=23.7%	0/3 =0%
Disalignment	4/27=14.8%	6/23=26.1%

the importance of residual dorsal angulation, the variation in the results being probably due to the smallness of these groups. For this reason and because it has already been shown that radial shortening apparently had the greatest deleterious effect on the functional end results in my series, I considered it advisable to disregard the dorsal angulation in this and the following calculation.

Disalignment also appears to be of great importance for the occurrence of articular changes in extra-articular fractures of the distal radius. Of the 48 extra-articular fractures given a special roentgenological examination, 13 out of 16 (81%) with distal displacement of the ulna had such changes, whereas only 7 out of 32 (22%) had changes in the joint surface without distal displacement of the ulna.

Tables 37 and 38 indicate the effect of shortening on the "unsatisfactory" end results in cases *without disalignment* in the distal radio-ulnar joint. Table 37 does the same for cases with functional disturbance in this joint and Table 38 for cases without such disturbance.

The tables show a somewhat varied influence of shortening in both series. It is clear, however, that *shortening has an unfavourable effect* on the functional

TABLE 37. *Incidence of unsatisfactory functional results in relation to shortening in cases without disalignment in the radio-ulnar joint (70 cases with disturbance of the D.R.U.-joint in the X-ray group).*

	Incidence of unsatisfactory results	
	No or slight dorsal angulation	Moderate or severe dorsal angulation
No shortening	8/15=53%	0/3= 0%
Slight, moderate or severe shortening	4/10=40%	2/2=100%

TABLE 38. *Incidence of unsatisfactory functional results in relation to shortening in cases without disalignment in the radio-ulnar joint (154 cases without disturbance in the D.R.U.-joint in the X-ray group).*

	Incidence of unsatisfactory results	
	No or slight dorsal angulation	Moderate or severe dorsal angulation
No shortening	6/60=10%	1/3=33%
Slight, moderate or severe shortening	9/38=23.7%	0/3= 0%

end result to about the same extent in both series (the "unsatisfactory" results in general are 15.6% and 10.8% more frequent in the presence of shortening).

In addition to changes in the joint surfaces, this shows that *shortening with disalignment is an important factor relating to the inferior functional end results in these cases.*

Relationship to other sequelae. The 80 cases with injury and functional disturbance in the distal radio-ulnar joint had a somewhat higher incidence of other sequelae compared with the total follow-up series.

Thus, in the total series, injury to the median or ulnar nerve was found in 11 cases (2.6%), of which no less than 5 (6.3%) belonged to the group with disturbance in the distal radio-ulnar joint.

Residual symptoms after a shoulder-hand-finger syndrome were found in five cases in the total follow-up series. Two of them only had remnants of organized oedema in the palm but no functional impairment; both presented symptoms of disturbance in the distal radio-ulnar joint. The other three had shortening of the ligaments of the fingers, with loss of finger mobility and varying degrees of functional impairment; two of these also presented signs of disturbance in the distal radio-ulnar joint.

Discussion. Functional disturbance in the distal radio-ulnar joint was found in 18.6% of the cases in my series. The importance of this for the functional end result has been shown to be statistically significant.

The analysis of clinical data from the cases with disturbance in this joints strongly indicates that the symptoms were chiefly elicited by two factors, *post-traumatic changes in the joint surface* and *disproportion between the lengths* of the distal radius and ulna.

In the present series, *laxity* in the distal radio-ulnar joint was so infrequent that its importance for the functional end result must be regarded as slight.

The cases with disturbance in the distal radio-ulnar joint also displayed a higher frequency of other complications after the radius fracture compared with the total series.

The higher incidence of *neurological complications* may be ascribed to narrowing of the carpal tunnel due to swelling in the wrist. It is not entirely clear whether the cases with disturbance in the distal radio-ulnar joint had a greater tendency to swelling, though it is worth noting that in one case (as well as in several outside this series), the compression of the nerve disappeared after subcapitular resection of the ulna.

The higher frequency of a *shoulder-hand-finger syndrome* among cases with post-traumatic disturbance in the distal radio-ulnar joint is paralleled in other series (e.g. Lidström, 1959). The tendency was clear in the present series, even though there were very few cases with this complication.

B 2. *Nerve injuries*

Review of the literature

Many authors report that nerve injuries are rare after fractures of the distal radius (Cotton, 1900; Meyer, 1925; Ghormley & Mroz, 1932; Gurd, 1937; Knapp, 1952; Lidström, 1959). In the opinion of certain authors (Turner, 1924; Abbot & Saunders, 1933; Sisefsky, 1950), this is because both patient and surgeon concentrate chiefly on symptoms from the fracture, with the result that any nerve injury is liable to be overlooked, particularly as such injuries are usually partial and the symptoms disappear relatively quickly. It is only seldom that any figures are reported for the incidence of nerve injury.

Bacorn & Kurtzke (1953) found that in more than two thousand compensation cases, the incidence of "post-traumatic neuritis" was 0.2%. Schlesinger & Leas (1959) report only one case of median nerve compression in 1000 fractures of the distal radius, while Lynch & Lipscomb (1963), studying a ten-year series of 600 cases from the Mayo Clinic, found symptoms of median nerve compression in 3.3%. It is worth mentioning that nerve injuries connected with distal fractures of the radius, having been generally ignored in the past, are mentioned more frequently in modern textbooks on fractures, orthopaedic surgery and neurology, e.g. by Haymaker & Woodhall (1953) and Moberg (1959).

Symptoms from the *median nerve* receive most attention in the literature, no doubt because of this nerve's intimate relation to the distal radius and the clinical importance of median nerve injuries. The first two cases were reported by Gensoul (1836) and Paget (1854). The former's case is particularly interesting as one of the few published instances of a primary median nerve injury in distal fracture of the radius. Most authors have compiled reports on cases from the literature and added a few of their own (de Rouville, 1905; Blecher, 1908; Kirchheim, 1910; Lewis & Miller, 1922; Zachary, 1945; Cannon & Love, 1946; Newman, 1948; Meadoff, 1949; Love, 1955; Bläckberg & Fex, 1956; Stein, 1962; Bessot & Masse, 1964; Manzotti, 1964).

One of the more discussed surveys of median nerve injuries in fractures of the distal radius is that published by Abbot & Saunders (1933), comprising nine cases. Their classification of these injuries, which has since been adopted by several authors (e.g. Meadoff, 1949; Lynch & Lipscomb, 1963), distinguished between (1) Primary injuries, (2) Secondary injuries, (3) Late or delayed involvement, and (4) Injuries associated with treatment in palmar flexion. They were the first to point out the risk inherent in immobilization in pronounced palmar flexion and ulnar deviation (the "Cotton-Loder position", particularly common in the United States). Their post-mortem studies showed that when Berlin blue or lipiodol was injected between the layers of flexor muscle in the forearm, pronounced palmar flexion and slight ulnar deviation at the wrist prevented the contrast from passing beyond the proximal limit of the carpal ligament, whereas in moderate flexion there was free passage to the carpal tunnel. Two explanations were given for the median nerve being so injury-prone in hyperflexion in the wrist: (*a*) the nerve passes from a deep to a superficial position just proximal of the wrist and is thus not amenable to displacement in conjunction with acute flexion; (*b*) the transverse carpal ligament has a sharp proximal edge close to the anterior border of the distal radius. Abbot & Saunders also report that primary median nerve injuries in connection with distal fracture of the radius are extremely rare; the only two they found were those published by Gensoul and Billroth (this assessment has since been supported by Watson-Jones, 1949). Most of the cases published previously were classified by Abbot & Saunders as "secondary injuries" due to continuous pressure from a bone fragment (either unreduced or incompletely reduced) or an excessive callus formation. They held that the "neuritis" could be elicited by combined traction and friction against the compressing piece of bone. They drew particular attention to the fact that in several cases the compression of the median nerve had developed after correction osteotomy of the distal radius because of defective healing of the fracture. Palmar flexion had been used after the osteotomy in order to prevent re-dislocation. Meadoff (1949) has also noticed the latter condition as well as the general risk inherent in the "Cotton-Loder position". He adopted Abbot & Saunders' classification, as mentioned above, and also observed from his own cases that the risk of median nerve injury apparently increases with repeated reduction of a distal radius fracture.

A valuable anatomical study of the median nerve in the carpal tunnel has been published by Robbins (1963), with comments on the etiology of the "carpal tunnel syndrome". He points out that acute volar flexion in the wrist causes the anterior part of the lunate bone to rotate so much that the bone projects volarwards. This in itself reduces the volume of the carpal tunnel, an effect which is heightened by the presence of bleeding and oedema in conjunction with the fracture of the distal radius. Robbins concludes that immobilization in volar flexion and ulnar deviation is conducive to compression of the median nerve and, like the authors mentioned above, strongly advises against such immobilization in fractures of the distal radius. Similar opinions have been put forward by Lynch & Lipscomb (1963) and Sponsel & Palm (1965). The 20 cases compiled in each of the last two publications also represent the largest collection of this type of injury in the literature.

Discussion concerning median nerve. From this review it is clear that opinions differ on clinical aspects of this complication of distal radius fractures. As far as treatment is concerned, however, recent publications generally agree on the principles to be found in Sponsel & Palm's article (1965). These authors recommend expectant treatment in early cases and decompression surgery in late cases with healed fracture. The least sign of thenar atrophy is considered an absolute indication for surgery in order to prevent further progress of the neurological symptoms. The only difference of opinion concerning these principles concerns primary injury to the median nerve, which according to e.g. Lynch & Lipscomb (1963) is caused by the nerve being pinched by the fracture fragment, necessitating immediate surgery.

It is remarkable that several very large series have no cases of injury to the median nerve (e.g. Böhler, 1938; Nissen-Lie, 1939; Valtonen, 1948; Wiklund & Müllern-Aspegren, 1956). This is certainly due to a lack of suitable examination techniques. Compare the late discovery of the very common "carpal-tunnel syndrome"!

Descriptions of injuries to the *ulnar nerve* in connection with fracture of the distal radius are less common in the literature compared with those to the median nerve. Complications involving the ulnar nerve have been mentioned by Turner (1924), Cassebaum (1950), Djorup (1962) and Older, Stabler & Cassebaum (1965). Neither these nor other authors who have dealt with corresponding problems provide any figures for the frequency of this complication. Individual cases have been described by Lilienfeldt (1907), Cotton (1922), Lidström (1959), Baitsch & Heller (1959), Lasserre (1963) and Hult (1964). Cotton (1922) emphasized that injury to the ulnar nerve after distal radius fracture is not so very rare, particularly in the form of "neuritis" with loss of sensibility due to recurrent dislocation of the caput ulnae. More recently, Hult (1964) also argued that opinions about the rarity of ulnar nerve injury should be revised and pointed out that a correct diagnosis may be difficult in those cases in which only the motor branch of the nerve is injured and which therefore do not present radiating pain and numbness of the 4th and 5th fingers. The case described by Lasserre (1963), with compression of the ulnar nerve fourteen years after a distal radius fracture, had only loss of the motor function. Lasserre's explanation was that the nerve had become caught between the deep fascia and the pronator quadratus muscle on one side and the head of the ulna on the other, but that only the dorsal outer segment of the nerve (containing the motor fascicles) had been compressed. While on this subject, it is remarkable that Mumenthaler's (1961) extensive monograph on ulnar pareses does not consider injuries to the ulnar nerve in connection with distal radius fractures.

Simultaneous injuries to the median and ulnar nerves after fracture of the distal radius have been reported in only two cases, by Turner (1924) and Dickson (1926).

Own investigations

The work of developing special diagnostic methods for examining the sensibility of the hand has meant that neurological problems have been taken into account ever since the Department of Bone and Joint Surgery was set up at Sahlgrenska Sjukhuset. It follows that the primary examination of the present series of distal radius fractures was carried out with such problems in mind.

As reported in the chapter on investigation techniques, all the patients in the series were asked at the follow-up examination whether they had had any neurological symptoms in connection with or after their distal radius fracture. The routine examination included functional tests of hand muscles innervated by the median and ulnar nerves. The sensibility to pain and touch and the palpable sudomotor function were examined and recorded for the innervation fields of the median, ulnar and radial nerves. A ninhydrin test according to Moberg (1958) was made in all cases and served as an objective verification in most of the cases in which impaired sudomotor function was noted on palpation in connection with injury to the median or ulnar nerve. In the cases displaying impaired nerve function, the above routines were supplemented with tests of tactile gnosis, using Moberg's (1958) picking-up test and Weber's two-point discrimination test.

Of the 430 cases in the follow-up series, 14 (3.2%) had signs of nerve injury, i.e. impaired function of the median or ulnar nerve during the period of treatment or appearing later. It is remarkable that no neurological symptoms had been observed in any of these cases at the time of the accident (see below).

The median nerve was affected most frequently—10 cases (2.3%) compared with 4 (0.9%) for the ulnar nerve. There were no cases with simultaneous symptoms from both nerves.

The most frequent subjective symptom from both nerves was numbness in the field of innervation. This was reported at the follow-up examination in eight of the median nerve cases and three of the ulnar nerve cases (see Tables 39 and 40, p. 155). Only exceptionally did the numbness involve the *entire* sensible field; the 2nd–4th fingers, however, were remarkably often involved in the median nerve cases. Only one of these cases had the night-time symptoms, with early wakening from numbness in the fingers, that frequently accompany compression of the median nerve from other causes. Three of the patients with impaired sensibility suffered from clumsiness in the affected hand, particularly in precision work with the thumb and forefinger. In two other cases, the loss of sensibility in the median field was accompanied by feelings of fatigue and weakness in the hand. The latter symptoms were present without a loss of sensibility in another case. Atrophy in the thenar muscles was noted at the examination in all these three cases.

Various proposals for classifying nerve injuries connected with distal radius fractures were mentioned above in the review of the literature. None of the cases in the present series can be described as "primary", i.e. with immediate symptoms. Nor are there any in which the neurological symptoms can be directly related to the treatment given. Consequently, I have divided my cases simply into *early* and *late nerve injuries*. In the *early* nerve injuries, the symptoms appeared during the period of treatment, between 14 and 47 days after the fracture of the radius; in the *late* nerve injuries, the symptoms did not appear until after treatment was complete, the interval from the time of the fracture being at least three months. (It should, however, be mentioned that both before and after the present series, there have been several cases at our clinic in which injury to the median nerve was observed immediately after the trauma. In most of these cases, the symptoms disappeared spontaneously after a few months.)

Since there were no cases in the present series in which injury was detected in both the median and the ulnar nerve, the injuries to each nerve are considered separately in the following clinical analysis.

Early injuries to the median nerve. Six cases in the series (1.4%) were of this type. Their clinical data are shown in Table 39. It will be seen that in two cases, no objective signs of impaired function in the median nerve could be detected at the follow-up examination, although one of the patients reported residual numbness in all fingers of the injured hand. (Both cases had clinical signs of disturbance in the distal radio-ulnar joint, which adversely affected the functional end result. Resection of the ulna had been performed in case no. 2, after which the objective signs of impaired median function had disappeared. However, this patient still had symptoms in the distal radio-ulnar joint as well as a marked loss of strength, which further contributed to a poor functional end result.)

As will be seen from the table, the other four cases had residual objective signs of injury to the median nerve. Two of them presented loss of tactile gnosis as well as atrophy and disturbed function of the thenar muscles. In none of these four cases could the result of the picking-up test be regarded as pathological. Nor, however, was the two-point discrimination so impaired as to be incompatible with a normal picking-up performance.

Late injuries to the median nerve. Four cases (0.9% of the total series) developed symptoms of disturbed function in the median nerve at least three months after the distal radius fracture (exact information about the time when the neurological symptoms appeared could not be obtained). All four cases displayed objective signs of impaired sensibility in the field of the median nerve as well as objective signs of loss of tactile gnosis. The picking-up test was definitely pathological in one case; when undertaken blind, the test could be performed satisfactorily only with the aid of the thumb and little finger. The normal picking-up test in the other three cases can be explained in the same way as for the early cases. The loss of sensibility in one of these four cases was combined with atrophy and disturbed function of the thenar muscles.

As will be seen from Table 39, all ten cases with injury to the median nerve had intra-articular fracture of the distal radius. All the different types of intra-articular fracture are represented, though with a preponderance of cases with such a fracture involving only the distal radio-ulnar joint and accompanied by fracture of the distal ulna (type VI).

Intra-articular involvement is the only etiological factor which these ten cases have in common as a possible contributory cause of the early and late appearance of dysfunction of the median nerve. In the early cases, intra-articular haematoma and swelling are conditions that may have reduced the volume of the carpal tunnel. In the late cases, a similar reduction may have arisen through intra-articular effusion and peri-articular oedema as a result of post-traumatic deformity in the radio-carpal and, in particular, the distal radio-ulnar joints. This is verified by the case in the series in which the objective signs of nerve injury disappeared after low resection of the ulna (see Table 39). (Similar cases outside the present follow-up series have been observed at our clinic, concerning the median as well as the ulnar nerve.)

In half of both the early and the late cases of median nerve injury there were also compressive processes in the form of voluminous volar callus formation or volar projection of a bone fragment, sometimes combined with fairly marked residual dorsal angulation in the distal radius fracture. This type of narrowing in the carpal tunnel is also likely to elicit symptoms of dysfunction of the median nerve.

As mentioned above, no importance was attached to the treatment of the fracture or, more particularly, the position of immobilization as a possible cause of the neurological symptoms in the present series. None of the early cases had been immobilized in volar flexion, nor had any of the cases undergone repeated attempts at reduction.

Early injuries to the ulnar nerve. This group comprised two cases out of the total series of 430 (0.5%). Clinical data are given in Table 40.

Late injuries to the ulnar nerve. This group also comprised two cases (0.5%) and the clinical data will likewise be found in Table 40. As in the case of the late injuries to the median nerve, the interval from the time of the fracture could only be determined approximately. In one case the symptoms were judged to have appeared after more than three months, in the other after more than four months.

One of the cases (no. 4) had had an open fracture of the distal radius and ulnar, the skin being pierced on the ulnar, volar surface of the wrist. After débridement and suture the wound had healed without complication. In addition, there was a comminuted fracture of the olecranon in the same arm. Open reduction was performed on this. At the follow-up examination the patient had no symptoms from the injured elbow, in which the loss of extension and flexion amounted to only 20°. In view of the good functional result after the elbow injury, the absence of subjective symptoms from the elbow and the lack of symptoms of injury to the ulnar nerve in the elbow region, it seemed reasonable to classify this case as a late injury to the ulnar nerve due to the distal radius fracture.

There is one extra-articular and one intra-articular fracture in both the early and the late group, while each of these four cases with symptoms from the ulnar nerve belongs to a different type of fracture. It is thus impossible to draw conclusions about any connection between type of fracture and type of nerve injury.

Only the two cases with late symptoms from the ulnar nerve were given a final x-ray examination. One of them displayed a distal displacement of the caput ulnae by 5 mm, with approximately the same shortening of the radius. This case also presented signs of post-traumatic disturbance in the distal radio-ulnar joint. It is not clear whether these findings, separately or in combination, contributed to the appearance of neurological symptoms. In view of the intimate relation of the ulnar nerve to both the distal ulna and the distal radio-ulnar joint, the possibility of a causal connection cannot be entirely ruled out. In the other case with late symptoms from the ulnar nerve, the distal fracture of the radius and ulna had healed with about 20° radial deviation of both the distal radius and the distal ulna fragments. In addition, the proximal fragment of the ulna was displaced volarwards approximately 5 mm. In this case it seems reasonable to conclude that this abnormal position after healing contributed to the occurrence of neurological symptoms, since it must involve some continuous effect on the ulnar nerve.

As with the injuries to the median nerve, no connection could be established between the impaired function of the ulnar nerve and the treatment of the fracture (including the position of immobilization) in these cases.

Discussion. All the 14 cases with early or late symptoms of injury to the median or ulnar nerve were given the same routine treatment as the other fractures of the distal radius in this series. A thorough neurological examination has been conducted on all fracture cases for many years now at this Department of Bone and Joint Surgery. I am therefore convinced that no "primary" nerve injuries were overlooked in this series.

For the same reasons it seems probable that the number of early nerve injuries reported here also reflects the true incidence. In view of the results from the examination, the same seems to apply to the incidence of late cases.

Of the conceivable etiological factors behind such nerve injuries in fractures of the distal radius (particularly injuries to the median nerve), it seems to me that the following deserve special consideration:

1. In primary injuries, a direct effect from the fracture fragment as illustrated in Fig. 28.

2. Primary intra-articular or peri-articular haematoma and swelling, leading to a reduction in the volume of the carpal tunnel.

3. Intra-articular effusion and peri-articular oedema as a result of disturbances in the distal radio-ulnar joint, similarly leading to a reduced volume of the carpal tunnel.

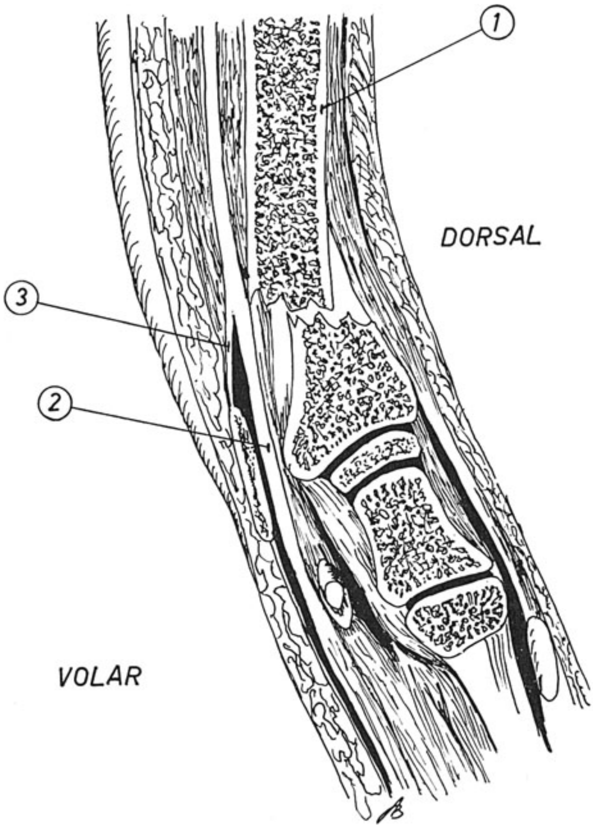

Fig. 28. Fracture of the distal radius involving the median nerve. 1, Radius; 2, Median nerve; 3, Palmar branch of median nerve.

4. Voluminous callus formation or volar projection of a bone fragment, again reducing the volume of the carpal tunnel.

As shown in Tables 39 and 40, the functional end results in these cases of nerve injury are generally less satisfactory than in the total follow-up series. The neurological symptoms, however, were of decisive importance for the functional end result only in case no. 7 among the median nerve patients—a 65 year old active businessman—and in case no. 2 in the ulnar nerve group—a 75 year old active housewife with subjective weakness in the injured hand and considerable discomfort from a non-sensible, accident-prone little finger.

It has been suggested in the literature that a clear connection exists between a carpal-tunnel syndrome after distal fracture of the radius and a shoulder-hand-finger-syndrome or related conditions (Sponsel & Palm, 1965). In this context and in the light of experience with cases outside the present series. I feel it should be pointed out that a transient nerve injury is also liable to contribute to a shoulder-hand-finger syndrome, even though this could not be demonstrated in the present series, in which the incidence of this syndrome was so low.

Conclusion. The minor practical importance of the nerve injuries in the present cases is no doubt explained by the relatively high age of these patients at the time of the follow-up examination. They were thus relatively inactive, with only moderate functional requirements. This impression is supported by the fact that none of the patients accepted an offer of decompressive surgery.

It should be added that *spontaneous regression* of the neurological symptoms can be expected in some cases when the swelling subsides. This was observed in case no. 9 in the median nerve group at a subsequent examination four years after the primary follow-up.

Experience at our clinic has shown, however, that there may also be a *secondary increase in incidence*, particularly for injuries to the ulnar nerve, as the deformation in the distal radio-ulnar joint increases over the years. This naturally applies chiefly to relatively young individuals.

Concerning the therapeutic aspects of this complication to distal fractures of the radius, I wish to emphasize the following:

1. Primary appearance of neurological symptoms seldom calls for acute exposure of the nerve because the symptoms of nerve compression usually diminish upon reduction of the fracture and generally disappear soon after. On the other hand, the subsequent treatment of these cases is usually more difficult than in fractures of the distal radius without this complication and calls for more thorough supervision. In particular, prophylactic measures should be taken against a shoulder-hand-finger syndrome, with intensive active exercises for both the shoulder and the finger joints in the injured arm.

2. Persistent neurological symptoms and late cases call for decompression of the median nerve.

3. In cases with symptoms of median or ulnar nerve injury and deformity in the distal radio-ulnar joint, the neurological symptoms may also disappear permanently after resection in the distal ulna.

B 3. *Shoulder-hand-finger syndrome*

Review of the literature

This highly complex condition was first mentioned by Mitchell, Morehouse & Keen (1864). As pointed out by e.g. Moberg (1951, 1955), the syndrome has been given many different names, which probably reflect the individual author's special interests in internal medicine, neurology, rheumatology, general surgery, orthopaedic surgery, hand surgery or neurosurgery, though they may also indicate that different components or different stages in the development of the syndrome have been studied. It seems that the most common terms in the French and Anglo-Saxon literature are Dyplay's syndrome, syndrome épaule-main, adhesive capsulitis, painful stiff shoulder, frozen shoulder, shoulder-hand syndrome and post-traumatic reflex dystrophy. In the German literature one finds terms such as schmerzhafte Schulterversteifung and das Sudecksche Syndrom.

This terminological confusion is understandable as such for several reasons. Thus Codman (1934), referring to the shoulder component, pointed out that this was "difficult to define, difficult to treat and difficult to explain from the point of view of pathology".

Moberg (1955) considered that the literature available *at that time* suggested that this opinion applied not only to the shoulder component but to the syndrome as a whole. He also observed that the complete syndrome is not often met with but that early stages of its various components are frequent. Zachariae (1964) also considered it common and reported that the shoulder-hand syndrome often starts with pain in the shoulder, the changes in the hand being secondary to this. She considered that a great deal was still unknown about the etiology and pathogenesis and that the syndrome had always been "surrounded by a haze of mystery or the supernatural".

It is therefore hardly surprising that, in the vast literature on this subject, it is difficult to find a concise definition of this complex syndrome. Moberg (1955) noted that it was "an entity and an important problem in surgery of the upper extremity". Wellmitz (1959) defined it as a neurovascular dysfunction through a hyperreactive state in the vegetative nervous system, which may be both exogenously acquired and endogenously inherited. Zachariae (1964) found "that certain patients may react in a special way to trauma, developing a state generally known as 'posttraumatic reflex dystrophy'. This is a serious complication, frequently to an originally negligible lesion, and at worst it may leave severe, permanent sequelae."

Regardless of the name adopted, the syndrome is usually described as developing in three stages (de Takats & Miller, 1943; Taylor, 1958; Friedman, Argyros & Steinbrocker, 1959) as follows:

1. A burning pain or a feeling of discomfort in the shoulder region develops after trauma to the upper extremity or during an internal disease. Shortly afterwards, sometimes with or before these symptoms, pains and swelling appear in the hand and fingers. The patient experiences pain on passive finger movements, the skin folds are smoothed out and the patient is unable to flex the fingers. Osteoporosis often occurs in the carpal and hand skeleton. This first stage may last 3–6 months.

2. The pain in the shoulder region disappears. The swelling in the hand diminishes, sometimes combined with increasing pain from finger movements and further loss of finger mobility. In some cases there may be changes resembling Dupuytren's contracture. There is usually a sensation of cold in the hand and some degree of dystrophic skin changes. This stage may gradually develop into the third stage.

3. Fibrosed, deformed hand with contracted fingers (frozen hand) combined with "frozen shoulder". The pains in the hand and shoulder have disappeared and the affected extremity presents a state of severe invalidity.

It is said that this progress may be arrested at any stage, either spontaneously or as a result of treatment. The second stage, like the first, is reported to last 3–6 months, whereas the third develops very individually, with irreversible changes and contractures, and may persist for years. A typical feature is said to be that the elbow joint is never affected.

Moberg (1951) appears to have coined the term *shoulder-hand-finger syndrome* for this condition. In subsequent reports on its clinical and therapeutic aspects (1955, 1960, 1963), he states that it comprises two components—a shoulder component and a hand-finger component—of which only one is generally present in the early stages, subsequently perhaps becoming the dominant clinical manifestation of the syndrome. The two components are closely interrelated, representing the main links in the sequential chain that gives the syndrome its character of a vicious circle.

As mentioned above, Zachariae (1964) found that, in spite of the extensive literature produced on the etiology and pathogenesis of the syndrome, these aspects were by no means exhaustively investigated. In this context I must limit myself to quoting from the major works to indicate the two main pathogenetic principles that seem to have emerged.

The *etiological factor* is said to vary from not infrequently very minor traumatic conditions in the upper extremity to internal diseases such as cardiac infarction, rheumatoid arthritis or paretic states due to cerebral injury. Mental and psychological factors have also been considered as a background to the syndrome, largely in an attempt to explain why, among patients with identical injuries, only some develop the syndrome. Wellmitz (1959), for instance, asserted that both dispositional and constitutional factors were involved. Zachariae (1964), referring to patients given a psychiatric examination before being operated upon for Dupuytren's contracture, also reported: "It is obvious, then, that the patient's mental status prior to the operation influences the development of postoperative dystrophy. Although these mental factors are probably not the sole explanation, they no doubt constitute an important detail in the syndrome."

Although Steinbrocker & Argyros (1958) found that it was usually anxious, hypersensitive patients who contracted the syndrome, they did not consider psychological factors were important for its genesis. They added, however, that psychogenic factors may play a major part in maintaining and aggravating the condition. Moberg (1960) expresses much the same opinion: "Obviously, the attitude of the patient to his disability plays an important role in all of these mechanisms. The active patient is not able to keep his damaged arm strictly immobilized, even if he attempts to do so. Therefore, the function of the pumping system is retained. On the other hand the passive patient, especially the hypersensitive one, will immobilize himself completely even following slight trauma."

From the *pathogenic aspect*, as already mentioned, the literature seems to distinguish between two main principles.

According to one of these, the shoulder-hand-finger syndrome is caused by disturbances elicited reflexly via the autonomic nervous system. As early an author as Sudeck (1900, 1901) proposed that the osseous atrophy described by him depended upon trophoneurotic disturbances, a theory which he based on the assumption of a dominant neurogenic factor. This theory has since been suported by several authors (Leriche & Fontaine, 1930; de Takats, 1937; Haldbo, 1942; de Takats & Miller, 1943; Miller & Miller, 1951; Bertelsen, 1958; Steinbrocker & Argyros, 1958; Friedman, Argyros & Steinbrocker, 1959; Mayfield & Newquist, 1959; Wellmitz, 1959; Thompson, 1961; Weissenbach, 1964). These authors' conception is that pain from a peripheral focus is transmitted on afferent pathways to spinal centres, from which the impulses travel via internuncial pools (described by Lorento de No, 1938) to the efferent sympathetic pathways. The importance of the cells described as internuncial pools has been particularly emphasized by Steinbrocker, Spitzer & Friedman (1948) and Thompson (1961). They comprise a diffuse network of interconnected neurones in the grey matter of the spinal medulla. Through them, impulses can be dispersed to lateral and anterior parts of the spinal cord as well as to different segments of this. Thompson considers that this may in fact explain why the shoulder-hand-finger syndrome has such a complex symptomatology and why it sometimes occurs bilaterally. Mayfield & Newquist (1959) found further support for this autonomic, neurogenic factor in the pathogenesis in the experimental finding that prolonged bombardment of extremital regions in both animals and man with painful stimuli elicited oedema in the tissues.

The other main theory concerning pathogenesis is based on quite different physiological phenomena. Earlier authors such as L. Böhler (1923) probably came close to this pathogenic factor with their theories, but it is not until fairly recently that its physiological background has been elucidated by Moberg (1951, 1955, 1960), whose opinions have subsequently been supported by e.g. Zukschwerdt (1962) and Beasley (1964). Moberg found that the central feature in the pathogenesis of the shoulder-hand-finger syndrome is an impairment of the pumping mechanism in the arm. The efficiency of the arterial supply depends upon the blood pressure, whereas on the venous side the pressure is low and the transport of blood and lymph away from the extremity requires external factors such as active muscle function in the arm and active function of the hand. Since the anatomical relationships are such that the pumping mechanism in the arm is most efficient at the shoulder and in the dorsal metacarpal region, it follows that functional disturbances in the shoulder region and the hand—separately or in combination—may seriously impair the backflow of the venous and lymphatic systems. The efficiency of the pumping mechanism in the shoulder is upset by immobilization of the shoulder joint. A similar deleterious effect on the pumping mechanism of the shoulder joint is produced by immobilization of the arm through the use of a sling or by the immobility of bed-ridden patients. The oedema in the hand appears first in the dorsal region, later in the palm and fingers as well. It prevents normal movements of the hand and fingers, finger flexion being affected first. The patient is no longer able to clench the fist completely and the efficiency of the pumping mechanism in the hand is also impaired. In conjunction with the disturbance in the shoulder mechanism, this increases the oedema in the hand, resulting in a vicious circle. This chain of events may be reversed, i.e. injury to the hand or paralysis of this as a result of injury to central or peripheral neurones impairs the pumping mechanism of the hand, resulting in oedema in this. The resultant defective function of the hand may then—particularly in inactive or elderly individuals—lead to impaired function of the arm and hence to contracture in the shoulder region.

According to Moberg, the shoulder-hand-finger syndrome is an entity, a vicious circle in which the chief links are the shoulder component and the hand-finger component. The shoulder component is perhaps less liable to *manifest itself clearly. The pathophysiological core of the syndrome, however,* is the disturbed circulation arising from the defective pumping mechanism and the most deleterious consequence of this—the hand oedema. In Moberg's opinion it is also the hand oedema which determines the long-term prognosis in this syndrome: "Oedema that has lasted for any time always leaves something behind. Some will always be converted into diffuse cobweb—like scar tissue. Most of this tissue is formed in the subcutis, particularly immediately peripheral to the fascia, but some will be found in all the tissues. The greater the oedema and the longer it persists, the more scar tissue is formed. Severe oedema leaves a hand with atrophic skin, stiff joints and a poor grasp, sometimes resembling a rake. Two forms of deformity may develop. In the more common variety, the metacarpophalangeal joints stiffen in extension and the interphalangeal in flexion ('intrinsic minus' hand). In the other variety, the interphalangeal joints stiffen in extension while the metacarpophalangeal joints retain a slight power of flexion ('intrinsic plus' hand). Which of the two deformities results is dependent on the strength of the long flexors and extensors compared to that of the short muscles of the hand (intrinsic muscles)."

Moberg holds that the disturbance to the pumping mechanism outlined above is quite sufficient to explain the genesis of the shoulder-hand-finger syndrome and that consequently there is "no reason to trace it to some unexplainable factor". Concerning the possible involvement of the sympathetic nervous system, Moberg considers that disturbances in this are definitely present in the cases of true causalgia associated with multiple lesions of peripheral nerves, the chief characteristic of which is hyperalgesia. Such cases, however, are usually ones of war-wounds with multiple lacerations and—unlike the shoulder-hand-finger syndrome—generally involve younger persons. In these cases the disturbance in the sympathetic nervous system soon intermingles with symptoms of a defective venous backflow. Summing-up on the shoulder-hand-finger syndrome, Moberg writes, "In injuries of every-day life, it is difficult to determine whether or not a mild form of reaction from the sympathetic nervous system is included in the shoulder-hand-finger syndrome."

The *treatment* recommended for the syndrome in the literature largely reflects the individual author's conception of the pathogenesis. If the autonomic nervous system is held to be chiefly responsible, blockade of the stellate ganglion, sympathectomy or ganglionectomy is recommended, usually together with both passive and active exercises. "Antiinflammatory" therapy with corticosteroids and phenylbutazone derivatives is also said to be effective. Supporters of the other pathogenic principle rely mainly on restoration of the pumping mechanism of the hand and arm, the chief aid being a systematic utilization of the patient's ability to perform *active* movements. It is also considered essential to avoid using slings, unnecessarily large plaster bandages and splints, i.e. devices which impede or prevent movement.

Irrespective of the pathogenic principle followed and the attendant treatment recommended, it seems to be generally agreed that the prognosis in cases with a shoulder-hand-finger syndrome entirely depends on early diagnosis and early treatment.

The occurrence of the shoulder-hand-finger syndrome and allied conditions *in connection with distal fractures of the radius* has been recognised for many decades now. von Lesser (1887) reported finding trophic disturbances in musculature and hand after "typical" fractures of the radius, leading to considerable loss of function in the hand. Le Breton (1915) published 10 cases that seem to have presented a typical shoulder-hand-finger syndrome, though he describes them as "arthritis of the joints of the hand following Colle's fracture". Four of these cases resulted in some degree of permanent invalidity. Hansen (1926), presenting a series of compensation cases, considered that in not a few instances, "dystrophy" was the cause of functional disturbances with stiff finger and hand joints after ideal reduction of distal radius fractures. Pickard (1927) regarded "the stiff hand" as the most deleterious residual symptom of such fractures, usually caused by faulty immobilization treatment, and held that the post-traumatic syndrome on a neurovascular basis was rare. Kotrnetz & Geiringer's (1937) series included a small number of severe and a larger number of mild circulatory disturbances after distal radius fractures, both types being particularly frequent in the fractures treated with primary reduction. They consequently recommended reduction to be postponed until at least 24 hours after the accident. de Takats & Miller (1943) had only one case of Colles' fracture in their series of 33 cases with post-traumatic dystrophy. In Rosen's (1947) series of 280 distal fractures of the radius, no less than 10 cases had post-traumatic dystrophy with swelling, oedema, pains and loss of mobility. Of the four cases with "posttraumatic reflex dystrophy" presented by Miller & Miller (1950), two had a fracture in the distal end of the radius. Cassebaum (1950) discussed the shoulder-hand-finger syndrome as a possible complication of distal radius fractures and recommended prophylaxis in the form of active finger and shoulder exercises. Knapp (1952) discussed two conditions as complications of distal radius fracture, one of which he termed post-traumatic fibrosis and the other Sudeck's acute post-traumatic atrophy of bone. The first he ascribed to post-traumatic oedema, the second to "reflex sympathetic dystrophy". Since both conditions were due to diminished activity, Knapp strongly emphasized the importance of maintaining "the activity of normal function" throughout the period of healing by convincing the patient that the injured hand could and should be used for normal, daily functions. In their large series of more than two thousand compensation cases of distal radius fracture, Bacorn & Kurtzke (1953) found "causalgia" in 0.1% and "Sudeck's atrophy" also in 0.1%; changes resembling Dupuytren's contracture were present in 0.2% and loss of shoulder mobility in 1%. If one assumes that these indefinite manifestations in fact represent one and the same condition, namely the shoulder-hand-finger syndrome, the frequency of this in their series would be 1.4%. Hoffman (1953) reported that his series of 35 cases of dislocated distal radius fractures included no less than 10 with clinical symptoms of "Sudeck's atrophy" during the post-traumatic period. Two of these cases presented a poor functional result two years after the injury. Lidström's (1959) series of 515 cases of distal radius fractures included 53 (10.3%) in which the post-traumatic course had been complicated or prolonged by "post-traumatic causalgia", by which Lidström does not mean "true" causalgia. The functional end results were unsatisfactory in 67% of this group, a much worse result than for the rest of the series. Lidström notes that repeated attempts at reduction had not contributed to the poorer results in this group. Discussing the incidence of "Sudeck's syndrome" after distal fractures of the radius, Baitsch & Heller (1959) note that Böhler had an incidence of only 0.33‰ but add that differences in this respect probably reflect the manner of interpreting the clinical picture. They had not found a single case of "true Sudeck" in a series of 365 cases of distal radius fractures from the Böhler Clinic, a result which they attributed to the Clinic's consistent application of certain therapeutic principles. The most important of these principles in the present context were said to be (1) Local anesthesia without delay in order to prevent all unnecessary pain, (2) Split the plaster bandage immediately after reduction, (3) Exercises at once, and (4) Frequent controls for the first few days after the accident.

In Djorup's (1962) series of compensation cases, the 39 patients with at least 10% invalidity after the distal radius fracture included as many as 10 (over 25%) in which the invalidity was occasioned by "reflex dystrophy". In the series of Raschle (1965) and Rehn (1965), the incidence of "Sudeck's atrophy" lay between 6.5% and 8.5%. They stated that this was one of the most severe complications after distal fractures of the radius. Rehn in particular warned against an *excessively* short period of immobilization, massage and passive exercise, i.e. factors which he considered liable to promote the development of the syndrome.

Discussion. I have not found any mention in the literature of series of distal radius fractures in which a consistent attempt has been made to prevent this complication or treat it early with measures aimed at a supposed *neurogenic* factor. The effect of such therapy when introduced at a late stage is of course extremely limited.

It thus seems that no studies of radius fractures have been published which provide a relatively exact picture of the pathogenesis of the complication referred to here as the *shoulder-hand-finger syndrome.*

As in the case of the distal radius fractures themselves, however, causal relationships can be studied—as indicated by the incidence data reported above—by collecting sufficiently large series of *similar* cases. A comparison in this respect seems to be feasible between my series and other large ones in the literature.

Own investigations

It seemed important to investigate whether a disturbed lymphatic and venous circulation (Moberg, 1951) can be shown to be the essential pathogenetic factor behind the shoulder-hand-finger syndrome. Since my series was treated consistently according to the principles outlined on p. 51 and since no measures were taken specifically to counteract any neurogenic, pathogenetic factor, I find the series suitable for the type of study indicated above.

Some points should be mentioned before proceeding to the clinical data of the cases with shoulder-hand-finger syndrome.

It is possible that the ages in these cases differ from those in other published series, since exact data in this respect are not generally provided for the latter. As pointed out below, however, a typical feature of the syndrome is said to be that it does not generally occur in patients below the age of 40, while it is most frequent above the age of 50. It is also said to be more common among women.

Some idea of the exactness of the reduction and the quality of the immobilization in my series can be derived from the information about whether reduction was attempted repeatedly. Repeated attempts are often cited as a possible etiological factor, but the incompleteness of data about this in the literature renders a comparison with my series impossible.

My follow-up series of 430 cases was found to include 9 (2.1%) in which the shoulder-hand-finger syndrome had been present during treatment. Only one of these developed the changes associated in the literature with Sudeck's syndrome.

It is worth noting that six of the nine patients were women, i.e. 1.8% of all the women in the series, while the three men comprised 3.6% of all the men. This runs counter to the general conception that the syndrome is more frequent among women, but the discrepancy in my series may of course be of an occasional nature.

The main clinical data on these nine cases have been compiled in Table 41, p. 155. In particular, I wish to note the following:

1. None of the patients with this complication was younger than 40, while only two were below the age of 55.

2. Most of the patients (six) displayed little personal activity during the period of treatment, while three seemed to be emotionally unstable and sensitive individuals. At the follow-up examination, these three cases (nos. 2, 3 and 7) displayed clear residual symptoms of a shoulder-hand-finger syndrome.

3. Two of these patients (nos. 2 and 3) had a disturbance in the distal radio-ulnar joint.

4. Seven of the nine cases had intra-articular types of fracture; this is a still larger proportion than in the total follow-up series (63.7%). The intra-articular fractures in the total follow-up series displayed a greater tendency to primary dislocation compared with the extra-articular group and hence reduction was indicated more frequently (cf. Table 49, p. 134). In the present group of nine cases, all the intra-articular and one of the extra-articular cases had the fracture reduced, while *in half of these the reduction had to be repeated*. This is a marked discrepancy from the total follow-up series, in which reduction had to be repeated in only 12 of 295 cases (4%).

5. The symptom was detected less than 20 days after the accident and the primary treatment in only two cases, neither of which called for repeated reduction of the fracture. Both the shoulder and the hand-finger components of the syndrome were present in five cases, of which four had undergone a repeated attempt at reduction (cf. above). Only the hand-finger component was manifest in the other four cases, two of which were those where the syndrome appeared early during treatment.

6. None of the nine cases had any injury to the affected arm apart from the distal fracture of the radius. A sling was never used to immobilize the arm. In fact the patients were all instructed from the start to perform active exercises in both the shoulder and the finger joints. In four of the nine cases (nos. 3, 6, 7 and 8) it was soon evident that the patient could not be relied on to perform the active exercises, which were consequently supervised by a physiotherapist, three of these patients (nos. 6, 7 and 8) being hospitalized for this reason.

7. *Brief hand status in cases 2, 3 and 7. Case no. 2*: Flexion defect in metacarpophalangeal joints II–V; on maximal clenching the finger-tips came to within 1½ cm of the proximal palmar fold; extension defect of 10–20° in the proximal interphalangeal joints of fingers II–IV. *Case no. 3*: Slight flexion defect in metacarpophalangeal joints II–V; on maximal clenching all the finger-tips reached the palm 1 cm proximal of the proximal palmar fold; extension defect of 10–15° in proximal interphalangeal joints of fingers II–IV but distal interphalangeal joints normal. *Case no. 7*: Slight flexion defect in metacarpophalangeal joints II–V; on maximal clenching the distances from the finger-tips to the proximal palmar fold were 1½, 2, 2 and 1½ cm; extension defect of 10–15° in proximal interphalangeal joints of fingers II–V. This

was the only case in the series in which an x-ray examination (about three months after the accident) revealed changes resembling Sudeck's osseous atrophy.

Discussion. At the follow-up examination, only three of the nine cases (0.7% of the total series) had such a degree of residual functional loss after the shoulder-hand-finger syndrome that their functional end result was affected. In two other cases (0.5% of the total series), traces of the syndrome were detected at the follow-up examination but did not influence the functional end result.

In eight of the nine cases in which the shoulder-hand-finger syndrome was present during treatment, the syndrome most probably contributed to a prolonged total incapacity for work.

All these eight cases had had the fracture reduced and in half of them the reduction was repeated.

None of the patients with the shoulder-hand-finger syndrome displayed signs of any vegetative disturbances or any multiple lesions of peripheral nerves with causalgia as a symptom.

All the patients were over 40 years of age at the time of the accident.

The majority were markedly inactive and three were also emotionally unstable. In my opinion, these two factors were undoubtedly important for the development of the syndrome in these cases. In the other cases, no endogenous factors could be associated with the appearance of the syndrome.

The findings from the follow-up examination indicate that the chief cause of residual changes after the shoulder-hand-finger syndrome was the finger-hand component of this.

The total incidence of the shoulder-hand-finger syndrome in my series of distal radius fractures (2.1%) is remarkably low compared with other published series, even though the nine cases undoubtedly include some relatively slight instances of the syndrome. There are still fewer cases with residual functional loss from the syndrome (3=0.7%) and the degree of this loss is also slight. My series also has a strikingly low incidence of cases corresponding to "Sudeck's osseous atrophy" (1=0.2%).

The only factors which distinguish my series from those most comparable to it in the literature are as follows:

1. A sling was never used for immobilization of the arm after fracture of the distal radius.

2. Active exercise of both the shoulder and the finger joints in the injured arm was always instituted at once and carefully supervised.

3. In cases in which the shoulder-hand-finger syndrome developed, the patient's actives exercises were very carefully supervised; most of these patients were consequently hospitalized for the intensified active therapy.

TABLE 42. *Lesion of the extensor pollicis longus tendon.*

Identification	Type and side of fracture	Reduction	X-ray before reduction (∧)	X-ray after the end of treatment (∧)	Length of immobilisation (days)	Onset of symptoms (days after injury)	Reconstruction	Other complication	Length of follow-up (months)	Functional end result	Remarks
1) ♀ 56 years	II Right	+	Dorsally dislocated fragment. 10° dorsal 10° radial	10° dorsal 10° radial	18	62	—	—	50	Fair	Grip strength impaired. Loss of mobility.
2) ♀ 62 years	VIII Right	+	15° dorsal 0° radial	30° dorsal 0° radial	28	28	+	Disturbance of D.R.U.	25	Fair	Grip strength impaired. Tendon function good, but unable to raise the thumb over metacarpal plane.
3) ♀ 73 years	II Left	—	15° dorsal 5° radial	Not done	No plaster (1st examination 3 weeks after injury)	90	—	—	29	Fair	Pinching grip impaired.

+ = Yes.
— = No.
D.R.U. = Distal radio-ulnar joint.

Conclusion. The most important conclusion from this investigation is that the incidence of the shoulder-hand-finger syndrome could be kept very low compared with most other published series *simply by instituting measures to promote the circulation right from the start.*

As far as can be judged, this follow-up series does not differ from other, similar series in respect of severity of the fractures, age of the patients or other factors that might influence the incidence of complications. Pathogenetically, therefore, the circulation factor described above (Moberg) has been found to be decisive for the occurrence of the syndrome—a finding which to my knowledge has not been demonstrated before.

B 4. *Rupture of the extensor pollicis longus tendon*

Ever since Heineke (1913) first published a case of subcutaneous rupture of the extensor pollicis longus tendon as a complication of a distal radius fracture, this tendon lesion has received a great deal of attention in the literature. Thus, recent compilers in this field (Strandell, 1955; Mendelaar, 1960) report that, out of all such tendon ruptures to be found in the available literature, some 80% were complications of fractures in the distal radius. The part played by the radius fracture in this context is the subject of considerable controversy, although most authors state that the complication occurs most frequently in such fractures without dislocation (Lipschutz, 1935; Aronson, 1939; Björkroth, 1941; Trevor, 1950; Strandell, 1955; Witter, 1960; Carlberg, Delmotte, Stehman & van Gaver, 1961).

Own in vestigations

My series of 430 fractures of the distal radius—with rupture of the extensor pollicis longus tendon in three cases (0.7%)—is not an adequate basis for an analysis of either the pathogenesis or the therapy in this complication. I shall therefore simply note that the incidence of this complication, which is interesting in many respects, agrees with corresponding data. This is a further indication that my series is fully comparable with those published earlier.

None of my three cases with this complication displayed any marked dislocation in the fracture at the primary roentgenological examination. In this respect, too, there is thus good agreement with current opinion.

Concerning pathogenesis and therapy I refer, for the reasons given above, to the studies by Strandell (1955), Davidsson (1956) and Bache (1959).

Table 42 gives the clinical data for the three cases in my series with subcutaneous rupture of the extensor pollicis longus tendon as a complication to distal fracture of the radius.

It may be mentioned here that in the statistical analysis of the total follow-up series by means of multiple regression analysis (cf. Chapter XII), this factor was found to be of some significance for the end result after the fractures of the distal radius in my series. As already pointed out, however, the number of cases is so small that this finding must be interpreted with the utmost caution.

CHAPTER XII

STATISTICS

The statistical analysis of the numerical data involved testing hypotheses concerning correlations between functional end results, Y, and one or several of the following variables, X_i: (1) age, (2) sex, (3) type of fracture, (4) fracture of ulnar styloid process, U.S.P., (5) dorsal angulation, (6) shortening, and (7) interval between injury and follow-up examination.

Processing of the data was formally facilitated by expressing the qualitative variables in numerical terms (e.g. for sex: men=1, women=2). This was also done for the variable "type of fracture", the different types being arranged in an ascending order according to the primary assessment of their severity.

It seemed reasonable to regard the functional end result as a purely linear function of the variables X_i:

$$Y = \alpha + \Sigma \beta_i X_i$$

This implies that one ignores all interactions, which appears biologically reasonable.

Under these conditions, the analysis of the correlations—in principle a multiple analysis of variance—can be undertaken in the form of a multiple regression analysis.

Since the statistical investigation was set up as a test of hypotheses, the estimates of the regression coefficients $\hat{\beta}_i$ were not calculated.

The hypotheses were tested in the form

$$t(\nu) = \frac{\hat{\beta}}{S_{\hat{\beta}}};\ \nu = d \cdot f$$

where $\hat{\beta}$ is an estimate of β and $S_{\hat{\beta}}$ is the estimated standard deviation of the estimation.

If $t(\nu) = t_{95}(\nu)$, the hypothesis that a correlation exists between a variable X_i and the functional end result Y is accepted.

Owing to a lack of uniformity in the data, they had to be divided into two groups, A and B. Complete data on all the variables were available for the individuals in group A, while in group B data were lacking on the variables "dorsal angulation" and "shortening", i.e. those which could not be registered until after the final roentgen examination.

A comparison of groups A and B with respect to their composition by sex, age and type of fracture did not reveal any significant differences and consequently they have been treated as random samples from the same population with respect to the variables studied.

An analysis was first made of the correlation between the functional end results and the factors X_i that were common to groups A and B. The results have been compiled in Table 43 together with the partial regression coefficients, making it possible to grade the strength of the correlation.

It will be seen that "type of fracture" and "age" are significantly correlated with the functional end result, whereas the other variables cannot be shown to influence the end result.

As already mentioned, the variables "dorsal angulation" and "shortening" had to be excluded from this analysis, which concerned all the individuals in the follow-up series. In order to test the hypothesis concerning the influence of these variables on the functional end result, a multiple regression analysis was performed on group A with the functional end result Y as the dependent variable and age, type of fracture, dorsal angulation and shortening as independent variables. The results are shown in Table 44.

It will be seen that shortening, too, is significantly correlated with the end result (owing to the smaller number of individuals, the significant correlation between age and functional end result in the total follow-up series cannot be demonstrated in this group).

Thus, *the statistical analysis demonstrates* that:

(1) The functional end result deteriorates with increasing age of the patient.

(2) The functional end result deteriorates with the severity of the type of fracture.

(3) Shortening involves a deterioration of the functional end result.

TABLE 43. *Functional end result as a function of age, sex, type of fracture, U.S.P. (fracture of the ulnar styloid process) and interval.*

$n = 430$.

Factor	Regr. coeff.	$S_{\hat{\beta}}$	t	Part. corr. coeff.
Age	0.0095	0.0029	3.26*	0.17
Sex	0.0839	0.1076	0.77	0.04
Type of fracture	0.0765	0.0176	4.34*	0.23
U.S.P.	0.0464	0.0870	0.54	0.13
Interval	0.0036	0.0040	0.91	0.04

TABLE 44. *Functional end result as a function of age, type of fracture, dorsal angulation and shortening.*

$n = 224$.

Factor	Regr. coeff.	$S_{\hat{\beta}}$	t	Part. corr. coeff.
Age	−0.0009	0.0038	−0.22	0.08
Type of fracture	0.0825	0.0210	3.92*	0.31
Dorsal angulation	0.1008	0.0606	1.66	0.24
Shortening	0.2562	0.0713	3.59*	0.31

As for the other factors, the above analysis has left the question of their influence on the end result open. All that can be said is that *the present data do not support any hypotheses that these factors influence the functional end result.*

Another analysis, analogous to the above, was undertaken concerning the correlations between various sequelae and functional end result. (Table 45). In order to isolate these relationships, an analysis was also made of group *A*, in which the effects of age, type of fracture and shortening could be eliminated. The results are shown in Table 46, with the significant factors marked with an asterisk.

TABLE 45. *Correlations between functional end result and sequelae, total follow-up series.*

Sequela	Part. corr. coeff.	T-value
Symptoms from distal radio-ulnar joint	0.38	5.76*
Injury of median or ulnar nerve	0.20	4.46*
Shoulder-hand-finger syndrome	0.26	3.97*
Injury to tendon of extensor pollicis longus	0.08	2.13*

TABLE 46. *Correlations between functional end result and sequelae, X-ray series.*

Sequela	Part. corr. coeff.	T-value
Symptoms from distal radio-ulnar joint	0.48	6.30*
Injury of median or ulnar nerve	0.18	3.03*
Shoulder-hand-finger syndrome	0.34	3.97*
Injury to tendon of extensor pollicis longus	0.07	1.63 not sign.

In order to test the value of the significant correlations reported above, an attempt was made to use the regression functions calculated in the first two analyses as "predictors" of the functional end result. In this procedure, each individual's "score" for age, type of fracture etc. is inserted in the regression function to produce a figure which should correspond to the functional end result achieved. The calculated figures are rounded of to the nearest whole number, since the variable "functional end result" is expressed in whole numbers.

In the total follow-up series, 47% of the results were correctly predicted, in group *A* 53% These figures should be judged in relation to entirely random predictions, which turn up correct for about 25% of the results in both cases.

CHAPTER XIII

CLINICAL ASPECTS OF END RESULTS IN CERTAIN TYPES OF CASES

This chapter contains brief descriptions of some clinical aspects of the end results in certain types of cases referred to in passing elsewhere in this thesis. These cases are grouped under four headings, namely (*a*) Fractures with volar displacement, (*b*) Fissure fractures, (*c*) A comparison between reduced and unreduced fractures, and (*d*) Fractures with open reduction.

Fractures with volar displacement

My series included 17 cases of fractures with volar dislocation. Their distribution by sex, age and type of fracture has been reported in Chapter V on p. 40, where it is noted that, compared with the total follow-up series, men and the young age groups are over-represented in these cases.

Table 47 gives the functional end results for these fractures with volar dislocation. There is no statistically significant difference between these results and those for the total follow-up series (cf. p. 77) and consequently this group is reported together with the latter.

Fissure fractures

In Chapter V (p. 39) it was noted that the 19 fissure fractures in my series included a much smaller proportion of intra-articular fractures compared with the total follow-up series and that the number of fissure cases in the youngest age groups was disproportionately high.

TABLE 47. *End results of fractures with volar displacement.*

Result		♀		♂		Total	
		No.	%	No.	%	No.	%
Excellent		3	30	1	14	4	23.5
Good		4	40	4	57	8	47
Fair		2	20	2	29	4	23.5
Poor		1	10	—	—	1	6
	Total	10	100	7	100	17	100

It was found in the follow-up series that the functional end results are better for extra-articular types of fracture and better too in the young age groups. It is therefore not surprising that, as shown by Table 48, the functional end results for the 19 cases with fissure fractures are considerably better than those for the total follow-up series.

An unsatisfactory functional end result was displayed in two of these nineteen cases. In both cases it was due to subjective symptoms and objective findings of a loss of strength.

Since not all the cases of fissure fracture had satisfactory end results, I did not feel justified in excluding them from the follow-up series.

TABLE 48. *End results of fissure fractures.*

Result		♀		♂		Total	
		No.	%	No.	%	No.	%
Excellent		6	43	5	100	11	58
Good		6	43	—	—	6	32
Fair		1	7	—	—	1	5
Poor		1	7	—	—	1	5
	Total	14	100	5	100	19	100

A comparison between reduced and unreduced fractures

Table 49 shows the reduced and unreduced cases in my series by type of fracture.

TABLE 49. *Type of fracture (reduced and un-reduced cases).*

Type of fracture		Reduced		Un-reduced	
		No.	%	No.	%
I		29	37.7	48	62.3
II		58	73.4	21	26.6
III		19	43.2	25	56.8
IV		39	72.2	15	27.8
V		19	61.3	12	38.7
VI		63	88.7	8	11.3
VII		12	85.7	2	14.3
VIII		56	93.3	4	6.7
	Total	295	68.6	135	31.4

It will be seen that the number of reduced cases predominates in the groups in which the radius fracture is combined with a fracture in the distal ulna. This seems natural in view of the greater tendency to dislocation that is presumably displayed by these types of fracture. Fracture types V and VII, however, are exceptions in this respect. Here it seems that reduction was indicated more frequently by involvement of the distal radio-ulnar joint, with malposition in this.

An attempt was made to compare the end results in reduced and unreduced fracture cases for the different types of fracture. Many of the groups in such a comparison were so small that random factors could not be excluded and consequently it was impossible to draw any definite conclusions from the results. As a single group, however, the reduced cases had somewhat inferior results compared with the unreduced cases (satisfactory results in 71.9% and 82.3% respectively). This does not of course imply that the reductions were responsible for the inferiority of the results. The true explanation is simply that the reduced and the unreduced fractures largely correspond respectively to those with primary dislocation and those without. The current opinion in the literature is that end results are adversely affected by primary dislocation. Consequently, my series does not differ appreciably in this respect from those published previously.

Fractures with open reduction

My series includes seven cases of open reduction, performed in each case after primary closed reduction. In five cases the result of the latter had proved unsatisfactory, while the other two had early re-dislocation in spite of optimal immobilization.

Table 50 gives the distribution of these cases of open reduction by age, sex and type of fracture. It will be seen that the cases concerned six men in the younger age groups and only one woman (62 years). The fracture was intra-articular in all cases, with considerable displacement of the joint surface. Malposition of articular fragments was thus the indication for the open reduction in all these cases. Four of the fractures displayed volar dislocation.

In five cases the fracture fragment was fixed with intraosseous steel-wire loops, in the other two with subcutaneous Kirschner wires. These measures gave a satisfactory position of the articular fragment and there was no further dislocation.

Table 51 gives the functional end results in these cases. Unfortunately, a roentgenologically and clinically comparable series of un-operated cases is not available against which to evaluate the surgical treatment in these cases. Their end results are inferior to those for the total follow-up series, but this

TABLE 50. *Distribution of fractures with open reduction by type of fracture, sex and age.*

Age	Type of fracture I ♀	I ♂	II ♀	II ♂	III ♀	III ♂	IV ♀	IV ♂	V ♀	V ♂	VI ♀	VI ♂	VII ♀	VII ♂	VIII ♀	VIII ♂	Total ♀	Total ♂	Total
16–25	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	1
26–35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
36–45	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	2	2
46–55	—	—	—	—	—	2	—	1	—	—	—	—	—	—	—	—	—	3	3
56–65	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1
66–75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
76–85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
86–95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	3	—	3	—	—	—	—	—	—	1	—	1	6	7
																	14%	86%	
	—		—		3		3		—		—		—		1		7		

is only to be expected—all the cases with open reduction had severe, dislocated intra-articular fractures, which experience has shown to have very poor functional results.

It should be noted that the four cases with an unsatisfactory end result all presented a combination of impaired wrist mobility and loss of strength in the hand.

The intention behind the open reduction in these seven cases was the same as that behind the closed reductions in the series in general—to achieve an acceptable, stable position of the fracture. The other treatment in these cases was in line with the total follow-up series. Consequently, the seven cases of open reduction have not been considered separately in the assessment of the end results for my series.

TABLE 51. *End results of fractures with open reduction.*

Result		♀		♂		Total	
		No.	%	No.	%	No.	%
Excellent		—	—	—	—	—	—
Good		—	—	3	50	3	43
Fair		1	100	2	33	3	43
Poor		—	—	1	17	1	14
	Total	1	100	6	100	7	100

CONCLUSIONS

The biomechanical investigation showed that clinical types of distal radius fractures can be reproduced experimentally with either static or dynamic violence provided the hand of the specimen is arranged within a certain range of dorsal or volar flexion.

I consider that the results of the clinical and statistical analyses of my consecutive series of distal radius fractures justify the following conclusions.

(1) The extensive analysis of the follow-up series indicates that fractures of the distal radius involve the *distal radio-ulnar joint* much more frequently than is generally realized and that this intra-articular involvement is far more important than has been assumed.

The incidence of this complication is relatively high. The complication is easy to diagnose with the technique reported here, making it possible to introduce adequate therapy. Without such therapy, the complication has a considerable deleterious effect on the end result.

(2) Of the various types of residual deformity after distal radius fractures, *shortening* of the radius seems to have the most adverse effect on the functional end result, probably because it frequently impairs the function of the distal radio-ulnar joint as a result of disproportion between the lengths of the radius and ulna (see also point 1 above).

(3) Although *nerve lesions* (i.e. to the median or ulnar nerve) are not particularly common in fractures of the distal radius, their presence has a serious effect on the end result. Here, too, an early diagnosis with adequate therapy may improve the prognosis.

(4) The *shoulder-hand-finger syndrome* has been practically eliminated with the therapy reported here. Consequently, this complication was of very little importance for the end results in my series.

It can thus be demonstrated for the first time that the shoulder-hand-finger syndrome can be prevented or treated effectively by promoting vascular drainage and counteracting oedema. This in turn seems to indicate that the syndrome is elicited by circulatory disturbances and not by neurogenic factors.

GENERAL SUMMARY AND CONCLUSION

The *Introduction* presents the aims of the study.

Chapter I deals briefly with the anatomical relationships pertinent to this study.

Chapter II reviews the theories of the fracture mechanism that are most frequently discussed in the literature (the blow and counter-blow theory, the avulsion theory and the bending fracture theory). Some previous experimental fracture studies are also cited.

Chapter III deals with the biomechanical investigation, the results of which show that clinical types of distal radius fractures can be reproduced with great regularity in forearm specimens with either static or dynamic violence. The results also indicate that the type of fracture produced depends on (*a*) the position of the wrist, (*b*) the direction of the violence, and (*c*) the degree of the violence.

The analysis of the course of the experiments and the types of fracture produced tends to support a suggested combined fracture mechanism through a blow and counter-blow and bending.

Chapter IV is concerned with the principles behind the systems used in the literature for classifying these fractures. The system used in my series is presented. The main distinction is between extra-articular and intra-articular fractures. The presence of a fracture in the distal ulna is also taken into account. Intra-articular fractures are sub-divided by involvement of the radiocarpal joint, the distal radio-ulnar joint or both these joints simultaneously. The complete classification comprises eight types of fracture (I–VIII).

Chapter V presents the follow-up series, which was derived from a consecutive series of 516 cases of dislocated and undislocated fractures. The follow-up series comprises 430 cases.

The distribution of the follow-up series by sex and age corresponds to that of other published series. On the other hand, my series appears to have a considerably larger proportion of intra-articular types of fractures. Differences of classification and assessment seem to provide a reasonable explanation for this discrepancy.

Chapter VI gives an account of the treatment employed in the follow-up cases. The only respects in which my series deviates from current principles are that slings and passive traction were prohibited, active shoulder and finger exercises being instituted immediately instead. These changes markedly reduced the incidence of the shoulder-hand-finger syndrome (possibly synonymous with Sudeck's atrophy) in my series, besides leading to a much reduced need for physiotherapy.

Chapter VII describes the examination techniques employed in the follow-up study. When collecting anamnestic data, particular attention was paid to the possible presence of neurological symptoms. The clinical examination was conducted along pre-determined lines and included an assessment of the appearance of the wrist, the degree of impaired mobility and loss of strength. A special technique was used to test the function of the distal radio-ulnar joint. A neurological examination of the injured hand, including a ninhydrin test, was undertaken in every case. Cases with signs of dysfunction of the median or ulnar nerves were further tested for tactile gnosis with the two-point discrimination test and the picking-up test.

A final roentgenological assessment was possible for a limited part of the series (224 cases), which proved to be representative for the total follow-up series. Residual angulation and shortening were measured from the roentgenograms. A special roentgenological technique employed in 125 of the 224 cases permitted a more exact assessment of any changes in the articular surfaces of the distal radio-ulnar joint.

Chapter VIII presents the results of the follow-up examination. Subjective symptoms were reported in 52.3% of the cases, the most frequent complaint being weakness in the hand and wrist.

The *anatomical end result*, assessed on the basis of the degree of angulation and shortening determined roentgenologically, was classified as excellent in 25% of the series, whereas 38% had an excellent *cosmetic end result*, denoting the degree of radial deviation and prominence of the caput ulnae. This discrepancy is a reflection of the circumstance that even a relatively marked skeletal deformity does not always affect the outward appearance of the wrist.

Some degree of *impaired mobility in the wrist* was observed in as many as 77% of the cases, being more frequent in those types of distal radius fractures that were combined with a fracture of the distal ulna. In most cases the loss of mobility had not been noticed by the patient.

Only three cases in the follow-up series had a *loss of finger mobility*; this was a residual symptom after a shoulder-hand-finger syndrome in all three cases.

A *loss of strength* in the injured hand was found in 24% of the cases, the leading hand being particularly prone in this respect. A functional disturbance in the distal radio-ulnar joint seemed to increase the incidence of loss of strength, as did an intra-articular compared with an extra-articular fracture. Most of the patients had themselves noticed the loss of strength.

The series included 11 cases with *neurological disturbances*. The median nerve was affected in eight cases, the ulnar nerve in three. All eleven cases also had subjective neurological symptoms.

In three cases there was *injury to the extensor pollicis longus tendon*.

Signs of *injury to the distal radio-ulnar joint* were detected in 80 cases (18.6%), all of which had various kinds of subjective symptoms.

The techniques reported here can thus objectively locate a considerable proportion of the symptoms directly to the distal radio-ulnar joint. These symptoms not infrequently dominate the individual case. In this way it has been shown that a fair number of cases can be ascribed to a group that will respond to treatment. I intend to return to this question in a future publication.

Chapter IX reports the criteria for an evaluation of the end results, based upon the findings from the follow-up study. Previous systems are discussed, particularly that used by Lidström (1959), which after certain modifications was also employed for assessing the end results in my series (see p. 75). The results are thus assessed from an evaluation of subjective symptoms as well as objective findings. Compared with Lidström, however, I have paid more attention to the presence of impaired loss of mobility and loss of strength.

The functional end results are classified under four headings: *excellent*, *good*, *fair* and *poor*.

Chapter X contains a discussion of the functional end results in my series. These were: Excellent, 105 cases (24%); Good, 218 cases (51%); Fair, 81 cases (19%); Poor, 26 cases (6%).

It is pointed out that, even though the proportion of poor functional results in my series is not particularly large, the well-known frequency of distal radius fractures means that a large number of individuals annually are liable to suffer permanent disability as a result of this injury.

Chapter IX is concerned with the clinical analysis of my series. Factors are considered which may be particularly relevant for the functional end result. A distinction is made between "general factors" (age, sex, type of fracture, fracture of the distal ulna, anatomical end result, i.e. angulation and shortening, and the interval between the accident and the follow-up examination) and "special factors" (injuries to the distal radio-ulnar joint, nerve injuries, shoulder-hand-finger syndrome and rupture of the extensor pollicis longus tendon).

The clinical analysis of the influence of these factors on the functional end result produced the following findings:

(1) Type of fracture is correlated with the end result, which is worse for intra-articular than for extra-articular fractures. The prognosis is particularly adversely affected by involvement of the distal radio-ulnar joint in the fracture.

(2) A simultaneous fracture in the distal ulna involves some deterioration in the functional end results of distal radius fractures.

(3) Of the two forms of roentgenologically determined deformity in the radius, shortening seems to have a more deleterious effect than angulation on the functional end result.

(4) The age factor shows only a very weak correlation with the functional end results.

(5) Neither the sex factor nor the interval in the present series between the accident and the follow-up examination appear to have any demonstrable effect on the end results.

(6) Injury to the distal radio-ulnar joint (including an intra-articular fracture here) leads to a deterioration in the functional end result.

(7) Residual conditions after a shoulder-hand-finger syndrome and unoperated rupture of the extensor pollicis longus tendon involve an impaired functional end result.

(8) The functional end results were unsatisfactory in the cases with nerve lesions in my series. These lesions appear to be a contributory factor but there were only two cases out of eleven in which the nerve lesion was solely responsible for the poor end result.

Interactions naturally exist between these factors. The validity of the conclusions from the clinical analysis was further tested by means of a statistical analysis of the individual factors.

Chapter XII presents the results from this statistical analysis, which took the form of a multiple regression analysis. This showed that, of the "general factors", age, type of fracture and shortening had a significant effect on the functional end results, whereas sex, fracture of the distal ulna, angulation and the interval between the accident and the follow-up examination did not significantly affect the end results.

Of the "special factors", injuries to the distal radio-ulnar joint, nerve injuries and shoulder-hand-finger syndrome were shown by the statistical analysis to have a significant effect on the end result.

Chapter XIII briefly reviews certain clinical aspects of the end results for the groups of cases having *fractures with volar displacement*, *fissure fractures*, and *fractures with open reduction*, together with *a comparison between the reduced and unreduced fractures*. No good reason was found for considering these groups of cases separately in other parts of this thesis.

General conclusion

Distal radius fractures can be reproduced in biomechanical experiments, provided the wrist is arranged within certain limits of dorsal or volar flexion.

The fracture's intra-articular involvement, particularly in the distal radio-ulnar joint, is of considerable importance and elicits both subjective and objective late symptoms from this joint in a large proportion of cases. The diagnosis of disturbance in the distal radio-ulnar joint makes it possible to introduce adequate therapy.

Shortening of the radius also has a considerable adverse effect on the end result. Here too, a disturbance in the distal radio-ulnar joint appears to dominate the symptoms.

Nerve lesions after fractures of the distal radius are not particularly common but, when present, their effect is considerable.

The shoulder-hand-finger syndrome—which leads to very poor end results when not treated adequately—can be prevented and treated with active exercises and by avoiding the use of immobilization with a sling. This strongly indicates that the shoulder-hand-finger syndrome is a sign of circulatory insufficiency, a theory which had previously been assumed but not to my knowledge proved.

ACKNOWLEDGEMENTS

The clinical investigation in this study was made at the Department of Bone and Joint Surgery and the biomechanical investigation at the Department of Orthopaedic Surgery of the University of Gothenburg.

I am extremely grateful to all those who have helped and encouraged me during the course of this study. For valuable guidance and stimulating discussions I am especially thankful to my present chief, Professor Erik Moberg, M.D., and to Professor Carl Hirsch, M.D. Docent Sven Scheller, M.D., has helped me with the special roentgenological examinations and their interpretation, besides discussing the roentgenological aspects of the series as a whole. Docent Svante Edshage, M.D., has provided much valuable advice and criticism. Fil. lic. Esbjörn Carlström undertook the statistical appraisal of the results of the study. Civ.ing. Bo Sörensson provided technical support in the dynamic biochemical experiments.

I have received financial support from the Faculty of Medicine at Gothenburg University.

Gösta Frykman

Göteborg, October 1967.

REFERENCES

Abbot, L. C. & Saunders, J. B. de C. M.: Injuries of the median nerve in fractures of the lower end of the radius. Surg. Gynec. Obstet. 57: 507, 1933.

Albert, S. M., Wohl, M. A. & Rechtman, A. M.: Treatment of the disruptured radio-ulnar joint. J. Bone Jt Surg. 45 A: 1373, 1963.

Alffram, P.-A. & Bauer, G. C. H.: Epidemiology of fractures of the forearm. A biomechanical investigation of bone strength. J. Bone Jt Surg. 44 A: 105, 1962.

Arbeitlang, E. & Boeckl, O.: Kritische Bemerkungen zur distalen Radiusfraktur. Arch. orthop. Unfall-Chir. 55: 1, 1963.

Aronson, H.: Ett bidrag till kännedom om den s.k. efterrupturen av tummens långa sträcksena efter handledstrauma. Nord. Med. 2: 1985, 1939.

Bache, I. F.: Posttraumatisk ruptur af extensor pollicis longus-senen; en oversigt og tre tilfaelde. Ugeskr. Laeg. 121: 793, 1959.

Bacorn, R. W. & Kurtzke, J. F.: Colles' fracture. A study of two thousands cases from the New York State Workmen's Compensation Board. J. Bone Jt Surg. 35 A: 643, 1953.

Bähr, F.: Die typische Radiusfraktur und ihre Entstehung. Zbl. Chir. 21: 841, 1894.

Baitsch, R. & Heller, H. R.: Speichenbruch an der typischen Stelle und Sudeckses Syndrom. Münch. med. Wschr. 101: 665, 1959.

Bange, F.: Die Behandlung der typischen Radiusfrakturen in der Zeit von 1907–21. Arch. klin. Chir. 118: 578, 1921.

Bankart, A. S. B.: The treatment of Colles' fracture. Brit. med. J. 1: 491, 1929.

Beasley, R. W.: Shoulder-hand syndrome. N. Y. St. J. Med. 64: 1717, 1964.

Bertelsen, A., quoted by Zachariae, L.: Posttraumatisk reflexdystrofi. Lecture at Centralized Postgraduate Course 1958.

Bessot, M. & Masse, P.: Les syndromes post-traumatiques du canal carpien. Ann. Méd. Nancy. 3: 1304, 1964.

Bette, H.: Über die traumatische Luxation im distalen Radioulnar-gelenk. Z. Orthop. 89: 497, 1957.

Birch-Jensen, A.: Uncomplicated luxation of the distal radio-ulnar joint. Acta chir. scand. 101: 312, 1951.

Björkroth, T.: Bidrag till kännedom om den posttraumatiska spontanrupturen av tummens långa sena. Nord. Med. 12: 3022, 1941.

Bläckberg, B. & Fex, J.: Syndrome of median nerve compression in the carpal tunnel. Acta orthop. scand. 26: 120, 1956.

Blaimont, P., Buchin, R., Geens, M. & Kinnaert, P.: La résection de l'extrémité distale du cubitus dans les séquelles des fractures de l'avant-bras et du poignet. Acta orthop. belg. 29: 641, 1963.

Blecher, S.: Die Schädigung des Nervus medianus als Komplikation des typischen Radiusbruches. Dtsch. Z. Chir. 93: 34, 1908.

Böhler, L.: Die funktionelle Bewegungsbehandlung der "typischen" Radiusbrüche auf anatomischer und physiologischer Grundlage. Münch. med. Wschr. 66: 1185, 1919.

— Die funktionelle Bewegungsbehandlung der "typischen" Radiusbrüche. Münch. med. Wschr. 70: 387, 1923.

— Technik der Knochenbehandlung. 6. Aufl. Wilh. Maudrich, Wien 1938.

Boutin, P.: Fractures graves de l'extrémité inférieure du radius. Rev. Chir. orthop. 46: 251, 1960.

Brady, L. P.: Double pin fixation of severely comminuted fractures of the distal radius and ulna. Sth. med. J. 56: 307, 1963.

Brahme, L.: A new constructed energodynamometer and its clinical use. Acta med. scand. 89: 268, 1936.

Broman, I.: Människokroppen del I. Gleerups förlag, Lund 1934.

Calberg, G., Delmotte, S., Stehman, M. & van Gaver, P.: Rupture du tendon long extenseur du pouce après fracture du poignet. Acta orthop. belg. 27: 493, 1961.

Cannon, B. W. & Love, J. G.: Tardy median palsy; median neuritis; median thenar neuritis amenable to surgery. Surgery 20: 210, 1946.

Cassebaum, W. H.: Colles' fracture. A study of end-results. J. Amer. med. Ass. 143: 963, 1950.

Cave, E. F. & Roberts, S. M.: A method for measuring and recording joint function. J. Bone Jt Surg. 18: 455, 1936.

Chandler, F. A.: Fractures of the distal end of radius. J. Iowa St. med. Soc. 11: 518, 1950.

Cobe, H. M.: The range of active motion at the wrist of white adults. J. Bone Jt. Surg. 10: 763, 1928.

Cochrane, W. A.: Colles' fracture. Brit. med. J. 1: 477, 1929.

Codman, E. A.: The shoulder. The author, Boston 1934.

Colles, A.: On the fracture of the carpal extremity of the radius. Edinb. med. J. 10: 182, 1813.

Cornell, N. W.: Fractures of the base of the radius in adults. Arch. Surg. 31: 897, 1935.

Cotton, F. J.: Fracture of lower end of radius. Ann. Surg. 32: 194 and 388, 1900.

— Wrist fractures; disabilities following restorative operations. Trans. Amer. surg. Ass. 11: 289, 1922.

Cox, F. J. & Meyer, A. W.: Treatment of difficult and involved Colles' fracture. Calif. Med. 74: 81, 1951.

Cunningham's Anatomy Ed. by Brash, J. C. & Jamieson, E. B. 8. Ed. Oxford University Press, London 1943.

Darrach, W.: Partial excision of lower shaft of ulna for deformity following Colles' fracture. Ann. Surg. 17: 764, 1913.

— Fractures of the lower extremity of the radius. Diagnosis and treatment. J. Amer. med. Ass. 89: 1683, 1927.

Davidsson, L.: Über die subkutanen Sehnenrupturen und die Regeneration der Sehne; eine experimentelle, klinische und pathologisch-anatomische Untersuchung. Ann. Chir. Gynaec. Fenn. Suppl. 6, 1956.

De Palma, A. F.: Comminuted fractures of the distal end of the radius treated by ulnar pinning. J. Bone Jt Surg. 34 A: 651, 1952.

De Rouville, G.: Section du nerf radial: Suture secondaire et guérison. Bull. Soc. Chirurgie Paris. 31: 1046, 1905.

Destot, E. & Gallois, E.: Recherches physiologiques et expérimentales sur les fractures de l'extrémité inférieure du radius (radiographie). Rev. Chir. (Paris) 18: 886, 1898.

Destot, E., quoted by Platt, H.: Traumatisme du poignet et rayons. Paris 1923.
de Takats, G.: Reflex dystrophy of the extremities. Arch. Surg. 34: 938, 1937.
de Takats, G. & Miller, D. S.: Post-traumatic dystrophy of the extremities. Arch. Surg. 46: 469, 1943.
Dickson, F. D.: Peripheral nerve injuries associated with fractures of the long bones. Sth. med. J. 19: 37, 1926.
Djorup, F.: Fractura extremitatis inferioris radii. Nord. Med. 67: 685, 1962.
Dowling, J. J. & Sawyer, B., Jr.: Comminuted Colles' fractures. Evaluation of a method of treatment. J. Bone Jt Surg. 43 A: 657, 1961.
Drill, F. E.: Complication with undisplaced Colles' fracture. Minn. Med. 47: 819, 1964.
Dupuytren, G.: Des fractures de l'extrémité inférieure du radius simulant les luxations du poignet. Leçons orales de clinique chirurgicale. 1: 140, Paris 1839.
Edwards, H. & Clayton, E. B.: Fractures of the lower end of the radius in adults. Brit. med. J. 1: 61, 1929.
— Colles' fracture. Brit. med. J. 1: 523, 1929.
Edwards, P.: Internal fracture fixation with Rush's pin. Experiences of a series of 116 cases. Acta chir. scand. 117: 480, 1959.
Ehalt, W.: Beitrag zur Behandlung der Vorderarmbrüche. Chirurg. 3: 1050, 1931.
— Die Bruchformen am unteren Ende der Speiche und Elle. Arch. orthop. Unfall-Chir. 35: 397, 1935.
— Behandlungsergebnisse der Brüche am unteren Speichenende. Arch. orthop. Unfall-Chir. 35: 443, 1935.
Eldridge, L. E.: An operation for recurrent inferior radio-ulnar dislocation. Ann. Surg. 156: 27, 1932.
Eskelund, V.: Fractura extremitatis inferioris radii (Collesii) og dens behandling. Ugeskr. Laeg. 89: 249, 1927.
Fagge, C. H.: Colles' fracture. Brit. med. J. 1: 705, 1929.
Friedman, H. H., Argyros, T. G. & Steinbrocker, O.: Neurovascular syndromes of the shoulder girdle and upper extremity—the compression disorders and the shoulder-hand syndrome. Postgrad. med. J. 35: 397, 1959.
Frykman, G. & Scheller, S.: Tidiga och sena komplikationer till distala radiusfrakturer. Nord. Med. 67: 495, 1962.
— Distal radio-ulnar joint symptoms—common sequelae after fracture of the radius. Acta chir. scand. 125: 524, 1963.
Gambier, R. & Venturini, G.: Fratture di Colles. Rilieri statistici e resultati a distanza. G. veneto Sci. med. 19: 175, 1964.
Gartland, J. J., Jr. & Werley, Ch. W.: Evaluation of healed Colles' fractures. J. Bone Jt. Surg. 33 A: 895, 1951.
Geckeler, E. O.: Treatment of comminuted Colles' fractures. J. int. Coll. Surg. 20: 596, 1953.
Gensoul, J. G., quoted by Lynch, A. C. & Lipscomb, P. R.: Observation et réflexions sur une complication grave des fractures. Arch. gén. Méd. 41: 198, 1836.
Ghormley, R. K. & Mroz, R. J.: Fractures of the wrist. Surg. Gynec. Obstet. 15: 377, 1932.
Glock, W. R., Mackel, F. O. & Brown, F. W.: Colles' fracture. J. Indiana med. Ass. 50: 43, 1957.
Golden, G. N.: Treatment and prognosis of Colles' fracture. Lancet 7280: 511, 1963.
Graham, H. F.: An efficient method for the reduction and immobilisation of Colles' fracture. Ann. Surg. 108: 156, 1938.

Grasby, E. D. & Trick, S. R.: An investigation of the end results of Colles' fracture. Brit. med.J. 1: 391, 1929.

Grath, G. B.: A new appliance for extension in reducing fractures of the lower leg and foot. Acta chir. scand. 111: 80, 1956.

Guillermo, J.: Le fibro-cartilage de l'articulation radio-cubitale inférieure chez l'adulte. Rev. Chir. orthop. 25: 125, 1938.

Gurd, F. B.: The Colles-Pouteau fracture of the lower end of the radius. Amer. J. Surg. 38: 526, 1937.

Guttman, A. P.: Treatment of Colles' fracture. J. int. Coll. Surg. 31: 341, 1959.

Haglund, P.: Zur Frage von der typischen Radiusfraktur am Handgelenk und ihrer Behandlung. Nord. med. Ark. 46: 1, 1913.

Haldbo, H.: Posttraumatisk extremitetsdystrofi (reflexdystrofi). Thesis. Munksgaard, København 1942.

Hammond, G.: Comminuted Colles' fracture. Amer. J. Surg. 78: 617, 1949.

Hamsa, W. R.: Treatment of Colles' fracture. Neb. St. med. J. 47: 573, 1962.

Hansen, P. N.: Discussion. Dansk kir. Selskabs forhandlinger. 27: 44, 1926.

Haymaker, W. & Woodhall, B.: Peripheral nerve injuries—principles of diagnosis. 2. Ed. W. B. Saunders Co., Philadelphia & London 1953.

Heineke, D.: Spontanruptur der Sehne des langen Daumenstreckers. Münch. med. Wschr. 40: 560, 1913.

Henschen, C.: Die Operation der Luxatio Ulnae im unteren Radioulnar-gelenk. Schweiz. med. Wschr. 68: 466, 1938.

Hilgenfeldt, O.: Vorschläge zur Behandlung des typischen Speichenbruches. Zbl. Chir. 75: 709, 1950.

Hirsch, C.: Method of stabilizing autopsy specimens in biomechanical experiments. Acta orthop. scand. 34: 374, 1964.

Hirsch, C. & Frankel, V. H.: Analysis of forces producing fractures of the proximal end of the femur. J. Bone Jt Surg. 42 B: 633, 1960.

Hirsch, C. & Lewis, J.: Experimental ankle-joint fractures. Acta orthop. scand. 36: 408, 1965.

Hirsch, G. & Sullivan, L.: Experimental knee-joint fractures. A preliminary report. Acta orthop. scand. 36: 391, 1965.

Hirsch, M.: Die Verletzungen der Handwurzel. Ergebn. Chir. Orthop. 8: 718, 1914.

Hitzrot, J. M. & Murray, C. R.: The factors that influence the prognosis in fractures at the base of the radius. Amer. J. Surg. 35: 17, 1921.

Hobart, M. H. & Kraft, G. L.: Malunited Colles' fracture. Amer. J. Surg. 53: 55, 1941.

Hoffman, B. P.: Fractures of the distal end of the radius in the adult and in the child. Bull. Hosp. Jt Dis. (N. Y.) 14: 114, 1953.

Hölund, T.: Behandling af fractura Collesi hos aeldre. Ugeskr. Laeg. 119: 187, 1957.

Hönigschmied, J.: Leichenexperimente über die Zerreissungen der Bänder in Handgelenk. Dtsch. Z. Chir. 10: 462, 1878.

Hult, L.: Ulnariskompression såsom komplikation vid typisk radiusfraktur. Nord. Med. 72: 1403, 1964.

Hultén, O.: Über anatomische Variationen der Handgelenkknochen. Ein Beitrag zur Kenntnis der Genese zwei verschiedener Mondbeinveränderungen. Acta radiol. 9: 155, 1928.

Humphries, S. V.: Severe Colles' fractures. Report on seven cases. Clin. Proc. 7: 339, 1948.

Hyman, G. & Martin, F. R. R.: Dislocation of the inferior radio-ulnar joint as a complication of fracture of the radius. Brit. J. Surg. 27: 481, 1939–40.
Jones, R.: Injuries to joints. Frowde, Hodder & Stoughton, London 1915.
Jung, J. & Heineman, G.: Zur Fixation dislocierter Frakturen des distalen Radius. Zbl. Chir. 86: 809, 1961.
Kahleyss, M.: Beitrag zur Kenntniss der Frakturen am unteren Ende des Radius. Dtsch. Z. Chir. 45: 531, 1897.
Kane, A. A.: Colles' fracture. West. Med. 5: 124, 1964.
Kenney, W. E.: Important details in the management of fractures of the distal radius. Conn. Med. 24: 324, 1960.
Key, J. A.: Colles' fracture. Surgery 36: 998, 1954.
Kirchheim, G. W. T.: Über Verletzungen des N. medianus bei Fractura radii an klassischer Stelle. Thesis. Friedrich-Wilhelm Universität, Berlin 1910.
Kleinschmidt, K.: Versuche zur Erklärung der Spätruptur der langen Daumenstrecksehne nach Radiusfraktur. Bruns' Beitr. klin. Chir. 146: 530, 1929.
Knapp, M. E.: Treatment of some complications of Colles' fracture. J. Amer. med. Ass. 148: 825, 1952.
Kotrnetz, H. & Geiringer, F.: Speichenbrüche des Erwachsenen an typischer Stelle. Arch. orthop. Unfall-Chir. 37: 504, 1937.
Krantz, W.: Über die Behandlung des typischen Radiusbruches. Dtsch. Z. Chir. 106: 270, 1910.
Kudelka, P.: On the treatment of Colles' fracture. Med. J. Aust. 1: 616, 1963.
Lambrinudi, C.: Injuries to the wrist. Guy's Hosp. Gazette 52: 107, 1938.
Lang, F.: Das distale Radioulnar-gelenk. Seine Bedeutung in der Unfallmedicin. Mschr. Unfallheilk. 36: 1, 1942.
von Lanz, T. & Wachsmuth, W.: Praktische Anatomie I. 1. Aufl. 1935, 2. Aufl. 1959. Jul. Springer, Berlin.
Lasserre, J.: Compression tardive du nerf cubital au-dessus de canal carpien, complication d'une fracture de l'extrémité inférieure du radius avec subluxation palmaire de la tête du cubitus. Bordeaux Chir. 4: 179, 1963.
Le Breton, P.: Arthritis of the joints of the hand following Colles' fracture. Surg. Gynec. Obstet. 20: 450, 1915.
Lecomte, O.: Recherches nouvelles sur les fractures de l'extrémité inférieure du radius. Arch. gén. Méd. 5: 641, 1860–61.
Leriche, R. & Fontaine, R.: Des osteoporoses douloureuses post-traumatiques. Presse méd. 38: 617, 1930.
von Lesser, L.: Zur Behandlung fehlerhaft geheilter Brüche der karpalen Radiusepiphyse. Zbl. Chir. 14: 265, 1887.
Lewis, D. & Miller, E. M.: Peripheral nerve injuries associated with fractures. Trans. Amer. surg. Ass. 40: 489, 1922.
Lewis, R. M.: Colles' fracture—causative mechanism. Surgery 27: 427, 1950.
Lidström, A.: Fractures of the distal end of the radius.—A clinical and statistical study of end results. Acta orthop. scand. Suppl. 41, 1959.
Lilienfeld, A.: Über den klassischen Radiusbruch. Arch. klin. Chir. 82: 166, 1907.
— Über die Erzeugung der typischen Verletzungen der Handwurzelknochen und des Radiusbruches auf indirektem Wege an der Leiche und ihre Entstehungsart, erläutert durch den Mechanismus der Handgelenkbewegungen. Z. orthop. Chir. 20: 437, 1908.
von Linhart, W., quoted by Rotter, H.: Die Brüche der unteren Epiphyse des Radius durch Gegenstoss. Z. Gesellsch. Ärzte Wien, 1852.

Lippman, R. K.: Laxity of the radio-ulnar joint following Colles' fracture. Arch. Surg. 35: 772, 1937.
Lipschutz, B.: Late subcutaneus rupture of the tendon of the extensor pollicis longus muscle. Arch. Surg. 31: 816, 1935.
Löbker, K.: "Sitzung des medicinischen Vereins zu Greifswald". Dtsch. med. Wschr. 27: 475, 1885.
Lorento de No, R.: Analysis of the activity in the chains of internuncial neurons. J. Neurophysiol. 1: 207, 1938.
Love, J. G.: Median neuritis; carpal tunnel syndrome: Diagnosis and treatment. N.C. med. J. 16: 463, 1955.
Lucas-Champonniere, J.: Traitement des fractures du radius et du péroné par le massage; traitement des fractures paraarticulaires simples et compliquées de plaie sans immobilisation; mobilisation et massage. Bull. Soc. Chirurgie Paris, 12: 560, 1886.
Lynch, A. C. & Lipscomb, P. R.: The carpal tunnel syndrome and Colles' fracture. J. Amer. med. Ass. 185: 363, 1963.
MacAusland, R.: Colles' fracture. Amer. J. Surg. 36: 320, 1937.
Mack, G. J.: Colles' fracture in the service-age patient. Med. Serv. J. Can. 15: 667, 1959.
Madsen, E.: Behandling av fractura radii. Nord. Med. 41: 1134, 1949.
Madsen, K. P.: Colles' fracture. J. Amer. Osteopath. Ass. 58: 484, 1959.
Magnus, G.: Indikationen und Kontraindikationen in der Frakturbehandlung. Arch. klin. Chir. 177: 274, 1933.
Malgaigne, J. F.: Traité des fractures et des luxations. T. 1: 603, Paris 1847.
Mandell, B. B.: Assessment of the results of treatment of 100 cases of Colles' fracture. S. Afr. med. J. 39: 171, 1965.
Manges, L. C., Jr.: Fractures of the lower end of the radius (Colles). Surg. Clin. N. Amer. 20: 1683, 1941.
Mannerfelt, L.: Studies on the hand in ulnar nerve paralysis. A clinical-experimental investigation in normal and anomalous innervation. Acta orthop. scand. Suppl. 87, Munksgaard, Copenhagen 1966.
Manzotti, G. F.: Sindrome compressiva del nervo mediano nel canale carpale in fratture di Colles malconsolidate. Minerva ortop. 15: 351, 1964.
Marthaler, P.: Das distale radio-ulnare Schlottergelenk und seine operative Behandlung. Z. Unfallmed. Berufskr. 52: 311, 1959.
Mason, M. L.: Colles' fracture. A survey of end-results. Brit. J. Surg. 15: 340, 1953.
— The management of Colles' fracture. Med. ill. (Lond.). 8: 837, 1954.
Mayer, J. H.: Colles' fracture. Brit. J. Surg. 27: 629, 1940.
Mayfield, F. H. & Newquist, R. E.: The shoulder-hand syndrome. Ohio St. med. J. 56: 63, 1959.
Meadoff, N.: Median nerve injuries in fractures in the region of the wrist. Calif. Med. 70: 252, 1949.
Mendelaar, H. M.: Post-traumatic ruptures of the tendon of the musculus extensor pollicis longus. Arch. Chir. Neerl. 12: 146, 1960.
Meyer, H.: Der klassische Speichenbruch. Klin. Wschr. 4: 554, 1925.
Milch, H.: So-called dislocation of the lower end of the ulna. Ann. Surg. 116: 282, 1942.
— Colles' fracture. Bull. Hosp. Jt Dis. (N.Y.). 11: 61, 1950.
— Treatment of disabilities following fracture of the lower end of the radius. Clin. Orthop. 29: 157, 1963.
— Torsional malalignments in transverse fractures of the lower end of the radius. Surgery 55: 396, 1964.

Miller, H. I. & Miller, G. F.: Post-traumatic reflex dystrophies. Amer. J. Surg. 79: 814, 1950.

Miller, W. E.: Colles' fracture. Sth. med. J. 53: 1382, 1960.

Mitchell, A. Ph.: Recurrent anterior dislocation of the lower end of the ulna complicated by ununited fracture of the styloid process of the ulna. Brit. J. Surg. 9: 555, 1922.

Mitchell, S. W., Morehouse, G. R. & Keen, W. W., quoted by Thompson, M.: Gunshot wounds and other injuries of nerves. J. B. Lippingcott Co., Philadelphia 1864.

Moberg, E.: Surgery of the hand. Trans. Nth. surg. Ass. 25. meet., p. 33. Munksgaard, Copenhagen 1951.

— Övre extremitetens kirurgiska sjukdomar. Nordisk laerebog i Kirurgi, Munksgaard, København 1955.

— The shoulder-hand-finger syndrome as a whole. Acta chir. scand. 109: 284, 1955.

— Objective methods for determining the functional value of sensibility in the hand. J. Bone Jt Surg. 40 B: 454, 1958.

— Underarm och hand. Nordisk lärobok i ortopedi. Svenska Bokförlaget, Stockholm 1959.

— The shoulder-hand-finger syndrome. Surg. Clin. N. Amer. 40: 367, 1960.

— Shoulder-hand-finger syndrome, reflex dystrophy, causalgia. Acta chir. scand. 125: 523, 1963.

Mumenthaler, M.: Die Ulnarisparesen. G. Thieme, Stuttgart 1961.

Nélaton, A.: Eléments de pathologie chirurgicale. T. 1: 739, 1844.

Newman, P. H.: Median nerve compression in the carpal tunnel. Postgrad. med. J. 24: 264, 1948.

Nissen-Lie, H. S.: Fractura radii "typica". Nord. Med. 1: 293, 1939.

Older, T. M., Stabler, E. V. & Cassebaum, W. H.: Colles' fracture: Evaluation and selection of therapy. J. Trauma. 5: 469, 1965.

Önne, L. & Sandblom, Ph.: Late results in fractures of the forearm in children. Acta chir. scand. 98: 549, 1949.

Paget, J., quoted by Sponsel, K. H. & Palm, E. T.: Lectures on surgical pathology, p. 42. Lindsay & Blakiston, Philadelphia 1854.

Patrick, J.: A study of supination and pronation with especial reference to the treatment of forearm fractures. J. Bone Jt Surg. 28: 737, 1946.

Petersen, F.: Zur Behandlung der typischen Radiusbruches. Arch. klin. Chir. 84: 708, 1894.

Pickard, N.: Colles' fractures. J. Mo. med. Ass. 44: 258, 1927.

Pilcher, L. S.: Fractures of the lower extremity or base of the radius. Ann. Surg. 65: 1, 1917.

Platt, H.: Colles' fracture. Brit. med. J. 2: 288, 1932.

Poulsen, Kr.: Studien über die sogenannte typische Fraktur des Radius. Arch. klin. Chir. 80: 902, 1906.

Raschle, R.: Unsere Erfahrungen in der Behandlung der Radiusfrakturen. Z. Unfallmed. Berufskr. 58: 113, 1965.

Reeves, B.: Excision of the ulnar styloid fragment after Colles' fracture. Int. J. Surg. 45: 46, 1966.

Rehn, J.: Behandlungsergebnisse typischer Radiusfrakturen. Chirurg. 36: 206, 1965.

Robbins, H.: Anatomical study of the median nerve in the carpal tunnel and etiologies of the carpal-tunnel syndrome. J. Bone Jt Surg. 45 A: 953, 1963.

Robbins, J. V.: Logical reduction of displaced Colles' fracture. N.Y. St. J. Med. 50: 2959, 1950.

Roberts, J. B.: A clinical, pathological and experimental study of fracture of the lower end of the radius with displacement of the carpal fragment toward the flexor or anterior surface of the wrist. Amer. J. med. Sci. 113: 10, 1897.

Rogers, S. C.: An analysis of Colles' fracture. Brit. med. J. 1: 807, 1944.

Rosen, E.: Fractura extremitatis distalis radii. Ugeskr. Laeg. 109: 603, 1947.

Rosenbach, J.: Über den Bruch des Radius am unteren Ende. Arch. klin. Chir. 66: 993, 1902.

Rotter, H.: Über Frakturen des Radius am unteren Ende. Dtsch. Z. Chir. 156: 235, 1920.

Rush, L. V. & Rush, H. L.: Evolution of medullary fixation of fractures by longitudinal pin. Amer. J. Surg. 78: 324, 1949.

Saikku, L. A.: Treatment of severe distal fractures of the radius by traction. Ann. Chir. Gynaec. Fenn. 42: 83, 1953.

Schinz, H. R.: Abbruch der proc. styl. ulnae. Dtsch. Z. Chir. 175: 81, 1922.

Schlesinger, E. B. & Leas, H. R.: Fundamentals, fads and fallacies in carpal tunnel syndrome. Amer. J. Surg. 97: 466, 1959.

Schnek, F.: Die Bedeutung der Subluxation im distalen Radioulnar-gelenk für die Behandlung des Speichenbruches. Dtsch. Z. Chir. 216: 351, 1929.

Schnek, M.: Long-term follow-up of the treatment of comminuted fractures of the distal radius by transfixation with Kirschner-wire and cast. J. Bone Jt Surg. 44 A: 337, 1962.

Schwetlick, W.: Wesentliches zur Behandlung von typischen Speichenbrüchen. Mschr. Unfallheilk. 65: 110, 1962.

Scott, I. H.: Comminuted Colles' fractures: Their treatment by skeletal pinning and external fixation. J. int. Coll. Surg. 41: 521, 1964.

Sirbu, A. B. & Collof, B.: Colles' fracture. A study of end results with conservative management. West. J. Surg. 59: 635, 1951.

Sisefsky, M.: Skada på N. medianus i samband med fraktur i distala radiusändan. Nord. Med. 44: 1208, 1950.

Smaill, G. B.: Long-term follow-up of Colles' fracture. J. Bone Jt Surg. 47 B: 80, 1965.

Soren, A.: Treatment of Colles' fracture. Med. Tms. (Lond.). 93: 1283, 1965.

Sponsel, K. H.: Colles' fracture. Minn. Med. 47: 55 and 175, 1964.

Sponsel, K. H. & Palm, E. T.: Carpal tunnel syndrome following Colles' fracture. Surg. Gynec. Obstet. 121: 1252, 1965.

Stein, A. H.: The relation of median nerve compression to Sudeck's syndrome. Surg. Gynec. Obstet. 115: 713, 1962.

Steinbrocker, O. & Argyros, T. G.: The shoulder-hand syndrome: Present status as a diagnostic and therapeutic entity. Med. Clin. N. Amer. 42: 1533, 1958.

Steinbrocker, O., Spitzer, N. & Friedman, H. H.: The shoulder-hand syndrome in reflex dystrophy of the upper extremity. Ann. intern. Med. 29: 22, 1948.

Strandell, G.: Post-traumatic rupture of the extensor pollicis longus tendon—pathogenesis and treatment. Survey based on 208 cases, including 14 personal cases. Acta chir. scand. 109: 81, 1955.

Sudeck, P.: Über die akute, entzündliche Knochenatrophie. Arch. klin. Chir. 62: 147, 1900.

— Über die akute (reflektorische) Knochenatrophie nach Entzündungen und Verletzungen an den Extremitäten und ihre klinische Erscheinungen. Fortschr. Röntgenstr. 5: 277, 1901.

Taylor, G. W. & Parsons, C. L.: The role of discus articularis in Colles' fracture. J. Bone Jt Surg. 20: 149, 1938.

— Fractures of lower end of radius. Surg. Gynec. Obstet. 67: 249, 1938.

Taylor, J. G.: Sudeck's atrophy and the shoulder-hand syndrome. Proc. roy. Soc. Med. 51: 879, 1958.

Thompson, M.: Shoulder-hand syndrome. Proc. roy. Soc. Med. 54: 679, 1961.

Thon, J.: Zur Entstehungsmekanismus der Luxationen im unteren Radioulnar-gelenk. Dtsch. Z. Chir. 84: 257, 1906.

Thorén, O.: Os calcis fractures. Acta orthop. scand. Suppl. 70, 1964.

Thornton, L. & Warner, P.: The management of Colles' fracture with the Rush medullary nail. Sth. med. J. 48: 654, 1955.

van Trappen, J. B.: Étude statistique sur les fractures de l'extrémité inférieure du radius et du cubitus. Acta orthop. belg. 30: 527, 1964.

Trevor, D.: Rupture of the extensor pollicis tendon after Colles' fracture. J. Bone Jt Surg. 32 B: 370, 1950.

Turner, H.: Über Nervenschädigungen beim typischen Radiusbruch. Arch. klin. Chir. 128: 422, 1924.

Walker, D.: Colles' fracture of the radius. A method of treatment. Lancet 263: 354, 1952.

Valtonen, O.: A study of results obtained in the treatment of fractures of the lower end of the radius in insured persons in Finland. Ann. Chir. Gynaec. Fenn. 37: 287, 1948.

Watson-Jones, R.: Colles' fracture. Brit. med. J. 1: 572, 1929.

— Léri's pleonosteosis, carpal tunnel compression of the median nerve and Morton's metatarsalgia. J. Bone Jt Surg. 31 B: 560, 1949.

Waugh, T. R.: Unreduced Colles' fracture. J. Trauma. 3: 254, 1963.

Weissenbach, R.: Problèmes diagnostiques du syndrome épaule-main. Vie. méd. 45: 847, 1964.

— Traitement du syndrome épaule-main. Vie. méd. 45: 1021, 1964.

Wellmitz, G.: Die typische Radiusfraktur und das Sudecksche Syndrom. Z. Chir. 84: 150, 1959.

Whipple, G. M.: Manual of mental and physical tests. 2. Ed. Warwick & York Inc., Baltimore 1914.

White, A. W. M.: Colles' fracture. Canad. med. Ass. J. 43: 148, 1940.

Wiklund, T. & Müllern-Aspegren, J.: "Typisk radiusfraktur". Nord. Med. 56: 1411, 1956.

Willenegger, H. & Guggenbühl, A.: Zur operativen Behandlung bestimmter Fälle von distalen Radiusfrakturen. Helv. chir. Acta. 26: 81, 1959.

Witter, H.: Ruptur der Sehne des Musculus extensor pollicis longus als Komplikation von Fraktur des Radius. Bruns' Beitr. klin. Chir. 201: 448, 1960.

Zachariae, L.: Incidence and course of post-traumatic dystrophy following operation for Dupuytren's contracture. Acta chir. scand. Suppl. 336, 1964.

Zachary, R. B.: Thenar palsy due to compression of the median nerve in the carpal tunnel. Surg. Gynec. Obstet. 81: 213, 1945.

Zukschwerdt, L.: Das Sudeck-Syndrom. Arch. klin. Chir. 299: 228, 1962.

TABLES NOS. 39, 40 AND 41

TABLE 39. *Lesion of the median nerve.*

Identification	Type and side of fracture	Onset of symptoms after injury (days)	Residual neurological symptoms (subjective)	Loss of sensibility	Impairment of sudomotor function	Pathological ninhydrin test	Two point discrimination	Pick-up test	Atrophy of thenar muscles	Reduction	X-ray before reduction (Dorsal ∧)	X-ray after the end of treatment (Dorsal ∧)	Position in plaster	Other complication	Length of follow-up (months)	Functional end result	Remarks
Early cases																	
1) ♂ 40 years (42)	VI Right	16	—	—	—	—	Not done	Not done	—	+	40°	10°	Neutral	Disturbance of D.R.U.	28	Good	Voluminous volar callus formation.
2) ♀ 54 years (57)	VIII Right	44	+ Dig. I–V	Uncertain	—	—	4–5 mm. same as left	Good	—	+	25°	30°	Neutral	Disturbance of D.R.U.	40	Poor	Resection of the ulna. Volar bone prominence. Grip strength impaired.
3) ♀ 61 years (65)	IV Right	44	+	—	+	+	4 mm.	Good	+	+	25°	30°	Neutral	—	47	Fair	Volar callus formation. Loss of mobility. Fatigability in the hand.
4) ♀ 65 years (69)	V Right	35	+ Dig. II–IV	+ Dig. II–IV	+	?	10 mm.	Good	—	—	15°	10°	Neutral	Disturbance of D.R.U.	47	Fair	—
5) ♀ 67 years (70)	V Right	43	+ Dig. II–IV	+ Dig. I–IV	+	+	5–6 mm. same as left	Good	+	—	15°	Not done	Neutral	—	36	Fair	Loss of mobility.
6) ♀ 67 years (70)	VII Left	47	+ Dig. II–IV	+ Dig. II–IV	+	+	6–8 mm.	Good	—	+	0°	Not done	Neutral	—	47	Fair	Grip strength impaired.
Late cases																	
7) ♂ 63 years (65)	IV Left	> 90	+ Dig. II–III	+ Dig. I–III	+	+	6–8 mm.	Good	—	+	15°	0°	Volar flexion	S.H.F. without sequelae	18	Fair	Volar callus formation. Compound fracture.
8) ♀ 51 years (53)	VI Right	> 90	+ Dig. II–IV	+ Dig. II–IV	+	+	6–8 mm.	Good	—	—	20°	20°	Neutral	Disturbance of D.R.U.	34	Fair	Volar bone prominence. Grip strength impaired.
9) ♀ 56 years (58)	VI Left	> 90	+ Vola	+ Vola+dig. II–IV	+	?	8–10 mm.	Defect	—	+	35°	Not done	Volar flexion	—	24	Poor	Loss of mobility.
10) ♀ 60 years (64)	VI Right	> 90	+ Dig. II–III	+ Dig. II–IV	+	+	5–6 mm.	Good	+	+	25°	15°	Neutral	—	40	Fair	Re-reduced. Grip strength impaired.

+ = Yes.
— = No.
? = Not estimable.
Age in brackets refers to time of follow-up examination.
D.R.U. = Distal radio-ulnar joint.
S.H.F. = Shoulder-hand-finger syndrome.

TABLE 40. *Lesion of the ulnar nerve.*

Identification	Type and side of fracture	Onset of symptoms after injury (days)	Residual neurological symptoms (subjective)	Loss of sensibility	Impairment of sudomotor function	Pathological ninhydrin test	Two point discrimination	Pinching grip	Atrophy	Reduction	X-ray before reduction (Dorsal ∧)	X-ray after the end of treatment (Dorsal ∧)	Position in plaster	Other complication	Length of follow-up (months)	Functional end result	Remarks
Early cases																	
1) ♀ 57 years (59)	III Left	30	—	—	—	—	Not done	Good	—	—	15°	Not done	Neutral	—	26	Good	Grip strength impaired.
2) ♀ 71 years (75)	I Left	14	+ Dig. V	+ Dig. V	+	+	8 mm.	Good	—	+	15°	Not done	Neutral	—	48	Fair	
Late cases																	
3) ♀ 60 years (62)	II Left	> 90	+ Dig. V	+ Dig. IV–V	+	—	6 mm.	Good	—	+	10°	20°	Dorsal flexion	Disturbance of D.R.U.	28	Fair	Distal displacement of ulnar head (½ cm.).
4) ♀ 73 years (77)	IV Right	> 120	+ Dig. IV–V	+ Dig. IV–V	+	?	8 mm.	Good	—	+	15°	10°	Neutral	—	45	Fair	Compound fracture. Simultanous fracture of the olecranon but good function of the elbow by follow-up examination. Distal radius and ulna healed with volar displacement. Distal displacement of the ulnar head (½ cm.).

+ = Yes.
— = No.
? = Not estimable.
Age in brackets refers to time of follow-up examination.
D.R.U. = Distal radio-ulnar joint.

TABLE 41. *Shoulder-hand-finger-syndrome (S.H.F. syndrome).*

Identification	Type and side of fracture	Shoulder component	Hand-finger component	Onset of symptoms after injury (days)	Unable to work after injury (days)	Reduction and type of anaesthesia	Re-reduction (days after injury) and type of anaesthesia	Residual shoulder symptom	Residual hand-finger symptom	Organized oedema of the palm	Other complication	Functional end result	Remarks
1) ♂ 63 years	IV Left	+	+	20	77	+ Plexus	—	—	—	—	Lesion of the median nerve	Fair	Inactive. Alcoholic. Did not understand instructions.
2) ♂ 57 years	V Right	—	+	4	92	+ Local	—	—	+ (intrinsic hand)	—	Disturbance of D.R.U.	Poor	Foreigner, could not speak Swedish. Sensitive. Inactive.—Grip strength impaired.
3) ♂ 58 years	VIII Right	—	+	27	142 (100%) 443 (50%)	+ Local	—	—	+ (intrinsic hand)	—	Disturbance of D.R.U.	Poor	Inactive. Sensitive.—Grip strength extensively impaired. Early physical therapy.
4) ♀ 41 years	VI Left	+	+	28	107	+ Local	+ 6 days Plexus	—	—	+	Disturbance of D.R.U.	Poor	Grip strength extensively impaired. Loss of mobility.
5) ♀ 55 years	II Left	—	+	28	44	—	—	—	—	—	—	Good	Subjective symptoms (pain).
6) ♀ 63 years	I Left	+	+	36	113	+ Local	+ Same day Local	—	—	—	—	Good	Subjective symptoms (impaired grip strength). Treated as in-patient.
7) ♀ 64 years	IV Left	+	+	38	220	+ Local	+ Same day Local	—	+ (intrinsic hand)	—	—	Poor	Inactive. Did not understand instructions. Sensitive. Logorrhea. Extensive loss of mobility. X-ray like Sudeck's syndrome. Treated as in-patient.
8) ♀ 65 years	IV Right	+	+	26	145	+ Plexus	+ 3 days Plexus	—	—	—	—	Poor	Inactive. Grip strength extensively impaired. Loss of mobility. Treated as inpatient.-
9) ♀ 71 years	VIII Right	—	+	11	83	+ Local	—	—	—	+	Disturbance of D.R.U.	Poor	Inactive. Grip strength extensively impaired.

+ = Yes.
— = No.
D.R.U. = Distal radio-ulnar joint.