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FRACTURES OF THE DISTAL END OF THE RADIUS

A Clinical and Statistical Study of End Results

By

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Anders Lidström

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INTRODUCTION

Fractures of the distal end of the radius merit special attention for two main reasons. In the first place, as they constitute approximately 10 per cent of all fracture cases admitted for hospital treatment (Hirsch, 1914; Nissen-Lie, 1939), they are the type of fracture most commonly seen in the human skeleton and as such have great economic and social significance. A second consideration is that although this is generally considered a simple fracture and its treatment often entrusted to inexperienced surgeons, its clinical management is still subject to widely diverging opinions.

The credit for having been the first to diagnose and describe a fracture of the lower end of the radius has been divided between Pouteau (1783) and Colles (1813). While Pouteau's description was in many respects diffuse, Colles' work was distinguished by such stringency and wealth of detail that no need for additions has been felt during the nearly 150 years that have since passed. By contrast, the treatment of the fracture, the therapeutic results, and the factors influencing these results have been a subject of constant discussion for generations of fracture and orthopaedic surgeons. The controversy has been concerned with such questions as preferred method, appropriate time for reduction, and methods of fixation. Other points of discussion have been the influence of age on the final results, the importance of perfect reduction for good functional results, the incidence of posttraumatic arthritis, and the injuries to the distal radio-ulnar joint. The debate continues with undiminished vigour, and so far no generally acceptable lines of approach have been established.

The purpose of the present study has been: (1) by means of a follow-up examination to analyze a clinical series treated according to currently accepted methods; (2) on the basis of these observations to evaluate the effect of the various clinical factors on the end result using standard statistical methods.

Chapter 1

DIFFERENTIATION OF FRACTURE TYPES

Anatomy

The anatomic features of interest in a discussion of the fractures of the distal end of the radius, comprise the form and structure of the end of the bone, the joint articulations with the carpus and ulna, and the stabilizing ligaments. The tendons, vessels and nerves passing through this region, on the other hand, are only rarely involved, and a description of these structures has therefore been considered superfluous in this connection.

At its distal end the radius is expanded into an irregular square shape. It is constructed of cancellous bone covered by a cortical layer which is fairly thin everywhere and attains its minimum thickness some centimeters proximally in the metaphysis. Because the fracture passes through this predominantly cancellous bone it has in many cases, in particular in elderly people, the appearance of an impacted fracture.

The end of the radius presents two articular surfaces. The distal surface, facies articularis carpea, consists of two shallow areas articulating with the navicular and lunate bones. It shows a volar and radial deviation in relation to the long axis of the radial shaft, varying within certain limits. The incisura ulnaris, which articulates with the capitulum ulnae, consists of an area of approximately 0.5 cm^2 most distally and ulnarward on the radial epiphysis.

The capsule of both the radio-carpal and radio-ulnar joint is attached to the border of the articular surface. It is thin and slack, but is reinforced by several ligaments. The strongest of these is the lig. radiocarpeum volare, whose strongest band originates in the radial styloid process and the distal aspect of the radius; it runs distally ulnarward and inserts in the lunate, triquetrum, capitate, and hamate bones. The dorsal radio-carpal ligament, which is considerably thinner, similarly runs distally ulnarward from the distal aspect of the radius and inserts in the dorsal surface of the triquetrum bone. To these are added two collateral ligaments, one running ulnarward from the ulnar styloid process to the pisiform and triquetrum bones, and one radially from the radial styloid process to the navicular bone. The dorsal and volar carpal ligaments run in a transverse direction from the radius to the ulna and from the dorsal and volar borders to the sheaths through which the tendons of the hands and fingers pass. Among the structures that reinforce the wrist region can also be counted the pronator quadratus muscle. Whereas the distal articular surface of the radio-carpal joint is formed by the proximal row of carpal bones, the proximal articular surface does not consist exclusively of radius but is formed by the triangular disk for about $^1/_4$ of its area. This disk is inserted along the distal aspect of the incisura ulnaris and runs in fan-like converging lines ulnarwards; it is inserted in the ulna at the base of the ulnar styloid process. Schintz (1922) suggested that this insertion may vary and in exceptional cases may be found on the capitulum ulnae more radially or at the tip of the styloid process.

The radio-carpal and radio-ulnar joint cavities are often connected by a perforation of the disk adjoining the radial insertion. Lanz and Wachsmuth (1935) stated the incidence of this perforation to be about 25 per cent. The disk is subject to the same type of degenerative changes as those found in similar structures in other joints; in elderly people this may result in fissures through the degenerated tissue (Lang, 1942).

The structures which connect the capitulum ulnae with its surroundings and contribute to stabilizing the distal radio-ulnar joint are the interosseous membrane, the joint capsule, the volar and dorsal radio-ulnar ligaments, the triangular disk, the ulno-carpal ligament, the dorsal and volar carpal ligaments, and the pronator quadratus muscle.

Mechanism of Injury

Fracture of the distal end of the radius is in nearly all cases due to a fall on the outstretched hand. The mechanism of its production has in the past, and in particular during the 19th century, received considerable interest, reflected by numerous experiments on cadavers.

Two theories have been proposed:

1. *The blow and counter-blow theory.* This implies that the force of the body weight as the result of a counter-blow from the striking surface is transmitted through the carpal bones directly to the lower radius, often producing a fracture of typical localization in the portion of the bone where the cortex is thinnest. This theory was first advanced by Dupuytren (1834) and subsequently adopted by Nelaton (1844) and Malgaigne (1847), later also by Bähr (1894) and Destot and Gallois (1898). The latter were able to produce the first roentgenologic evidence that the carpal bones on forced dorsiflexion of the hand come to rest against the striking surface while the head of the radius is pressed against the humerus, thus allowing the force to continue directly to the lower end of the radius.

2. *The avulsion theory.* Lecomte (1861) contended that the ulna alone, as the only bone of the forearm to enclasp the lower end of the humerus, can absorb the impact of a fall on the hand. The force must be transmitted to the radius

through the ligaments and, to some extent, the interosseous membrane. The fracture is produced by avulsion due to traction of the strong volar ligament.

Löbker (1885) and Bähr (1894) objected that if the concept of avulsion as the primary causative mechanism were true, the fracture line should run volarward, proximally to dorsally, and distalward; in other words, altogether different from what is commonly observed. This argument completely invalidated the avulsion theory. On the other hand, Löbker considered that comminution of the joint surface should be more common if the blow and counter-blow theory were the most reasonable explanation. He believed the fracture to be due to a combination of mechanisms.

This concept of a complex mechanism is also reflected in the more or less similar arguments put forward by Pilcher (1917), Rotter (1920), and Lewis (1950). They stated that the injury is caused by the patient "falling over" the hand, resulting in hyperextension; the volar ligament is not disrupted and the radius is pressed against the carpal articular surface which also remains intact, so that the force continues to the radius where it produces a fracture in the weakest portion of the bone.

The results of Lilienfeld's experiments on cadavers have been more or less determinative of the general concept of the mechanics of injuries to the wrist. He observed that it was possible to produce different types of injuries at will by varying both the direction of the forearm in relation to the striking surface and the position of the hand. A distal fracture was produced if the forearm made an angle of 60–90 degrees with the striking surface. Fractures of the radial styloid process could be produced if the hand was placed in ulnar or radial abduction. Vertical loading of the hand generally produced a fracture of the navicular bone.

The multifarious appearance of the fractures of the distal radius indicate a varying mechanism with changing emphasis on the different factors. A certain uniformity in localization and line of fracture, and in the displacement of the distal fragment has earned these fractures the epithet "typical". As the variations are numerous and strongly influence the prognosis, the term "distal fracture" more adequately designates these injuries.

Earlier Classifications

Numerous attempts have been made to arrange the variety of fractures of the distal radius in separate groups, to differentiate between various types of fracture. Kotrnetz and Geiringer (1937) considered this essential to the clinical management of these injuries, which present such a wide range of variations that they must actually be seen as entirely separate clinical entities involving completely different problems of treatment and with different prognosis. Similarly, a comparison of the results of different methods of treatment is not feasible unless based on some sort of classification, according to Wiklund and Müllern-Aspegren (1956). By contrast, other authors have suggested that the various classifications have led to confusion (Chandler, 1950).

The classifications published earlier were based on the following factors:

Fracture line. Here a distinction has been made between fractures involving the joint and extra-articular fractures, and, in addition, between complete and incomplete fractures, the latter including those cases where the fracture passes across part of the distal radius only, for instance, the radial or ulnar styloid process, or merely produces a break along part of the margin of the articular surface. Although frequently referred to in the literature, the dorsal marginal fracture which bears the name of the American surgeon who first described it, Barton's fracture, must be relatively rare.

Direction of displacement. It would seem to be generally accepted today that displacement of the distal fragment is due to the active force at the moment of injury rather than to secondary muscle spasm. The displacement may take various forms (Pilcher, 1917; Humphries, 1948; Key, 1954):

Hyperextension of the fragment with dorsal angulation of the distal articular surface and compression of the cancellous bone dorsally.

Posterior displacement of the fragment.

Supination of the fragment.

Radial displacement, often combined with compression of the cancellous bone radially and decrease of the radial tilt of the articular surface.

Shortening due to impaction of the proximal into the distal fragment.

Comminution of the distal fragment, often continuing into the radial articular surface and combined with widening of the distal fragment.

Volar angulation of the distal articular surface, generally associated with volar displacement of the fragment.

The various forms of displacement are encountered both separately and, more commonly, in combination. Generally, they are easily detected in a routine roentgenogram, except for the supination deformity which in a lateral view is practically indistinguishable from posterior displacement (Mayer, 1940). Schüler (1937) has pointed out, however, that a considerable difference in size between the surfaces of distal and proximal fragment may be considered suggestive of this type of deformity.

With respect to type of displacement, the fractures have in most instances been classed in two groups, posterior dorsal and anterior volar fractures.

Degree of displacement. Here fissure fractures constitute one clearly defined group. In addition, a distinction has been made between fractures with merely dorsal angulation and those with more pronounced displacement of the fragments in several directions.

In some instances fracture-dislocations have been arranged in a separate group.

Degree of joint involvement. In this respect the obvious distinction has been between fractures without communition involving the joint surface and those with severe comminution. Some authors have made a further distinction and according to the line of fracture for instance divided the fractures into so-called T-shaped and Y-shaped fractures and fractures causing disruption of an ulnar fragment.

Injuries to the distal radio-ulnar joint. In this respect the injuries to the triangular disk have been considered the essential feature. The first description of such injuries was published by Nelaton (1834). In the latter part of the 19th century, experiments on autopsy specimens showed that a rupture could occur either at the ulnar insertion or through the fibers of the disk itself (Moore, 1880; Cotton, 1900). Don (1897) published the first roentgenologic evidence of a diastasis between ulna and radius in a fresh fracture, as a sign of such a lesion.

Mayer (1940) demonstrated in the cadaver that even a slight dorsal or radial displacement indicated damage to the disk, whereas supination, caused by rotation of the fragment round the ulna, could take place even if the ligament was intact. From this he concluded that in most cases the force fracturing the distal radius is sufficient to cause a rupture of the disk.

Knowledge of other soft tissue injuries in association with these fractures is scarce, as the fractures are rarely treated by open reduction and cadaveric experiments have been of doubtful issue. The prevailing opinion is, however, that the other ligaments around the lower part of the distal radius and ulna usually remain intact, in particular since the fracture line as a rule runs proximally to their insertion (DePalma, 1952).

Mechanism of injury. A distinction has been made between fractures considered mainly due to ligament avulsion and those with a blow and counterblow as the probable cause of injury. According to the position of the hand in the moment of injury, a further distinction has been made between extension–flexion, abduction and adduction fractures, with different fracture lines in each case.

The majority of the classification systems introduced in the literature have found no practical application except by the authors themselves (Kahleyss, 1897; Hitzrot and Murray, 1921; Ghormley and Mroz, 1932; Cornell, 1935; Ehalt, 1935; Kotrnetz and Geiringer, 1937). In a few instances, however, the system has been adopted and recommended by later authors. In this connection, mention should be made of the classifications devised by:

1. *Destot* (1923). According to the direction of displacement he distinguished two main groups of anterior and posterior fractures. Within these groups a

Fig. 1. Fracture type II A.

Fig. 2. Fracture type II B.

Fig. 3. Fracture type II C.

Fig. 4. Fracture type II D.

Fig. 5. Fracture type II E.

further distinction was made with respect to the line of fracture. This divided the fractures into one group with the fracture line either passing across the entire shaft of the radius (Smith's fracture) or involving only the radial styloid process or the dorsal margin, and a second group which included the classical Colles' fracture and Barton's dorsal marginal fracture. Destot's system has been recommended by Platt (1931) and Hoffman (1953).

2. *Taylor and Parsons* (1938). These authors classified the fractures in two main groups, with injuries to the triangular disk as the determining factor. In their opinion, prognosis was to a great extent governed by the presence or

absence of such injuries. Their ideas were later adopted by Mayer (1940) and by Manges, Jr. (1941).

3. *Nissen-Lie* (1939). His classification has found general recognition among Scandinavian authors. Fractures in adults were divided into: 1. Fissure fractures. 2. Simple displaced fractures not involving the articular surface. 3. Comminuted fractures. 4. Fractures of the radial styloid process. 5. Fractures with volar displacement. This system has been adopted among others by Rosen (1947), Madsen (1949), and Wiklund and Müllern-Aspegren (1956).

4. *Gartland and Werley* (1951). They distinguished three groups: 1. Simple fractures not involving the joint surface. 2. Fractures involving the joint surface but without displacement of the fragments. 3. Comminuted fractures with the line of displaced fragments running into the joint surface. This classification has been adopted among others by DePalma (1952).

The system published by Ehalt (1935), on the other hand, has found no followers. This is not surprising considering the overwhelming wealth of detail which characterizes his classification. The 822 fractures in adults analyzed in Ehalt's study were divided in not less than 34 groups, some of them comprising only a few isolated cases.

Principles Used in the Present Study

The guiding principle in developing this system has been to include the factors discussed in the foregoing only in so far as they tended to elucidate certain clinical problems.

One of the questions to be settled in this connection was whether the degree and, to some extent, the type of displacement, with the consequent variations in treatment could be expected to influence the final results. Fissure fractures and fractures without displacement could in this respect be regarded as one group, as they hardly pose any clinical problems and variations in treatment are rare. Severe displacement, on the other hand, usually implies extensive crushing of the cancellous bone at the fracture site. Such cases require a particularly accurate technique for reduction and varying methods of fixation may be indicated. Displaced fractures were classified in the order of their severity according to the principles outlined by Kotrnetz and Geiringer (1937). These authors distinguished between fractures with dorsal angulation and compression of the cancellous bone dorsally as the main deformity, and fractures with gross displacement where the fragments are shifted in several of the directions typical for fractures of the distal radius. As fractures with volar displacement are due to a different mechanism and require a special technique of reduction, these had to be regarded as a separate group.

Another of the factors to be determined was the importance of joint involvement as a guide to prognosis. With regard to this, the patients were according to the severity of the involvement divided into cases with and cases without comminution of the fragments.

The wish for a further distinction with respect to primary injuries to the distal radio-ulnar joint had to be abandoned, as the hospital records did not include this information.

A system based exclusively on line of fracture and angulation of the fracture surfaces was considered of little value.

A classification according to position of the hand at the time of injury and manner of injury proved impossible, as the information supplied by the patients was not sufficiently clear in this respect.

Based on these considerations, the following classification was evolved for the present study:

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. Fig. 1.
  B. Fractures with merely dorsal angulation, involving the joint but without comminution of the articular surface. Fig. 2.
  C. Fractures with complete displacement, not involving the joint surface. Fig. 3.
  D. Fractures with complete displacement, involving the joint but without comminution of the articular surface. Fig. 4.
  E. Fractures with complete displacement and comminution of the joint surface. Fig. 5.
III. Fractures with volar displacement.

Fractures combining merely dorsal angulation with comminution of the joint surface were not present in this material. Fractures of the radial styloid process with displacement were placed in group II E, fracture-dislocations depending on the degree of joint surface involvement either in group II C, II D, or II E. (The fractures in group II correspond to those in Nissen-Lie's groups 2 and 3, and are the types of fracture most often discussed in the Scandinavian literature.)

Chapter 2

PRESENTATION OF THE MATERIAL

The cases reviewed in this study were in part chosen from a routine hospital material, and partly from the records of an insurance company of disabled persons. The arrangement of the latter series will be discussed in a separate section. The selection of a series from the routine material treated at the outpatient department of the Surgical Clinic of Karolinska Sjukhuset in Stockholm was based on the records on file at the hospital's Department of Roentgenology. A perusal was made of all records for the period from January 1949 to November 1955 which concerned fractures of the lower end of the radius and at the time of selection had been entered in the registers.

Of the total number of 1588 cases, 205 were children under 15 years of age. They had been admitted during the period between 1949 and 1952, at which time this part of the service had been assumed by the newly founded Surgical Clinic for Children. Fractures of the lower end of the radius in children are as a rule of a different type from the fractures seen in adults. They tend to have a somewhat more proximal localization and are often of the greenstick-type in which only the cortex is crushed; in addition, they are sometimes complicated by epiphyseal injuries. The ability of the growing bone to compensate any remaining deformity furthermore makes prognosis in these cases considerably more favourable (Önne and Sandblom, 1949). These considerations appeared to justify the omission of an analysis of the fractures in children from this study, and the limit was determined at 15 years.

The remaining 1383 cases were distributed over the different fracture groups as follows: Group I, 542 cases; Group II, 815 cases; Group III, 26 cases.

GROUP I

The age and sex distribution of the various types of fracture represented in this group is given in Table I.

An interesting feature was the high frequency of fractures and fissure fractures of so-called typical localization. They constituted 31 per cent of the total series of 1383 adult cases. Nissen-Lie reported in 1939 a 22.4 per cent incidence of this type of injury among the cases he studied in Oslo. The present high figure may partly be due to the fact that even relatively insignificant breaks in the cortex were registered as fissure fractures, to some extent also to the

TABLE I. *Age and Sex Distribution of Fracture Types in Group I.*

	Years										Total no. of patients
	15–30		31–40		41–50		51–60		> 60		
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	
Fractures of typical location	77	29	30	36	27	38	18	79	12	86	432
Fractures of the radial styloid process	15	4	12	1	10	4	9	5	5	6	71
Fractures of the ulnar styloid process	8	—	5	1	5	—	4	2	—	1	26
Longitudinal fractures	3	—	3	—	3	—	—	—	2	2	13

fact that in the present series the indications for roentgen examination had been generous even for apparently harmless injuries.

Another point of interest was the predominance of men in the youngest age group. This is explained by the fact that the out-patient department at the Surgical Clinic of Karolinska Sjukhuset simultaneously functions as the surgical service for Stockholm's garrison.

The incidence of fractures and fissure fractures of the radial (5.1 %) and ulnar (2 %) styloid process closely approached the figures reported in earlier studies (Ehalt, 1935; Nissen-Lie, 1939).

Table I furthermore illustrates that fractures of the radial styloid process occur predominantly in men in the younger age groups.

Earlier studies (Kotrnetz and Geiringer, 1937; Rosen, 1947; Wiklund and Müllern-Aspegren, 1956; and others) have demonstrated that fractures without displacement rarely cause prolonged symptoms. In order to correlate the results in the present series with these experiences, a follow-up questionnaire was sent out to 40 patients (14 men and 26 women), three years after injury. The age incidence in this group agreed with that of the total series. Thirty-eight patients reported a rapid and permanent recovery. The remaining two patients, who indicated residual symptoms in the form of weakness and pain, were requested to submit to an examination. Personal questioning elicited that the remaining symptoms were extremely mild and did not prevent normal function of the hand. No objective anatomical or functional defects could be found.

The choice of treatment for fractures without displacement is axiomatic. A follow-up examination of this group could hardly be expected to furnish significant information concerning the factors influencing the end results of fractures of the distal radius. Further analysis of this type of fracture was therefore considered unprofitable.

GROUP II

This group comprised 815 patients with what in clinical terminology are called "typical" fractures. Age and sex incidence are given in Table II. The age curve follows the usual pattern with a maximum frequency for women between 56 and 65 years. For men this maximum occurs considerably earlier, between 36 and 45 years. The high incidence in men between 15 and 25 years of age is, similar to what has been stated with regard to undisplaced fractures, influenced by the proportion of recruits cared for at the Army Clinic.

The present figures show good agreement with those reported from studies likewise based on material from surgical out-patient departments (Kotrnetz and Geiringer, 1937; Nissen-Lie, 1939; Rosen, 1947; Madsen, 1949; Wiklund and Muellern-Aspegren, 1956; Hölund, 1957; and others). A different age and sex incidence have been reported, on the other hand, from studies of insurance material where the average age was lower and the frequency among men higher (Conti, 1922; Ehalt, 1935; Valtonen, 1948).

Group II included the majority of cases of clinical interest. Patients over 75 years of age, however, were excluded from the follow-up examination to which this group was subjected. The reason for this was that many were in such poor health that they were either unable or unwilling to submit to this examination. In addition, their activities were often so restricted that function of the wrist under conditions of strain was difficult to evaluate.

Of the remaining 741 patients in group II that were invited to a follow-up examination, 502 appeared. Ninety-nine, although unwilling to submit to examination, did answer a questionnaire. Thirty-six patients had died. A number of patients that at the time of treatment had been short-time residents or casual visitors to Stockholm, had left only temporary or incomplete addresses. Due to this, 99 patients could not be reached. Five others had left the country. The follow-up examination was therefore restricted to 71% of the surviving patients in group II.

The distribution of the various types of fracture among the 502 examined cases is given in Table III. In 24 cases (5%) where reduction had been performed, either no roentgen examination had been made at the time of injury,

TABLE II. *Age and Sex Distribution of Fractures in Group II. Total series.*

	Years							Total no. of patients
	15–25	26–35	36–45	46–55	56–65	66–75	> 75	
Men	37	16	37	29	21	6	8	154
Women	13	31	36	153	229	133	66	661
Total no. of patients	50	47	73	182	250	139	74	815

TABLE III. *Distribution of Fracture Types in Group II. Follow-up series.*

	Type of Fracture						Total
	II A	II B	II C	II D	II E	Undiffer-entiated	
No. of patients	123	39	216	68	32	24	502
Per cent	*24.5*	*8*	*43*	*13.5*	*6*	*5*	*100*

TABLE IV. *Age and Sex Distribution of Fracture Types in Group II. Follow-up series.*

Type of fracture	Years															
	15–25		26–35		36–45		46–55		56–65		66–75		Total no.		%	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
II A	8	2	0	10	6	7	10	28	1	37	0	14	25	98	*5*	*19.5*
II B	2	1	3	2	2	2	1	8	0	13	0	5	8	31	*2*	*6*
II C	3	1	3	8	4	13	5	52	6	83	0	38	21	195	*4*	*39*
II D	3	0	3	3	4	3	0	13	0	27	0	12	10	58	*2*	*11.5*
II E	0	0	0	0	5	4	7	5	4	3	1	3	17	15	*3*	*3*
Undiffer-entiated	0	2	0	0	3	1	0	7	0	7	1	3	4	20	*1*	*4*

or the films were no longer available. In these cases the type of fracture could not be ascertained.

The incidence of the different types of fracture in relation to age and sex of the 502 patients is summarized in Table IV. Some dissimilarity could be observed in the incidence in relation to sex. In the group with comminuted fractures, the majority were men. In the group with completely displaced fractures without comminution women clearly predominated (89 %), whereas the proportion of women in the group with merely dorsal angulation was 80 %. Age, on the other hand, did not appear to influence the distribution of fracture types. It should be noted, however, that comminuted fractures were not represented in the two youngest age groups.

GROUP III

Fractures with volar displacement or volar angulation of the distal fragment occurred in 26 cases (2 %) of the total adult series. In 9 cases the displacement was so slight, however, that reduction had not been attempted.

TABLE V. *Age and Sex Distribution of Fractures in Group III. Total series.*

	Years						Total no. of patients
	15–25	26–35	36–45	46–55	56–65	66–75	
Men	1	4	2	2	0	0	9
Women	1	4	2	3	4	3	17
Total no. of patients	2	8	4	5	4	3	26

TABLE VI. *Age and Sex Distribution of the Series Not Included in the Follow-Up.*

	Years						Total no.
	15–25	26–35	36–45	46–55	56–65	66–75	
Men	21	7	13	8	10	4	63
Women	7	9	7	40	59	58	180
Total no. of patients	28	16	20	48	69	62	243

TABLE VII. *Distribution of Fracture Types in the Series Not Included in the Follow-Up.*

	Type of Fracture							Total
	II A	II B	II C	II D	II E	III	Undifferentiated	
No. of patients	57	15	97	20	10	4	40	243
Per cent	*23*	*6*	*40*	*8*	*4*	*2*	*17*	*100*

The incidence of these fractures in relation to age and sex is given in Table V. Of the 17 patients with reduced fractures, 13 were included in the follow-up examination. Four patients could either not be reached or were unable or unwilling to submit to examination.

Of the 758 patients between 15–75 years of age with displaced fractures, 515 (68%) appeared for a follow-up examination. It can be discussed whether the results of these 68 per cent may also be considered representative of those not included in the examination. Obviously, a final answer to this question is impossible. If, however, the material not included in the examination permits analysis of a sufficient number of significant factors, and this analysis produces the same pattern as in the examined cases, there are good grounds for the assertion that the conclusions are representative of the total material. This obviously presupposes a random selection of the series subjected to examination. In the present study it was possible to determine sex, age, and type of fracture of the cases not included in the follow-up examination. The age and sex incidence is given in Table VI. The distribution of the different fracture types is shown in Table VII.

Both with respect to age incidence and to distribution of fracture types good agreement was observed between the examined series and the remaining material. As treatment had been uniform, there are excellent grounds for considering the examined cases representative of the total material.

As a further test of the accuracy of this assumption, 99 patients whose address was known, but who were either unable or unwilling to present themselves for examination, received a questionnaire requesting them to report any residual symptoms. Of these, 58 per cent considered themselves completely asymptomatic. The relevant figure in the examined series, where personal questioning elicited this information, was 54%.

CHAPTER 3

METHODS OF CLINICAL EVALUATION

History. As far as possible, an attempt was made to obtain a complete history of each patient from the moment of injury up to the time of follow-up examination. The records kept in the out-patient department generally contained detailed information about the manner of injury and the patients' condition at the time of entry to the hospital, but data concerning the ensuing course were sometimes meagre. Additional information about the posttraumatic course, specifically with respect to pain during or after the period of immobilization in plaster, and any swelling or stiffness of the wrist, was therefore elicited by careful questioning of the patients. In most instances, it was difficult to ascertain exactly when the patient had been able to return to work. The majority of patients were housewives, who had gradually resumed their various tasks.

To evaluate the patients' present condition, they were questioned as to pains, weakness and stiffness, with particular reference to any restriction of their working capacity, the degree of such functional impairment, and the type of activity that had become difficult.

Physical examination. The objective evaluation of end results was based on a routine clinical examination requiring no special equipment. This type of examination was considered best fitted for the purpose, in the first place as the entire study was designed as an evaluation of results obtained with routine methods of treatment, and secondly, because it might be desirable to incorporate this experience into routine clinical fracture management.

The first factor to be determined was the appearance of the wrist. Palpation thereafter established the presence of any persisting tenderness. Skin changes and scar formation were considered, and the patients were tested for neurologic symptoms, specifically sensory chânges and pareses.

Joint motion was recorded according to the system described by Cave and Roberts (1936). The extended hand in mid-position between pronation and supination and with the palm flat against the palm of the other hand, was chosen as the neutral point from which all motions were measured. The range of motion was measured with an ordinary goniometer, and compared with that of the opposite hand. Earlier observations (Cobe, 1928) have indicated that the normal range of motion varies according to sex and even within the same sex, and furthermore depending on which hand is involved. Cobe also suggested

Fig. 6. Measurement of dorsal angulation.

that one isolated measurement would be a none-too-reliable criterion of joint motion, as the full range of motion of a joint is rarely exhausted so that extreme movements cannot be tested. In addition, it should be considered that the motion of the opposite and apparently sound wrist may be affected by trauma or illness dating far back in time and not mentioned by the patient. This method of testing joint motion consequently contains several sources of error, but is nevertheless, for practical reasons, the only feasible system in a routine clinical examination. These considerations apply even more to the subsequent dynamometric examination of the handgrip for muscle power. In this test, the average value of three measurements was compared with the muscle power in the opposite hand.

The stability of the distal radio-ulnar joint was tested by trying to move the capitulum ulnae back and forth in dorso-volar direction. The most satisfactory procedure for this examination was to grip the end of the radius between the thumb and first finger of one hand, with the thumb and first finger of the other hand grasping the end of the ulna. This permitted simultaneous testing of the mobility and of any persisting tenderness over the capitulum ulnae. A slight mobility of the end of the ulna is not uncommon even under normal conditions, but in such cases it is always equal in both wrists. In my examination of a large number of normal wrists in patients treated for other complaints, I have in no single instance been able to find a difference of any consequence between the left and right wrist in this respect. Palpably increased mobility on the injured side may therefore be considered indicative of damage to the distal radio-ulnar joint.

Roentgen examination. In all cases both wrists were roentgenographed in the two standard projections. In a few instances, where the clinical findings indicated

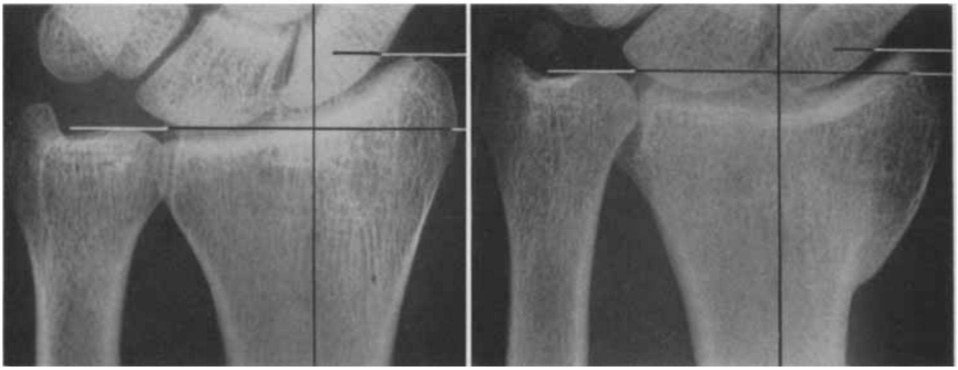


Fig. 7. Measurement of shortening.

instability of the radio-ulnar joint, additional roentgenograms were taken in the frontal projection with the hand in extreme radial or ulnar deviation. This was done in an attempt to obtain an objective record of the increased mobility of the ulna.

To assure a reasonably objective evaluation of the degree of residual deformity from the roentgenographic evidence, it was necessary to make measurements on the roentgenograms. In the personally conducted follow-up roentgen examinations, a uniform focus–film distance of about 55 cm was used. No information was availabe concerning the focus–film distance in the initial roentgen examinations, but it seems likely that this has varied from case to case. The variations appeared not to have been large enough, though, to influence the results of the measurements to any significant degree. Another source of error in measurements on roentgenograms of this type may be contained in variations in the projections. However, as these measurements were merely intended as a basis for a general evaluation of deformity in the lower radius, the method could be profitably employed in this study.

In the lateral view the standard of measurement is self-evident in the angulation of the carpal articular surface (Fig. 6). If this measurement is to be as exact as possible, two requirements must be satisfied. The roentgenogram must be a true lateral view, which is most clearly shown by the overlap of ulna and radius. In addition, the articular surface must be clearly exposed, which is usually ensured by directing the tube proximally at an angle of about 25° (Parker and Culpepper, 1946). Comparative measurements of the unfractured wrists gave an average of 80.5 degrees as the normal angulation.

The frontal view offers several alternative standards of measurement. Radial compression may be rated by measuring the decrease in the angle between the articular surface and the long axis of the radius, radial shortening by comparison with the ulna. In cases of severe deformity, however, it often proved difficult to find points permitting exact comparison for measurement of the angulation of the articular surface. All roentgenograms, on the other hand, permitted fairly exact measurement of the distance the radial styloid process projected distal to the ulna. A decrease of this distance as compared to the opposite wrist could be due to either radial shortening or radial compression as the chief deformity, or reflected a combination of both elements. This measure, defined as "shortening", was decided on as the most reliable criterion of deformity in the frontal view measurements (Fig. 7). The average values were established as 13.7 mm in men and 12.2 mm in women. In a few cases, where some deformity persisted following a fracture of the opposite wrist, the amount of shortening could nevertheless be determined by comparing the anatomical end result with the post-reduction roentgenograms which showed that reduction had restored normal anatomical relationships in these cases.

The roentgenologic evaluation of the distal radio-ulnar joint presented special aspects, which will be discussed later. A disturbance of the normal relationship between the joint surfaces as a result of radial shortening is often regarded as the most severe deformity in this joint. The distance between the distal surface of the capitulum ulnae and the ulnar aspect of the radial articular surface was therefore chosen as a measure to evaluate the significance of injuries to this joint for the functional end result.

In addition to these measurements, the roentgenograms were scrutinized for evidence of posttraumatic arthritis in the radio-carpal and radio-ulnar joints and the other parts of the wrist.

In 20 cases where the follow-up examination indicated an injury to the distal radio-ulnar joint, an arthrogram was made of this region. For comparative purposes, a few other cases where no such symptoms were present were included in this examination.

Chapter 4

THE TREATMENT OF THE FRACTURE

In nearly all cases, the initial treatment was given by the surgeon chancing to be on duty when the patient was admitted to the accident section of the surgical out-patient department. In a few instances, reduction and initial immobilization were entrusted to interns under the surgeon's supervision. The management of these fractures has consequently involved a large number of different surgeous of varying experience, which should make the results in this series fairly representative of the average results obtained in Swedish surgical out-patient departments.

At certain times in the past, fracture of the distal radius has been regarded as so uncomplicated that it was thought unnecessary to adhere too strictly to the general principles of reduction and, more particularly, immobilization, that were applied to more severe forms of fracture. Yet, despite or possibly even due to the limited anatomical involvement caused by these fractures, the technical details of their initial treatment have raised considerable discussion. The debate has centered around the following points: 1. Technique of reduction, 2. Appropriate time for reduction, 3. Method of anaesthesia, 4. Technique of immobilization, 5. Length of immobilization, 6. Position of the hand during immobilization, 7. Physical therapy.

Technique of Reduction

It has been stated (Ford and Key, 1955) that there are as many methods of reduction as there are fracture surgeons. Still, it is possible to discern certain generally adopted standard techniques that have come to the fore during different periods in the past.

During the 19th century and the first decades of the 20th century, most methods were based on the principle of restoring the distal fragment to its normal position by a rapid manoeuvre often amounting to a jerk. The method recommended by Robert Jones in one of his first publications has become the standard procedure in England. His technique consisted in manipulating the fragments into position with the parallel hands grasping the radial side of the patient's forearm and hand. As the first step, he recommended dorsiflexing the wrist in order to break up the impaction that is usually present. The importance of this detail was later stressed by Zuppinger (1910) and Pilcher (1917). The latter observed that the dorsal periosteum is often undamaged and by its pressure keeps the distal fragment in its impacted position. He considered dorsiflexion of the wrist, in order to relax the pressure of the periosteum, indispensable, if manipulative reduction is to have any effect. This disimpaction manoeuvre has not become universally accepted, however. Carothers and Berning (1950) commented that it could hardly be desirable to risk a further increase of the bone defect already present dorsally.

During the nineteen-twenties clinical management was strongly influenced by Böhler's publication (1923), which stressed the importance of extension in reducing these fractures. His technique is nowadays standard practice almost everywhere on the European continent. As a rule, it is carried out according to Böhler's original instructions, with several assistants applying manual traction to produce extension. Both Böhler and later authors (Pilcher, 1917; Ghormley and Mroz, 1927; Carter, 1937; White, 1940) observed that, in addition to extension, direct manual pressure on the distal fragment is often needed to achieve accurate reduction.

Böhler's technique has not been universally accepted, however. Hilgenfeldt (1950) regarded the procedure as too complicated and requiring too much personnel to be profitably employed outside a hospital. Some time before, Graham (1938) had reached the same conclusion from his follow-up examination of 125 patients, 75 of which had been treated by different surgeons in private practice. Both these authors recommended methods which in principle resembled the technique current before Böhler's publication. Others have adopted a more elaborate version of the extension technique, applying traction by means of some form of extension apparatus instead of manually. A spring extension splint was constructed by Bardenheuer as early as the late 19th century, but never became popular. Caldwell (1931) introduced so-called Chinese finger-stalls for traction of 5–11 kg, applied over a period of up to 30 minutes. With this apparatus he secured accurate reduction even of fractures with severe comminution. Whereas Caldwell's system involved traction on all fingers, Carothers and Berning (1950) recommended that traction be applied to the thumb only, which automatically ensures the desired ulnar deviation. Good results with similar apparatus have been reported by Joldersmaa (1943), Johnson, Mahlstrom and Behrens (1946), Chaffin (1949), Ford and Key (1955), and Strong (1955). In Scandinavia, Wiig (1939) introduced a device which immobilized the fingers in a sheet of rubber, while Saikku (1953) applied adhesive strapping to the wrist, leaving the fingers free. In Switzerland, Klapp (1943) presented a contrivance of his own design, whereas Hoffman (1954) used a cloth cuff. All these authors stressed the ease with which even severe fractures could be rapidly and gently reduced by means of their respective devices.

In the present series, Böhler's technique was the standard procedure for reduction. Dorsal angulation was often corrected by direct pressure on the distal fragment and palmar flexion of the hand. Extension was achieved by an assistant applying traction on the fingers, and maintained while the plaster splint was being applied. No extension apparatus was used.

Appropriate Time for Reduction

The majority of authors consider immediate reduction an obvious requirement and do not raise it as a point of discussion.

Haglund (1914) considered reduction at the earliest possible moment imperative for a satisfactory end result. In his opinion treatment could not be delayed for more than 6 hours at the utmost without unfavourable consequences for the subsequent course. Hitzrot and Murray (1921) shared this viewpoint and reported decidedly less satisfactory results in cases where reduction had been delayed. Meyer (1925) and Boorstein (1925) expressed the same opinion. Manges, Jr. and Lewis (1941) observed that reduction during the first 24 hours following injury is technically uncomplicated, but thereafter becomes considerably more difficult.

A few authors have stated diametrically opposite viewpoints. Kotrnetz and Geiringer (1937) mentioned as one of the essential principles of their method of treatment that reduction is not carried out until at least 24 hours have elapsed. They believed that any attempt at reduction before this time adds to the risk of renewed haemorrhage in the fracture haematoma, causes increased swelling, and results in a higher frequency of early circulatory disturbances. The end results reported by these authors from an extremely large series are among the most satisfactory to be found in the literature. Hand (1957) preferred several days' delay until the initial swelling has subsided, when reduction can be attempted without risk of further circulatory complications.

In the present series, immediate reduction was standard practice. The result was checked by roentgen examination and, if not satisfactory, renewed attempts were made without delay.

In only 17 cases could reduction not be performed immediately. Fourteen patients did not present themselves for treatment until some time after injury. In 7 cases the delay was 24 hours, in the others 3–7 days. In the remaining 3 cases reduction was on initial examination considered unnecessary, but after reconsideration the patients were summoned some days later for treatment. In all these cases satisfactory reduction was obtained. The post-reduction course did not present any complications, with the exception of one case.

In 28 cases the displaced fracture was not reduced. Twenty-three of these belonged to the group with merely dorsal angulation of the distal fragment; in 14 cases there was an angle of 90–99 degrees, in the remaining 9 cases it measured between 100 and 108 degrees. Four patients belonged to group II C. The fractures were at the time of admittance over two weeks old and as the displacement in all cases was slight, reduction was not attempted. The last case represented a "reversed" fracture with a volar angulation of about 10 degrees as the sole deformity; it was not considered necessary to correct this.

Method of Anaesthesia

In the past, reduction without any form of anaesthesia has been common practice (Haglund, 1914; Robert Jones, 1929). Currently, however, the discussion is primarily concerned with the value of local anaesthesia as compared to general anaesthesia.

Although Poulsen already in 1906 had observed that the results of the former method compared favourably with those obtained under general anaesthesia, it was Böhler's introduction of local anaesthesia in 1919 which has made it the most popular method nowadays. McAusland (1937), among other authors, stressed the importance of injecting the anaesthetic not only into the fracture line on the radius, but also around the ulnar styloid process.

Bankart (1929), Ghormley and Mroz (1932), White (1945), Robbins (1950) and Milch (1950) all recommended some form of general anaesthesia, claiming this to be the only way to achieve the complete muscular relaxation required for perfect reduction.

In the present series, local anaesthesia was the rule; it was given in 388 of the 486 cases where the fracture was reduced. In the follow-up examination, 108 patients claimed to have suffered severe pains during the manipulations for reduction. Several patients spontaneously declared that they would have preferred general anaesthesia. It is, of course, possible that these unfavourable experiences are to be ascribed to a faulty technique in injecting the anaesthetic into the fracture line, which may be difficult to locate. Another explanation might be neglect to include the area around the ulnar styloid process in the anaesthesia, but this theory seems contradicted by the fact that the incidence of fractures of the ulnar styloid process was only 46% in the group of patients who had experienced pain during reduction, as against 64% in the total series.

General anaesthesia was administered to, in all, 98 patients, 23 of them men. In 14 cases, 2 men and 12 women, reduction had in the first instance been attempted under local anaesthesia, but when this did not succeed, general anaesthesia was given. Accurate reduction was obtained in 7 cases, but minor displacements persisted in the remaining cases.

In 6 cases, finally, where the initial attempts at reduction under local anaesthesia had failed, a brachial block was used. For this procedure, the patients were hospitalized.

Immobilization

TECHNIQUE OF IMMOBILIZATION

This is undoubtedly the most controversial detail in the management of fractures of the distal radius. The debate has been going on for over a century and has been actively continued to the present day. A variety of methods have been introduced for maintaining reduction, ranging from complete absence of any fixation device to circular plaster bandages extending from the tips of the fingers up to the fossa axillae. The problem has been to devise a method of fixation which would permit a maximum of functional exercise as early as possible after reduction, while at the same time effectively preventing redisplacement of the distal fragment during the period of immobilization. The various methods recommended in the past are a reflection of the different authors' beliefs as to which factor was decisive for the final result.

Colles (1813) used both a volar and a dorsal wooden splint. During the 19th century, immobilization techniques were developed along two lines. On the one hand, there was a trend in favour of plaster bandages, which were often circular and extended over a large part of the limb, whereas another trend became apparent in the introduction of numerous splints of different types and constructions.

As a reaction against the former method, which only too often resulted in stiffness of the arm and hand (Amendola, 1938), a new method was introduced by Lucas-Championnière (1886), who recommended that apparently stabile fractures with moderate or insignificant displacement not be immobilized and functional exercises started immediately. Comminuted fractures, on the other hand, should be immobilized. Championnière's ideas were adopted by many later authors. As recently as 1911, De Marbaix, although recommending reduction as the first step, immediately followed this by active motion without any form of immobilization. Petersen (1894) presented a modified version of this method, in which the forearm after reduction was placed in a sling permitting the hand to hang down in ulnar deviation, which made it easier to maintain the reduced position. With the same object in view, Storp (1896) placed an adhesive dressing around the wrist, which was fastened to a sling around the neck. The latter method was successfully employed by Eden (1921).

Standardized splints were gradually discarded, as it became recognized that the type of displacement presented such infinite variety that no ready-made splint could answer the purpose (Braatz, 1887). Various types of splints were still used, however, by Pfanner (1920), Rotter (1920), Meyer (1925), Edwards and Clayton (1929), and new constructions launched even during the past two decades (Mooney, 1944).

Immobilization by means of some form of bandaging became popular during the first decades of the 20th century and has been recommended by Lexer (1909), Troell (1913) and Huelsmann (1923).

For several decades now, immobilization in plaster has been the standard procedure throughout the world and, properly speaking, only the type and size of the plaster fixation remain a point of discussion at present. Although Böhler's method of using only a dorsal splint for immobilization has gained wide recognition throughout the European continent since its introduction in 1919 and 1923, many authors consider this fixation inadequate. They maintain that the general principle of immobilizing the joints both above and below the fracture site is equally important in the treatment of fractures of the distal radius as in all other fracture management. White (1945), Wier (1948), Humphries (1949), Cozen (1951), Steinhäuser (1952), McNutt (1956), and Glock, Mackel, and Brown (1957) immobilized any fracture of the distal radius in a circular plaster cast extending above the elbow. Taylor and Parsons (1938) and Mayer (1940) considered this type of fixation necessary only for fractures associated with instability in the radio-ulnar joint. Others, adopting a middle course, used circular plaster casts around the forearm only (Klapp, 1921; Gurd, 1937; Höjensgaard, 1945; Chandler, 1950; Osmond-Clark, 1951), or both a volar and dorsal plaster splint (Hitzrot and Murray, 1921; Ghormley and Mroz, 1932; Amendola, 1938; Gartland and Werley, 1951).

As plaster fixation was found ineffective in preventing shortening in cases with comminution of the fracture, some authors have during the past 25 years advocated the use of skeletal traction in special cases. Ehalt (1935) considered skeletal traction indicated in approximately 3 % of all fractures of the distal radius. Goodwin and Cameron (1942) inserted a fixation device through the proximal phalanx of the thumb, whereas Geckeler (1953) preferred to introduce a Kirschner wire into the first metacarpal and the upper aspect of the distal ulna. Hammond (1949) adopted the extension technique for immobilization of comminuted fractures. Roger Anderson (1945) devised a special apparatus which has been used by Johnson, Mahlstrom and Behrents (1946), and was recommended by Glock, Mackel, and Brown (1957) for severely comminuted fractures. Murray (1939) reported good results with a splint incorporated in a circular plaster, with traction provided by adhesive strapping fixed around the base of the thumb and over the second and third fingers. A purely operative form of fixation was practised by DePalma (1952) for fractures involving the joint. After reduction had been achieved under extension, a pin was introduced through the ulna obliquely into the distal portion of the fragment. This procedure was followed by immobilization in plaster for 8 weeks. Forgon and Bercenyi (1955) used this method successfully in 14 cases, under local anaesthesia and without hospitalizing the patients. A similar technique was introduced by Rush and Rush (1949), who considered fracture of the distal radius eminently suited to fixation with their special pin, which was stated to provide a stabile position permitting immediate functional exercise. Thornton and Warner (1955) also used Rush pins, with excellent results.

In the present series, immobilization by means of only a dorsal plaster splint was the standard procedure. The splint was usually made so wide that it extended over the radial and ulnar aspects of the forearm. In 12 cases a circular plaster was used, in two cases extending above the elbow. The reason for this was that reduction of the fracture had proved difficult and resulted in an unstable position of the fragments.

LENGTH OF IMMOBILIZATION

For a short period around the turn of the century and the first decades after that, early physical therapy was considered all-important and splints were removed daily to permit this treatment. Otherwise, the trend has gone steadily towards ever-increasing periods of immobilization, as illustrated by the following data from the literature.

Author	Recommended length of immobilization	Year
Petersen	8 days–3 weeks	1894
Poulsen	2 weeks	1906
Lilienfeld	10–14 days	1907
Lexer	2 weeks	1909
Böhler	3 weeks	1919
Pfanner	10–14 days	1920
Klapp	3 weeks	1920
Boorstein	3 weeks	1925
Darrach	2–3 weeks	1927
Platt	5 weeks	1932
Klapp	3 weeks	1943
Ingebrigtsen	5–6 weeks	1946
Robbins	6–10 weeks	1950
Hilgenfeldt	At least 6 weeks	1951
Gartland & Werley	6 weeks	1951
McNutt	Up to 10 weeks	1956
Glock, Mackel & Brown	8 weeks	1957

Geckeler (1953) recommended a minimum immobilization time of 8 weeks for comminuted fractures treated with internal fixation.

In the present series, the length of immobilization varied between 21 and 60 days, with an average of 34.8 days. For fractures with merely dorsal angulation the average time of immobilization was somewhat shorter (32.4 days) than for the group of completely displaced fractures (35.7 days). Comminuted fractures were immobilized for 35.7 days on an average, Smith's fractures for 43 days. These figures represent the period of absolute immobilization. In many cases the dorsal plaster splint was for an additional week or two used as a support during the night or part of the day, when the hand was not being exercised.

POSITION OF THE HAND

The attention given to this detail of treatment has chiefly been stimulated by, on the one hand, the idea that, by adapting the position of the hand, redisplacement during the period of immobilization might be prevented, and, on the other hand, by the desire to create the most favourable conditions for restoring the integrity of the distal radio-ulnar joint.

With these objects in view, many authors adopted the principle of immobilizing the wrist in a position opposite to the common direction of displacement. Widely used during the 19th century, for instance, was Schede's splint, which was strongly palmarflexed in order to aid retention of the normal inclination of the articular surface achieved on reduction. Soon after the introduction of this method, it was recommended that the hand simultaneously be placed in a position of pronation and ulnar deviation. The procedure is still used at present, in particular in the U.S.A., where it is known as "Cotton-Loder's position". Among earlier authors who have reported good results with this method are Braatz (1887) and Troell (1913); contemporary American authors who can be mentioned are Walking (1938), Chandler (1950), Milch (1950), Gartland and Werley (1951), and McNutt (1956). Taylor and Parsons (1938) and Mayer (1940) stressed as a particular advantage of this method that injuries to the triangular cartilage have a better chance of healing completely. Platt (1932) and Carothers and Berning (1950) used a position of moderate palmar flexion. All these authors agree that it is essential to change the position of palmar flexion in from 10 to at most 14 days to one of light dorsiflexion or extension, while preserving ulnar deviation and pronation.

Lippmann (1927), at variance with Taylor and Parsons, considered supination the position of choice in cases with injuries to the radio-ulnar joint.

Zuppinger (1910) condemned the widely used method of immobilizing the hand in ulnar deviation and palmar flexion in a circular plaster, asserting that the position of ulnar deviation produced permanent deformity and palmar flexion an irrevocable loss of mobility of the fingers. He was the first to recommend *immobilizing the hand in the position of function.* Zuppinger regarded muscle spasm as the chief cause of the redisplacements it was the object to prevent and stated that, as maximum relaxation of both the dorsal and palmar muscles was achieved by bringing the hand into moderate dorsiflexion, this position was obviously the one to be preferred. Böhler (1919) shared Zuppinger's opinion that the position of palmar flexion was responsible for a considerable number of disabilities. He immobilized the extended wrist in midposition between pronation and supination combined with ulnar deviation. His contribution has determined the course of further development on the European continent. Böhler's technique was used in the series reported by Ehalt (1935) and Kotrnetz and Geiringer (1937), as well as in several of the Scandinavian studies that have been published (Nissen-Lie, 1939; Höjensgaard, 1945; Rosen, 1947; Madsen, 1949; Wiklund and Müllern-Aspegren, 1956). Pickard (1925) shared Böhler's opinion that palmar flexion was never indicated if manipulative reduction had been effective in dislodging the distal fragment.

In the present series, the wrist was as a rule immobilized in a neutral position, if possible combined with ulnar deviation. In 13 cases the wrist was placed in a position of palmar flexion, in most cases because it had proved difficult to reduce the dorsal angulation. Several of these cases showed marked compression and a dorsal bone defect. The position of palmar flexion was maintained for 10–14 days, after which the hand was placed in extension.

Physical Therapy

Views on the value of physical therapy have changed with the times. Similarly, the form in which this treatment should be given has been open to discussion.

For several decades after the turn of the century, early and intensive physical therapy with massage and heat was considered the determining factor for the functional end result. Already during the first week, immobilization was temporarily discontinued so that physical therapy could be instituted.

As early as 1896, Braatz had stressed the desirability of active motion of the fingers during the period of immobilization, but again it was Böhler's contribution (1919) that determined the trend of development even in this respect. He strongly emphasized the importance of active functional training and provided a detailed outline for the exercises, which included early movements for pronation and supination, up to that time regarded as dangerous.

Today, the only question which remains a point of discussion is whether active functional exercises should as a routine measure be supplemented by physical therapy and be carried out under the supervision of a physical therapist.

Valtonen (1948) and Bacorn and Kurtzke (1953) reviewed large series of compensation cases and concluded that the effect of such a regimen is doubtful. Tawast-Ranken (1956) believed that adequate instruction of the patients practically dispenses with the need for additional therapy.

In the present series, physical therapy did not form part of the routine clinical management and was given on special indications only. Such indications were usually late complications such as prolonged swelling, stiffness of fingers or wrist, or pain and tenderness. A total of 144 patients, 23 of them men, received physical therapy. Its duration varied greatly, from a short series of 3 treatments to, in a few cases, prolonged treatment stretching over a number of years. In the follow-up examination, the functional end result was found less satisfactory for this group of patients than for the total series. In 30 % of the group that had received physical therapy the result was judged as excellent, good in 40 %, fair in 15 % and poor in another 15 %. Although these results may in part be ascribed to the somewhat higher incidence of grossly displaced and comminuted fractures in this group, the essential factor is in all probability that physical therapy was almost exclusively given in cases where the post-reduction course had been prolonged and complicated by pain, swelling, or stiffness. It is not possible to express an opinion on the value of physical therapy on the basis of the present series. The only conclusion that can be drawn is that physical therapy has not quite succeeded in counter-balancing the negative influence of the above-mentioned factors on the final results.

Chapter 5

EARLY RESULTS

The fundamental principles of fracture treatment can be summed up in three points:

1. Reduction, as accurate as possible,
2. Immobilization of the fragments in good alignment until consolidation has occurred, and
3. Restoration of function, as early as possible.

The present study included an appraisal of the immediate results obtained in each of these stages of treatment with the methods described in the preceding chapter.

Accuracy of Reduction

The demands made on the accuracy of reduction vary greatly with the location of the fracture. An applicable general principle is that the nearer the fracture is to a joint, the more stringent the need for restoring exact anatomical relationships. Fracture of the distal radius forms no exception to this rule.

In evaluating the results *in the present series,* the criteria of a satisfactory reduction were defined as follows:

1. Dorsal angulation not exceeding 90 degrees,
2. Shortening not exceeding 2 mm in comparison with the opposite hand, and
3. Perfect apposition of the radial and volar cortical surfaces.

Fulfilment of the first two requirements is obviously essential in preventing deformity of the distal radius. Apposition of the cortical surfaces, in its turn, is particularly important in obtaining as stabile a reduction as possible.

The number of cases in which the above requirements for perfect reduction were satisfied, and their distribution over the different fracture groups are given in Table VIII. Perfect reduction was observed only in every other case. The results were better for groups II A and II B, where only dorsal angulation had to be reduced, than for fractures with complete displacement (71% and 41%, respectively). In the group of comminuted fractures, perfect reduction was only seen in every fifth case.

In the 257 cases where reduction was judged less than perfect, inexact reposition of the distal fragment was the dominating feature, observed in 159 cases. Reposition was considered inexact in all cases where the displacement of the cortex exceeded 1 mm. In 96 cases, this was the only imperfection in the

TABLE VIII. *Incidence of Perfect Reductions in Relation to Sex and Type of Fracture.*

	Type of Fracture							Total
	II A	II B	II C	II D	II E	III	Undiffer-entiated	
Men	17	4	12	5	3	1	3	45
Women	71	23	78	23	3	4	11	213
Total	88/123	27/39	90/216	28/68	6/32	5/13	14/24	258/515
Per cent	72	69	42	41	19	38	58	50

reduction, in the remaining 63 cases it was combined with dorsal angulation or shortening.

Residual dorsal angulation was observed in 108 cases, in 43 combined with other deformities. As a rule, the angulation was moderate and in only 21 cases, 18 women and 3 men, did it amount to more than 100 degrees. The high incidence of dorsal angulation as the sole residual deformity was partly due to the fact that reduction of this deformity in elderly patients often had not been attempted.

Radial shortening as the sole deformity after reduction was rare, and was only seen in a few elderly women. In these cases, an almost telescopic impaction of the proximal into the distal fragment was apparent, but the deformity was in all instances moderate.

Efficiency of Immobilization

The frequency of redisplacements may be taken as a yardstick for evaluating the efficiency of immobilization. Redisplacement is one of the fundamental problems in the treatment of fracture of the distal radius, due to the fact that it is a characteristic compression fracture (White, 1940). Cornell (1935), among others, observed that the force of injury produces a triangular zone of compression on the dorsal portion of the bone if there is any noticeable dorsal angulation. A similar zone radially results from the radial displacement. Cornell furthermore contended that an abrupt reduction manoeuvre ran the risk of increasing this damage to the bone and that volar flexion could cause crushing of the volar cancellous bone, something which does not normally occur in a typical fracture of the distal radius.

It has long been recognized that union of the fracture in a good position cannot be expected unless these bone defects are repaired with new bone before the hand is mobilized. The desire to encourage this process as much as possible is the underlying principle of most of the different methods recommended for the position of the hand during immobilization, plaster fixation, internal fixation, and similar details discussed in the preceding chapter.

It soon became obvious that the usual methods of immobilization in themselves could often not prevent the reduced fragments from slipping back to more or less the original position of fracture. Muscle pull has been considered an important factor in this connexion (Klapp, 1921; Böhler, 1923). For this reason, Zuppinger (1910) and Böhler (1923) recommended immobilization of the hand in mid-position with relaxed muscles. The brachio-radialis muscle in particular has been considered to play an important role in causing redisplacement (Böhler, 1919; King, 1932). Steinhäuser (1952) thought it essential to eliminate the supinating effect of this muscle, for which he recommended a plaster extending above the elbow.

A relatively long time elapsed before any accurate figures on the frequency of redisplacement became available. It is only during the past few decades that, among others, Scandinavian authors have begun to publish their experiences.

Nissen-Lie (1939) reported a frequency of 42% redisplacements among the displaced fractures in a series of 143 cases, immobilized by means of a dorsal plaster splint. Höjensgaard (1945) found in a comparable series of 217 patients a frequency of 24% redisplacements, which in 18% were severe. He believed these figures to represent the minimum frequency to be expected. It was a complication which occurred predominantly in elderly people and was more frequent in women than in men. The fractures in his series had been immobilized for 3–5 weeks. The above figures represent the average frequency among all fractures of the distal radius, including those without displacement. In his group of displaced fractures not involving the joint the frequency was 28.6%, among comminuted fractures 40.6%.

Madsen (1946) contended that the simple precaution of letting the plaster extend above the elbow can lower the number of redisplacements considerably. Immobilization with only a dorsal splint gave in his series a frequency of 59% redisplacements, a circular plaster which included the elbow 11%. Madsen counted even the slightest loss of position as redisplacement. In a later publication from the same hospital, Hölund (1957) reported a frequency of 46% redisplacements, despite the fact that the elbow had been immobilized according to the method adopted as a result of Madsen's observations. Sirbu and Collof (1951) considered it essential to change the plaster fixation around ten days post reduction. In a series of 46 cases where the hand was initially immobilized in 35 degrees palmar flexion, redisplacement of the fracture occurred in every one of the cases where the same plaster was retained during the entire immobilization period of 5 weeks, whereas a frequency of only 33% was found in cases where the original fixation was discarded after 10 days. Gartland and Werley (1951) similarly immobilized the hand for two weeks in strong palmar flexion by means

TABLE IX. *Incidence of Redisplacements in Relation to Age and Sex.*

	Years						Total
	15–25	26–35	36–45	46–55	56–65	66–75	
Men	2	1	5	13	7	0	28
Women	0	2	3	20	56	34	115
Total	2	3	8/54	33/138	63/186	34/78	143/515
Per cent			15	25	34	43	28

of a dorsal and volar plaster splint, but did not immobilize the elbow. Despite this, they observed a frequency of 60% redisplacements. Wiklund and Müllern-Aspegren (1956) determined the occurrence of redisplacement on the basis of dorsal angulation and shortening. A dorsal angulation of or exceeding 5 degrees and a shortening of 2 mm was recorded as a redisplacement. With this rating they found a 37% frequency in fractures with clear primary displacement.

In the present series, only such an obvious deformity as an increase of dorsal or volar angulation of at least 10 degrees, or a shortening amounting to 4 mm was registered as redisplacement. There were two reasons for choosing such high criteria. In the first place, the measurements on which this evaluation was based were, as mentioned earlier, no more than approximate. In the measurement of dorsal angulation, even the slightest deviation in projection could influence the results. Such variations in projection are to be expected in a routine series such as the present one. To be taken into account, therefore, any loss of position had to be so obvious that the possibility of technical variations simulating a redisplacement could be dismissed. A second consideration was the clinical aspect. It was felt that to be recorded as redisplacement, the loss of position should have clinical significance, i.e. require attention as a complication liable to affect the functional result.

On the basis of these criteria, 144 (28%) redisplacements were recorded. Table IX illustrates their distribution in relation to age and sex of the patients. The increased incidence in the higher age groups was to be expected in view of the greater fragility of the skeleton to which, in particular, elderly women are liable. There was no difference between men and women in frequency of redisplacement.

The incidence of redisplacement in relation to type of fracture is shown in Table X. Redisplacements were twice as common in the group of completely displaced fractures as compared to the group with merely dorsal angulation.

TABLE X. *Incidence of Redisplacements in Relation to Type of Fracture.*

	Type of Fracture							Total
	II A	II B	II C	II D	II E	III	Undifferentiated	
Incidence of redisplacements	17/123	6/39	68/216	22/68	17/32	4/13	9/24	143/515
Per cent	14	15	31.5	32	53	32	41	28

Comminution of the fracture further increased the incidence. Some joint involvement without comminution, on the other hand, did not predispose towards redisplacement. These figures are hardly surprising considering that severe primary displacement causes extensive crushing of the cancellous bone, resulting in instability of the fracture. What is surprising is that even mild fractures in a considerable number of cases showed redisplacement.

As an additional point of interest, an attempt was made to determine whether the quality of the reduction had any significance for the frequency of redisplacement. As mentioned before, the roentgenograms had shown an entirely successful reduction in 50 % of the total series. Table XI shows the number of redisplacements in relation to the quality of reduction. For adequately reduced fractures a total redisplacement frequency of 19 % was found. For less perfectly reduced fractures this figure was 37 %. Although it undoubtedly had some effect in preventing redisplacement, accurate reduction was in no way a guarantee against this complication.

It seems reasonable to suppose that poor apposition of the cortex on reduction plays a major rôle in causing redisplacement. In such cases, the distal fragment comes to rest entirely or partially on a portion of the metaphysis consisting of loose cancellous tissue. Under such conditions, it seems extremely likely that the shaft of the radius will be pressed into the fragment.

The roentgenograms showed poor apposition, either radially, volarly or in both areas, in 159 cases. The incidence of redisplacements in this group is shown in Table XII. Redisplacement of the fracture occurred in every other of the cases with poor apposition, proving that this component of the reduction plays an important rôle. It appeared to be of no consequence, on the other hand, in which part of the roentgenogram this imperfection in the reduction was observed.

In 75 cases the reduction was only marred by some residual dorsal angulation. Redisplacement occurred in 17 (24 %) of these cases. In 14 cases it appeared as a further increase of dorsal angulation without any appreciable effect on the

TABLE XI. *Incidence of Redisplacements in Relation to Achieved Reduction.*

	Type of Fracture						
	II A	II B	II C	II D	II E	III	Undifferentiated
Perfect Reduction:							
Incidence of redisplacements	8/88	3/27	22/90	7/28	4/6	0/4	4/16
Per cent	9	11	24	25	67	0	25
Imperfect Reduction:							
Incidence of redisplacements	9/35	3/12	46/126	15/40	13/26	4/9	5/5
Per cent	26	25	37	37	50	44	100

TABLE XII. *Incidence of Redisplacements in Relation to Poor Adaptation.*

	Incidence of Redisplacements	%
Poor radial adaptation	28/57	48
Poor volar adaptation	22/44	50
Poor radial-volar adaptation	28/58	48

other components of displacement. Compared with poor apposition of the cortex, inadequate correction of dorsal angulation appeared to have less significance as a contributing factor to redisplacement.

The direction and extent of redisplacement showed considerable variety. Sometimes there was an almost complete return of the original displacement, in other cases the loss of position was only partial, causing an increase of either dorsal angulation or shortening but with no appreciable effect on the other components of the reduction. Table XIII shows the direction and extent of redisplacement in relation to type of fracture. The group with combined displacement included 7 cases with volar angulation and shortening. In 106 of the 144 cases where redisplacement occurred, the loss of position was of little consequence. In 40 of these cases the appearance of the wrist was found to be completely normal on follow-up examination. Although the frequency of redisplacement was high, its clinical significance was in most instances slight.

Repeated attempts at reduction, resulting in further damage to the cancellous bone, was considered as an additional factor which might tend to increase the frequency of redisplacement. In 55 cases it had been necessary to re-reduce the fracture, in some instances several times. In 22 cases these attempts resulted

TABLE XIII. *Direction and Degree of Redisplacement in Relation to Type of Fracture.*

	Type of Fracture													
	II A		II B		II C		II D		II E		III		Undifferentiated	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Dorsal angulation:														
Slight (10–20°)	10	8	4	10	10	5	5	7	2	6	1*	8	2	8
Considerable (21–30°)	5	4	1	2.5	7	3	1	2	0	0	0	0	1	4
Severe (> 30°)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shortening:														
Slight (4–9 mm)	2	2	1	2.5	26	12	10	15	9	29	2	16	4	17
Considerable (10–15 mm)	0	0	0	0	1	0.5	1	1.5	0	0	0	0	2	8
Severe (> 15 mm)	0	0	0	0	1	0.5	0	0	0	0	0	0	0	0
Combined displacement:														
Slight	0	0	0	0	14	6	3	4	4	12	1*	8	0	0
Considerable	0	0	0	0	5	2.5	2	2.5	2	6	0	0	0	0
Severe	0	0	0	0	4	2	0	0	0	0	0	0	0	0
Total incidence	17/123	14	6/39	15	68/216	31.5	22/68	32	17/32	53	4/13	32	9/24	37

* Volar angulation.

in a reduction which in the roentgenograms appeared satisfactory. Redisplacement occurred in 21 (40%) of the 55 cases, 10 of them belonging to the group where accurate reduction had not been achieved. This factor appeared to have no clear effect on the frequency of redisplacement.

In 20 cases with considerable or extreme redisplacement, an attempt was made to correct the position by a new reduction. In most cases this was attempted after about 10 days. In 6 patients considerable and permanent improvement was obtained and on follow-up examination the appearance of the wrist was normal. In an additional 5 cases the attempt succeeded in partially restoring normal relationships. In the remaining cases it had no effect whatsoever.

Time of redisplacement. Of 49 redisplacements in a series reported on by Madsen (1949), 29 occurred within the first two weeks following reduction, 11 during the third week, and 9 during the fourth and fifth weeks. Cornell (1935) considered the crucial period to be the second week, Sirbu and Collof (1951) the first ten days.

In the present series, post-reduction examination of the patients had taken place at more or less irregular intervals, so that a detailed and accurate evaluation of this point was not possible. It could be established, however, that it was often difficult to fix the occurrence of redisplacement at any particular time in the post-reduction course. In many cases the loss of position took place gradually and its various stages could be followed at successive roentgen examinations.

Recovery of Function

It is extremely difficult in a routine clinical series to determine the average time required for restoration of function. The patients are predominantly middle-aged or elderly women engaged in more or less heavy housework, or who are retired. The usual household tasks are gradually resumed, often immediately following removal of the fixation, and the patients find it impossible to state when a stationary condition was reached.

The problem takes a somewhat different aspect where compensation cases are concerned, since here the period of absence from work may be taken as a yardstick of the duration of disability. Magnus (1933) found an average disability period of 54 days in a series of miners. Ehalt (1935) gave the average period of disability for a series of 81 cases handled by the Austrian Accident Insurance Company as 57 days, but the fact that more than half of these cases received disability compensation for over a year decreases the significance of this figure. Valtonen (1948) reported full recovery of function within two months in 72% of a series of compensation cases in Finland, but in this instance the average age lay below 40 years. Most authors (e.g. Rosen, 1947) consider two months disability normal.

In the present series, determination of the period of disability in each individual case could only partly be based on the hospital records. Not only were these brief, but it often happened that patients whose treatment had been concluded in a short time in the follow-up examination volunteered information about symptoms of long duration which had caused disability, even though they had not prompted a return visit to hospital. The information supplied by the patient became therefore necessarily an important factor. For this reason, obviously, the results of the evaluation were somewhat inconclusive, but it was possible to form some idea of the incidence of complications during the post-reduction course.

A period of 3 to 3.5 months was determined as the maximum time of disability that can be regarded as normal for fracture of the distal radius. In 77 cases (15%), including 70 women and 7 men, function of the wrist was still strongly

TABLE XIV. *Posttraumatic Complications.*

	Men	Women
Causalgia, including pain, finger swelling, stiffness, and weakness	3	50
Loss of mobility at the wrist	3	13
Weakness, tremor	0	6
Nerve injury	0	2
Rupture of extensor pollicis longus tendon	0	1

impaired by the end of this period and the pre-injury activities had not been resumed.

The symptoms underlying this impairment of function are listed in Table XIV. Twelve patients reported prolonged shoulder stiffness, in all cases combined with symptoms from the hand. The two nerve lesions consisted of an injury to the ulnar nerve and an injury to the median nerve. In the former instance the damage was severe, causing loss of sensation and muscle atrophy, whereas the effects of the median nerve injury passed off fairly rapidly. Nerve injuries proved to be a rare complication, and the results of this study in no way support the theory proposed among others by Turner (1924) and Sisefsky (1950), that the effects of such injuries may be obscured by other symptoms and thus have a higher frequency than commonly believed.

The one case of rupture of the extensor pollicis longus tendon occurred 2 months after injury. Immediate tenoplasty was performed, with satisfactory results.

Extensive literature is available at the present time on these posttraumatic ruptures. Over one hundred cases have been described and a variety of operative procedures presented. Figures on the incidence of this complication range from 1 in 270 (Kwedar and Mitchell, 1940) and over 1 in 400 (Oppolzer, 1933) to practically nil, as reported by Ehalt (1935), who believed this to be due to the high accuracy of reduction. The etiology of the injury is still undecided. Kleinschmidt (1929) believed the damage to be caused by fracture fragments at the moment of injury; Hauck (1923), Lipschutz (1935), Smith (1946), and Trevor (1950), among others, regarded it as due to a necrosis of the tendon resulting from damage to the vessels in the mesotendon. Several authors, finally, mention the oblique course of the tendon as a predisposing factor (McMaster, 1932; Björkroth, 1941; Smith, 1946).

Chapter 6

END RESULTS

Review of Earlier Investigations

Although the literature on fracture of the distal radius is abundant, the number of systematic follow-up studies permitting an evaluation of the final results of treatment is relatively small. In most of the literature, the authors' conclusions regarding principles of treatment and prognosis are based on mere impressions from everyday clinical work.

For an appraisal of the end results reported in earlier studies, it is important that material and methods be comparable. A strict comparison would require data on age and sex incidence, type of fracture, degree of displacement, technique and duration of immobilization, period of follow-up, and methods and criteria used in evaluating the end results. However, as it proved to be the exception rather than the rule to find adequate information on all these points in the literature, a basis of comparison narrowed down to one common factor had to be accepted. In the following discussion of end results reported in the literature, the common denominator is, unless stated otherwise, displacement of the fracture.

Storp (1896) used a special technique, merely immobilizing the hand by means of a small adhesive dressing suspended from a sling. Of 95 patients, 91 were discharged with perfect functional and cosmetic results. No information is given on type of fracture. Rosenbach (1902) published a detailed report on a series which included children. The period of observation varied from only a few to more than 20 years. Roentgen examination was not made. In 70% of his series no residual deformity could be observed, moderate deformity was found in 20%, and severe deformity in 10%. Satisfactory function had been restored in 70%, slight impairment of function was found in 19%, and poor function in 11%. The group in which results were considered satisfactory included a number of cases with slight loss of mobility and some residual deformity. Kranz (1910) analyzed 300 cases where the fracture had been immobilized by means of a flannel bandage according to Lexer's technique. No information is given about age, type of fracture, or period of follow-up. Full recovery was obtained in 92.7%, in 2.7% function was somewhat impaired, and in 1.8% it was extremely poor.

The first Scandinavian study was published by Troell (1913). His series of 117 cases included both undisplaced and severely displaced fractures. The hand was immobilized in palmar flexion by means of either an adhesive dressing or a splint. Good functional results were obtained in 76% of the total series, satisfactory anatomical results in 80%. The group with displaced fractures showed less favourable results; in only 42.8% of these cases was function entirely unimpaired. Bange (1921) published an end-result study of 650 cases treated between 1907 and 1921. Different techniques had been used for immobilization, a factor which was clearly reflected in the final figures, the proportion of unsatisfactory results varying from 2.8% to 13.4%. Eskelund (1927) examined a series of 206 cases, constituting a typical out-patient population. After only a short time, 8 days at most, of immobilization with the hand in palmar flexion, mobilization exercises were started at once. Functionally, the results were excellent in 60%, good in 33%, fair in 6%, and poor in 1%. The anatomical results were excellent in 55%, good in 36%, and fair in 9%. Poor anatomical results were not seen.

Edwards and Clayton (1929) evaluated end results in a series of 321 patients on the basis of a questionnaire. Full recovery was reported by 73.2% of the patients, 23% had mild symptoms consisting of pain after exertion, swelling, and stiffness, whereas 3.7% regarded function of the wrist as poor. Grosby and Trick (1929) reported undoubtedly the worst results ever published. In a series of 50 cases, the results were rated as poor in 62.5% and as merely fair in the remaining cases. However, the authors do not state exactly on what criteria their evaluation was based. Platt (1932) reported excellent results in 83%, good results in 14%, and poor results in 3% in a series of 111 cases. No information is given about the methods and criteria used in evaluating these end results. Hein (1935) rated end results in a series of 159 cases, of which 100 with displaced fractures. For the total series, including all cases without appreciable displacement of the fracture, the anatomical results were good in 79%, fair in 16%, and poor in 5%. Functionally, the results were good in 85%, fair in 13%, and poor in 1.3%. Kotrnetz and Geiringer (1937) described a series of 873 cases in which every type of distal radius fracture was represented. In the group with displaced fractures, the anatomical end results were on roentgen examination found to be perfect in 55.7%, good in 30.8%, fair in 10%, and poor in 3.5%. The functional end results, based on the degree of mobility of the wrist, were perfect in 68%, good in 25%, fair in 5.1%, and poor in 0.9%. The cosmetic results were considered perfect in 58.5%, good in 24.7%, fair in 12.3%, and poor in 4.5%. The subjective rating, finally, based on the patient's opinion of the results, was as follows: excellent in 83%, good in 10%, satisfactory in 4%, and poor in 3%. The period of follow-up of the patients, who made up a normal clinical series, varied from 1 to 5 years. The treatment in this series had a special feature in that reduction was generally not attempted until 24 hours after injury, in order to avoid early posttraumatic circulatory disturbances. These authors classified their cases in 7 different groups and although they considered it inadvisable to combine end results for the different fracture types, this has been done here in order to permit comparison with the results reported by other authors. Graham (1938) examined a series of patients treated by various surgeons, either in private practice or in different hospitals in New York. Of 125 cases, the results were good in 66%, fair in 17%, and poor in 17%. Residual deformity was observed in 25%, loss of flexion in approximately 50%, impaired finger mobility in 20% and loss of supination in 17%. Nissen-Lie (1939) analyzed a series of 133 cases. In all cases the deformity to be corrected had been severe. On roentgen examination exact anatomical reduction was observed in scarcely $^{1}/_{7}$ of all cases. The author does not state on what criteria his evaluation was based, however. In 77.5% of the series no functional impairment was found. White (1940) found in a series of 66 cases with primary displacement of the fracture good functional results in 59.3%, fair results in 28.8%, and poor function in 11.9%. Residual deformity was present in 68.2%. The period of follow-up was short, varying from 3–12 months. Rosen (1947) reported 65% excellent functional results in a series of 140 displaced fractures, 27% fair results, and 8% poor results. The corresponding figures regarding the anatomical results were 61%, 22%, and 17%. Madsen (1949) found the results unsatisfactory in 8.65% of his series. This rating was given if the patient was unable to resume pre-injury activities or if the loss of mobility exceeded 30 degrees. The period of observation in this series was 7–24 months. Cassebaum (1950) collected a series of 81 cases from various hospitals. The period of follow-up varied from 1–2 years. He found excellent functional results in 75%, good results in 20%, and poor results in 5%. The group with excellent results included cases with some residual deformity and loss of mobility not exceeding 15 degrees. Gartland and Werley (1951) published a careful analysis of 60 displaced fractures. The average follow-up period was 18 months. Satisfactory functional results were obtained in 68.3%. Their evaluation was based on a point system taking into account subjective symptoms, deformity, loss of mobility, and any complications such as arthritis and nerve injuries. Hoffman (1953) examined 35 patients with displaced fractures more than one year after injury. He found good functional results in 54.3%, fair results in 34.3%, and poor results in 11.4%. The normal appearance of the wrist had been restored in 43.3%, whereas fair cosmetic results were observed in 31.4% and poor results in 26.3%. Follow-up roentgen examination showed that normal anatomical relationships had been restored in only 26.3% of the series. Mason (1953) analyzed 100 cases with gross displacement of the fractures 16–20 months after injury. Satisfactory functional results were recorded in 95%, normal appearance of the wrist in 70% of this series. Green and Gay (1956) considered the results unsatisfactory in 17.3% of their series, but in this case end results were rated as early as 12–16 weeks after injury. The series comprised 75 cases. Wiklund and Müllern-Aspegren (1956) found in a series treated at Sabbatsberg Hospital in Stockholm more or less severe residual deformity in over 30%. A comprehensive evaluation of the functional end results, based on both subjective symptoms and objective findings, was not made by these authors. Hölund (1957) presented a series of 103 cases. The follow-up period was 2–2.5 years. On the basis of a roentgen examination the anatomical results were rated as good in 38%, as unsatisfactory or extremely poor in another 38%, and as fair in 24%. Subjectively, 74% of the patients were entirely satisfied with the result.

Several end-result studies have been published concerning compensation cases. Magnus (1933) reported results for a series of 428 miners. No information is given about type of fracture. Residual disability was present in 30% of all cases at the time of the patient's return to work, but after 5 years this figure had dwindled to 2.5%. Valtonen (1948) found in a series of compensation cases in Finland no single case with more than 10% disability. Bacorn and Kurtzke (1953) reported entirely different figures from their study of 2000 cases selected from the files of the New York State Workmen's Compensation Board. The follow-up period was approximately one year. End results were rated according to the principles introduced by McBride (1942), with the emphasis placed on functional performance, such as coordination, nimbleness, strength, and resistance to strain. Full recovery was obtained in only 2% of all cases. The average impairment of function was estimated at 24%. In 94.5% there was a loss of palmar flexion, in one-third of the series a defect of pronation and supination.

In the present series, end results were rated 15 months to 8 years after injury, making an average follow-up period of 3 years and 9 months. After recording the nature and severity of the subjective symptoms, an objective evaluation was made of cosmetic and anatomical results, loss of mobility, strength of the grip, neurologic signs and symptoms from the distal radio-ulnar joint. The sum total of these observations formed the basis for the final evaluation of function in the injured wrist reported in chapter 7.

Frequency of Weakness and Pain

A total of 236 patients (45.8%) reported on follow-up examination subjective symptoms from the injured wrist. In 133 cases the symptoms were so mild, however, that the patients regarded them as negligible and in no way affecting satisfactory function of the wrist.

Among the rather varied complaints, the most common was a sensation of *weakness in the hand and wrist.* This symptom was reported by 141 of the 236 patients. Generally, the weakness was apparent only in activities involving particular strain on the wrist, such as carrying a suitcase or opening a can. A large group of patients, on the other hand, stated that strength in the wrist was adequate for work in which the hand was held vertical, but that they were unable to lift even fairly light weights with the forearm in a horizontal position. In particular, weight-bearing with the hand in supination, as in carrying a tray or emptying a saucepan, was reported to cause difficulties.

Pain following exertion proved to be the second most common symptom; it was the chief complaint in 59 cases. Both the intensity of the pain and, even more, its duration varied greatly. Twenty-seven patients reported spontaneous pains, as a rule not very severe, coinciding with changes in the weather.

Continuous pain independent of exertion, changes in weather, or other outside factors, was reported by 9 patients. In all cases the pain was so severe that analgesics were required. Mainly for this reason, this group of patients was classified as disabled.

Thirty-four patients suffered from a condition best designated as *decreased resistance to strain.* Use of the arm resulted after a shorter or longer time in a sensation of tiredness, not felt under similar strains before injury. There was no actual pain, although a feeling of tenderness over the wrist was not uncommon.

Pain on weight bearing was a common symptom, reported by 54 patients. In these cases the pain did not last for some time following exertion, but it set in the instant the patient lifted something or made an exaggerated movement, and it disappeared the moment the weight on the hand or wrist was relieved. After some time, the patient instinctively learnt to protect the hand so that the symptoms automatically became greatly reduced.

Forty-eight patients complained on follow-up examination of *decreased mobility at the wrist.* Objectively, a loss of mobility could be demonstrated in 250 cases. This stiffness could be a disadvantage under certain conditions, for instance, if a special grip was required to play a musical instrument or to perform certain handicrafts, but the majority of patients considered the function of the wrist not significantly impaired by the loss of mobility. A defect of pronation and supination was the most common complaint.

Swelling following exertion of the arm was reported by 20 patients. No objective confirmation of this symptom could be obtained on follow-up examination.

A small group of 7 patients reported mild symptoms most accurately described as *locking.* At a certain point, generally in the final phase of pronation or supination movements, the patient had a sensation of the wrist locking. This locking, which in all cases was associated with some pain, could always be undone by moving the wrist in different directions.

Anatomical and Cosmetic End Results

ANATOMICAL RESULT

Depending on the degree of residual deformity found by measuring the follow-up roentgenograms, the patients were divided into four groups:

1. No or insignificant deformity: dorsal angulation not exceeding 90 degrees, or shortening of less than 3 mm.
2. Slight deformity: dorsal angulation of 91–100 degrees and/or shortening of 3–6 mm.
3. Moderate deformity: dorsal angulation of 101–114 degrees and/or shortening of 7–11 mm.
4. Severe deformity: dorsal angulation of or exceeding 115 degrees and/or shortening of at least 12 mm.

The anatomical end result for the total series is presented in Table XV. Table XVI gives the results in relation to type of fracture. Entirely satisfactory results were found in every fourth case, poor results in 5% of the series. Results were better in the two groups with negligible displacement of the fracture. As the two factors which determined the anatomical end result were accuracy of reduction and efficiency of immobilization, this observation was hardly surprising, since both the number of unsatisfactory reductions and the incidence of redisplacements were lower in these groups. Still, even among these "innocent" fractures moderate or severe deformity, mostly residual dorsal angulation, was observed in nearly every fourth case. The decidedly most unfavourable results were found in the group with comminuted fractures, where moderate or severe deformity was present in 72%.

COSMETIC RESULT

In evaluating the cosmetic result even slight deviations from the normal, scarcely noticed by the patients themselves, were taken into account. Depending on the degree of deformity, the patients were classed in 4 groups:

1. Normal appearance,
2. Normal appearance except for prominence of the capitulum ulnae,
3. Slight radial deviation,
4. Moderate to pronounced radial deviation, silverfork deformity.

The results for the total series are presented in Table XVII, whereas Table XVIII shows the results in relation to type of fracture. Perfect cosmetic results were seen in 60% of the series, moderate or pronounced deformity in 11%. On the whole, the cosmetic and anatomical results agreed, although in many cases even fairly considerable anatomical deformity did not cause any cosmetic disfigurement. This depended in part on the amount of soft tissue, and furthermore

TABLE XV. *Anatomical End Results.*

	No. of cases	%
No deformity	124	*24*
Slight deformity	197	*39*
Moderate deformity	166	*32*
Severe deformity	28	*5*
Total	515	*100*

TABLE XVI. *Anatomical End Results in Relation to Type of Fracture.*

	Type of Fracture													
	II A		II B		II C		II D		II E		III		Undifferentiated	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
No deformity	46	*37.5*	13	*33*	38	*18*	13	*19*	4	*12.5*	5	*38*	5	*20*
Slight deformity	51	*41*	16	*41*	81	*37.5*	28	*41*	5	*15*	2	*15*	14	*60*
Moderate deformity	23	*19*	9	*23*	80	*37*	27	*40*	19	*60*	3	*23.5*	5	*20*
Severe deformity	3	*2.5*	1	*3*	17	*7.5*	0	*0*	4	*12 5*	3	*23.5*	0	*0*
Total	123	*100*	39	*100*	216	*100*	68	*100*	32	*100*	13	*100*	24	*100*

TABLE XVII. *Cosmetic End Results.*

	No. of cases	%
Normal appearance	309	*60*
Prominent capitulum ulnae	56	*11*
Slight radial deviation	94	*18*
Silverfork deformity	56	*11*
Total	515	*100*

on the type of deformity which dominated in the roentgenogram. Dorsal angulation not exceeding 105 degrees, 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-

TABLE XVIII. *Cosmetic End Results in Relation to Type of Fracture.*

	Type of Fracture													
	II A		II B		II C		II D		II E		III		Undifferentiated	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Normal appearance	95	*77*	27	*69*	115	*53*	42	*62*	10	*31*	5	*39*	15	*63*
Prominent capitulum ulnae	12	*10*	7	*18*	23	*11*	5	*7*	1	*3*	3	*23*	5	*21*
Slight radial deviation	13	*11*	5	*13*	46	*21*	13	*19*	12	*38*	3	*23*	2	*8*
Silverfork deformity	3	*2*	0	*0*	32	*15*	8	*12*	9	*28*	2	*15*	2	*8*
Total	123	*100*	39	*100*	216	*100*	68	*100*	32	*100*	13	*100*	24	*100*

tissue injury in the distal radio-ulnar joint causing the end of the ulna to displace ulnarwards and palmarwards.

For the category of patients making up this series, the residual deformity was important only in exceptional cases. If the deformity was not combined with any functional defects, the patients generally declared themselves fully satisfied with the result.

Loss of Mobility

A loss of mobility was not registered unless it exceeded 10 degrees in any direction in comparison with the opposite hand. In twelve cases, there was a history of a distal fracture of the "sound" wrist, but as mobility on this side was within normal limits and permitted comparison, these cases also were included. A defect of palmar flexion was sometimes found without any other impairment of mobility, but in all other cases more than one movement was limited. Table XIX shows the incidence of impaired mobility in relation to type of fracture. A residual loss of mobility was observed in 48 % of the total series. Although lower than for the groups with severely displaced fractures, the incidence was high even for less complicated fractures. In the group with comminuted fractures, 4 out of 5 cases showed loss of mobility.

As illustrated by Table XX, there were large variations in both the degree of impairment and the direction in which motion was restricted. A loss of palmar flexion was the most common defect, seen in 41 % of the total series, whereas a defect of dorsal flexion was present in 14 %. In 113 cases palmar flexion was the only movement that had become restricted. A defect of either pronation or supination, or of both movements, was present in 62 cases (12 %).

TABLE XIX. *Incidence of Impaired Mobility in Relation to Type of Fracture.*

	Type of Fracture							Total
	II A	II B	II C	II D	II E	III	Undifferentiated	
Incidence of cases with impaired mobility	44/123	19/39	104/216	38/68	26/32	7/13	12/24	250/515
Per cent	36	49	48	56	81	54	50	48.5

TABLE XX. *Loss of Mobility.*

Loss of	10–19°	20–29°	30–39°	40–49°	50–59°	Total	% of total series
	No. of cases						
Palmar flexion	92	79	32	5	2	210	41
Dorsiflexion	43	23	7	0	0	73	14
Ulnar deviation	64	14	0	0	0	78	15
Radial deviation	36	0	0	0	0	36	7
Pronation	26	3	3	6	0	38	7.5
Supination	26	8	4	6	3	47	9

As a rule, the loss of mobility was slight; in the majority of cases it did not exceed 20 degrees.

It was remarkable that even a considerable restriction in the range of motion, such as a defect of palmar flexion amounting to 25–30 degrees, had often gone unnoticed by the patient. In 89 cases where the loss of mobility was large enough to be recorded, the patient himself considered the function of the wrist completely restored at the time of the follow-up examination. Only 48 patients spontaneously mentioned the rigidity.

Loss of finger mobility of any consequence was observed in 22 cases (4%), representing all types of fracture. The loss of mobility was slight, except for one case where signs of a posttraumatic dystrophy had been present and where it was so severe that the tips of the fingers could not be made to reach the palm of the hand. In 7 cases there were signs of arthritis with swelling over the interphalangeal joints and occasionally roentgenologic changes. In a few cases other joints also appeared to be involved, possibly indicating incipient rheumatoid arthritis. It is questionable if restriction of finger motion was in all 22 cases due to fracture of the distal radius. As a factor influencing the functional end result it had hardly any significance. The same was true for stiffness of the shoulder joint. Only 7 patients found shoulder motion on the injured side restricted after injury and on examination the loss of mobility proved in all cases slight.

Strength of the Grip

It proved extremely difficult in the follow-up examination to establish reliable criteria for evaluating a possible impairment of muscle power. Examination was made by the common clinical method of measuring the strength of the handgrip by means of a dynamometer. The average value of three successive measurements was taken as a measure of the muscle power. With this system, evaluation is based on a comparison between both hands and presupposes normal conditions in the "sound" wrist. This requirement could not be satisfied in 34 cases because of old finger injuries, signs of polyarthritis, brachialgic pains, or other symptoms, and these cases were consequently excluded. Likewise, it was difficult to determine within what limits a difference in strength between the two handgrips could still be regarded as normal. Not only must this factor be subject to large individual variations, but it is also bound to vary at different times of examination. To be registered as an impairment of muscle power, it was decided that the average value for the injured leading hand must be clearly lower than for the opposite hand. If the injury involved the non-leading hand, the average value of 3 measurements must be 50% lower than for the opposite hand.

Using this system of rating, impairment of muscular power was registered in 84 (17.5%) of 481 cases. In groups II C and II D, the incidence was twice that of groups II A and II B. The highest incidence was found in the group of comminuted fractures. There was very little agreement between the patients' subjective evaluation of strength in the wrist and the objective evidence of impaired strength as provided by the dynamometer test. Sixty-eight of the 84 patients thought strength in the hand and wrist adequate and considered function in this respect complety restored.

Neurologic Signs

Five patients, all women, reported numbness in the two ulnar fingers as a residual symptom. In all cases these subjective symptoms were mild and in only one case they were supported by the objective evidence of a loss of sensation in the fifth finger to pinprick and touch, together with atrophy of the hypothenar muscles. Starting four months after the injury, this patient suffered for some time from intense pain over the ulnar aspect of the wrist which was aggravated by motion at the wrist. Six months after injury a distinct paresis of the ulnar nerve was diagnosed as the cause of a loss of sensation. After some months the symptoms regressed spontaneously and exploration of the ulnar nerve, which had been discussed, proved unnecessary. In another case, where the distal fragment had been displaced volarwards, the patient reported subjective symptoms from the distribution of the median nerve causing paraesthesias, but no objective signs of this were found. No other patient in this series reported symptoms which could be interpreted as a so-called carpar tunnel syndrome.

Symptoms from the distal radio-ulnar joint will be discussed separately in a later chapter.

Chapter 7

CLASSIFICATION OF END RESULTS

In a clinical analysis of the type of series presented here, the selection of criteria for evaluation of the functional end results is extremely important, since this to a great extent determines both the author's and the reader's interpretation of the final results of treatment. A first condition is, therefore, to define the factors that are significant. These may vary depending on the patients' age, sex, occupation, social standing, etc., and the factors selected as significant in this study are consequently valid only for a series of Swedish patients treated at a surgical out-patient department.

The two essential factors to be considered are the objective findings and the patients' subjective evaluation of function of the wrist as compared to pre-injury conditions. For the patients the latter factor is the decisive one. Only in exceptional cases do they attach much importance to perfect cosmetic results and unrestricted mobility, requirements which are often considered essential in an evaluation of end results. This is illustrated by the fact that objectively demonstrated loss of mobility, as mentioned previously, had only in a small proportion of cases been noticed by the patients themselves. This is not surprising, considering that the unskilled labour in which practically all housewives are engaged hardly ever requires the full range of motion of the wrist. To classify all cases with a 25-degree loss of palmar flexion as unsatisfactory functional results would, in view of these considerations, paint the clinical picture darker than it is in reality. On the other hand, a small category of patients have a tendency to minimize their symptoms, and it would hardly be justified to regard a case of a 60-degree loss of pronation and supination as a good functional result, even though the patient may not experience any direct inconvenience from the stiffness of the wrist. In view of these considerations, any final evaluation of the functional end result must inevitably represent a compromise.

On the basis of the clinical findings, the results for the present series were classed into four groups:

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

2. *Good results:* Function of the wrist unimpaired. Negligible subjective symptoms. Deformity accepted if not producing subjective symptoms.

3. *Fair results:* Function of the wrist less satisfactory for activities requiring

TABLE XXI. *Classification of End Results.*

	No. of cases	%
Excellent results	214	*41.5*
Good results	195	*38*
Fair results	61	*12*
Poor results	45	*8.5*
Total	515	*100*

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.

4. *Poor results:* Working capacity diminished or general way of life affected. Cases with continuous pain.

The limits between fair and poor results were often not very clearly defined; in the following analysis of end results, these two groups have therefore generally been combined into one class designated as "*unsatisfactory* functional end results".

The functional end results for the total series are shown in Table XXI.

A review of the literature makes it clear that opinions on the outcome of these fractures are remarkably varied. Some authors regard fracture of the distal end of the radius as a major injury with doubtful prognosis, whereas others claim uniformly satisfactory results. Expressed in figures, the results range from almost 100 per cent good functional results in Ehalt's series from the Böhler Clinic, to 62.5% poor results in the study published by Grosby and Trick, and an average loss of function of 24% according to the figures reported by Bacorn and Kurtzke from a series of compensation cases. The final result of treatment is not the only controversial point; equally little agreement exists about a number of details, as, for instance, the incidence of various complications.

This divergency of opinion seems surprising, considering that it concerns an anatomically limited and fairly uniform type of fracture, for which treatment, apart from certain details, is based on uniform principles. The explanation may to some extent lie in variations in either the technical details or the quality of treatment. Still, it is practically impossible to establish a clear correlation between the varying quality of the results and variations in technique. Some particular technique, such as letting the plaster fixation extend over the elbow, may improve results in the hands of one surgeon, whereas others may regard it as ineffective and without importance for the final result. It would seem, therefore, that technical variations are of only minor importance. The essential cause of the discrepancies in the literature must rather be sought in the variety of criteria applied in evaluating residual symptoms. The importance of impaired mobility has already been mentioned as one of the disputed points. Some authors (Madsen, 1949) classify all cases with a defect of palmar flexion amounting to 15 degrees as unsatisfactory functional results, whereas others (Cassebaum, 1950) include those cases in the group of excellent results. Even a small detail like this can produce considerable differences in an evaluation of end results.

Bacorn and Kurtzke (1953) reported only 2% entirely satisfactory results in their series of American compensation cases and, on the basis of the principles introduced by McBride, rated the average disability at 24%. They recorded the objective findings in a typical case, where 25% disability compensation had been awarded, as a moderate defect of dorsal and volar flexion, slight loss of lateral motion, slight loss of flexion in the second, third, and fourth fingers, and some swelling of the wrist. The authors admitted that such defects, which were common in their series, "are of minor importance for the unspecialized use of the hand. Nevertheless, such considerations should not militate against the recognition of actual disability." Provided there were no subjective symptoms of any importance, a case with this final result would undoubtedly in most studies by both patient and author have been classified as a "satisfactory result".

The figures obtained on the basis of the criteria used in the present evaluation lay somewhere between those reflected by the two extreme points of view. It did become clear that a fracture of the distal end of the radius in most cases causes certain permanent deviations from the normal with respect to both anatomical relationships, cosmetic appearance and mobility. Only in a small number of cases, however, did the fracture cause any permanent impairment of function, whereas disability, which was generally limited, occurred only in every tenth case. Although this may seem a satisfactory result, in view of the high frequency of fracture of the distal radius it still means a considerable number of more or less disabled patients every year.

Chapter 8

ANALYSIS OF FACTORS SIGNIFICANT FOR THE LATE RESULT

CLINICAL ANALYSIS

It has been mentioned in a previous chapter that every year a fairly large number of patients are left with more or less severely impaired function of the wrist as a consequence of fracture of the distal radius. This stresses the need for an analysis to determine to what extent the individual factors that make up the clinical picture of this fracture contribute to a permanent loss of function.

In the present series, treatment had in practically all cases followed a similar pattern, so that it was impossible to determine whether technical variations in reduction or fixation of the fracture or variations in the length of immobilization might have had any influence on the results. The analysis was inevitably for the greater part restricted to the factors which could be ascertained on follow-up examination, specifically age, sex, type of fracture, fracture of the ulnar styloid process, injuries to the distal radio-ulnar joint, the anatomical end result, posttraumatic causalgia, the length of the follow-up period, and arthritis.

Age

Diverging opinions are found in the literature concerning the influence of this factor on the functional end result.

Rosenbach (1902) believed that prognosis was most favourable for patients under 40 years of age. The age group between 40 and 70 years showed uniform results, but after 70 years of age function tended to be more severely impaired. Hitzrot and Murray (1921) considered impairment of function more common in the age group over 50 years. Eskelund (1927) found the functional result more favourable in the younger age groups. Ehalt (1935), on the other hand, obtained good results regardless of age. He did find, however, that the fracture tended to heal more quickly in the younger age groups. White (1940), analyzing a series of patients between 45 and 70 years of age, found that within these limits age had no effect on the functional end result. Bacorn and Kurtzke (1953) found in their large series of compensation cases that the amount of disability showed an almost linear increase of 4% per decade. Glock, Mackel, and Brown

TABLE XXII. *End Results in Relation to Age.*

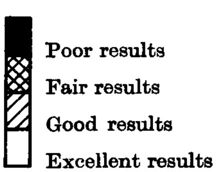
	Years																								Total no. of cases
	16–20		21–25		26–30		31–35		36–40		41–45		46–50		51–55		56–60		61–65		66–70		71–75		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Excellent results	9	*64*	5	*56*	7	*58*	10	*45*	5	*29*	14	*43*	28	*47*	33	*42*	41	*40*	39	*46*	20	*32*	3	*15*	214
Good results	5	*36*	3	*33*	3	*25*	7	*32*	7	*41*	12	*36*	21	*35*	26	*34*	37	*36*	34	*39*	31	*50*	9	*45*	195
Fair results	0	*0*	1	*11*	2	*17*	4	*18*	3	*18*	5	*15*	9	*15*	6	*8*	13	*12*	7	*8*	8	*13*	3	*15*	61
Poor results	0	*0*	0	*0*	0	*0*	1	*5*	2	*12*	2	*6*	2	*3*	12	*16*	12	*12*	6	*7*	3	*5*	5	*25*	45
Total	14	*100*	9	*100*	12	*100*	22	*100*	17	*100*	33	*100*	60	*100*	77	*100*	103	*100*	86	*100*	62	*100*	20	*100*	515

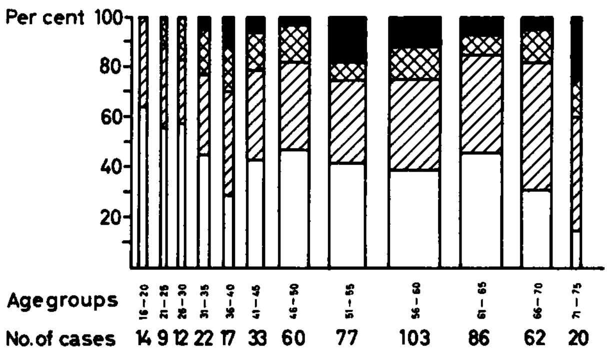
(1957) adhered to the same opinion, but presented no case material to support their viewpoint.

The relation between the functional end result and the age of the patients at the time of injury *in the present series* is illustrated by Table XXII and Fig. 8. The results pertain to the total series including all types of fracture. The lowest incidence of impaired function was found in the youngest age group, under 30 years, the highest in the oldest group, over 70 years of age, whereas the group between 50 and 60 years showed a higher incidence than the one between 61 and 70 years. A definite tendency of the results to vary in relation to age could not be discerned and the differences that were observed between the various age groups were rather slight on the whole.

It can be concluded, therefore, that in this series, made up for the greater part of patients between 50 and 70 years of age, the age factor was of minor importance for the ultimate function of the wrist. It should be noted, however, that this result is greatly influenced by the criteria used in this evaluation, with the emphasis placed on the function of the hand rather than on cosmetic appearance or loss of motion not affecting the practical use of the hand. The

Fig. 8. End results in relation to age.





number of redisplacements increased with age, producing somewhat less satisfactory anatomical results. Contrary to what might be expected, this was not accompanied by less satisfactory functional results in the higher age groups. There are two possible explanations for this. In the first place, the redisplacements were in most cases slight, and secondly, the demands made on the function of the wrist are lower where elderly people are concerned, so that fewer subjective symptoms were reported by this group. Hölund (1957) made a similar observation in his study of a series of 102 cases. In cases with residual deformity in the younger age groups, pain and weakness were reported twice as often as in the age group over 60 years, where the incidence of subjective symptoms was in no way influenced by the anatomical end result.

Sex

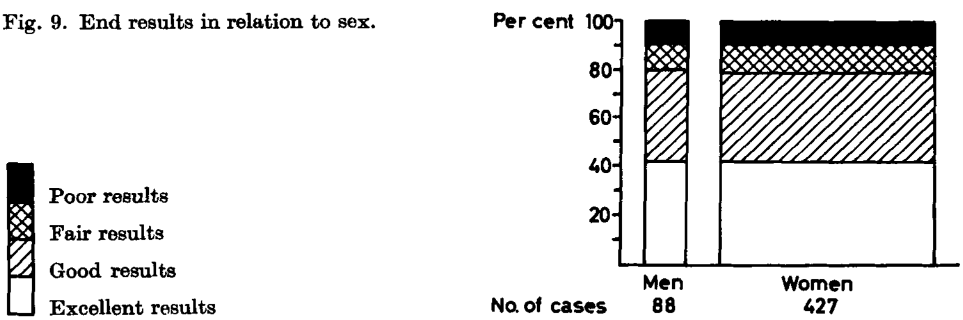
Earlier authors are unanimous in reporting that no difference can be observed between the functional end results for men and women.

This observation was confirmed *in the present series.* As illustrated by Table XXIII and Fig. 9, the functional end result was the same for both sexes, despite the fact that comminuted fractures, which have a more unfavourable

TABLE XXIII. *End Results in Relation to Sex.*

	Men		Women		Total no. of cases
	No.	%	No.	%	
Excellent results	37	*42*	177	*42*	214
Good results	33	*38*	162	*37*	195
Fair results	10	*11*	51	*12*	61
Poor results	8	*9*	37	*9*	45
Total	88	*100*	427	*100*	515

Fig. 9. End results in relation to sex.



prognosis, had a higher incidence among men. This was compensated by the fact that the average age in this group was lower. Twenty-one of the men were under 30 years of age, and this age group included only 2 cases with unsatisfactory end results.

Type of Fracture

In considering this factor, the primary question was whether severely comminuted fractures have a less favourable prognosis than fractures with comparatively slight primary displacement and joint involvement.

Among the authors claiming a definite relationship between comminution of the fracture and end results are Gartland and Werley (1951), DePalma (1953), and Glock, Mackel, and Brown (1957). Ehalt (1935), on the other hand, reported satisfactory results even for severely comminuted fractures. Kotrnetz and Geiringer (1937) found that cosmetic results were less satisfactory for fractures with serious joint involvement, but function was satisfactory in 80% of these cases with comminuted fractures.

Several authors have reported good results from small series of comminuted fractures treated with special techniques, such as adhesive or skeletal traction

TABLE XXIV. *End Results in Relation to Type of Fracture.*

	Type of Fracture														Total no. of cases
	II A		II B		II C		II D		II E		III		Undifferentiated		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Excellent results	69	*56*	14	*36*	90	*42*	25	*37*	2	*6*	1	*8*	13	*54*	214
Good results	38	*31*	19	*49*	79	*36*	32	*47*	12	*38*	6	*46*	9	*38*	195
Fair results	7	*6*	6	15	29	*14*	6	*9*	8	*25*	4	*31*	1	*4*	61
Poor results	9	*7*	0	*0*	18	*8*	5	*7*	10	*31*	2	*15*	1	*4*	45
Total	123	*100*	39	*100*	216	*100*	68	*100*	32	*100*	13	*100*	24	*100*	515

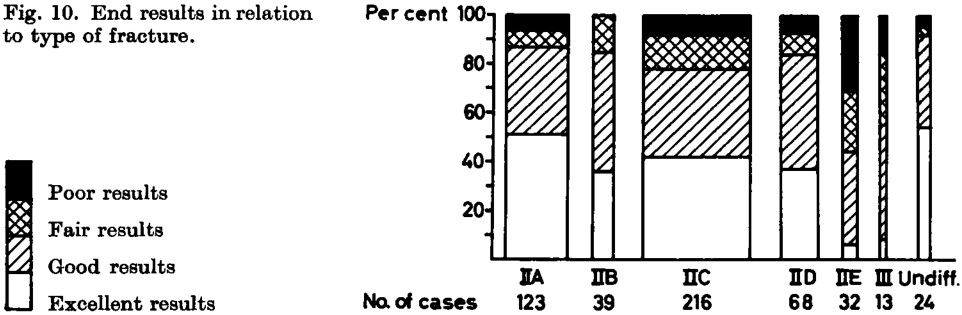


Fig. 10. End results in relation to type of fracture.

(Saikku, 1953; Geckeler, 1953; among others) or internal fixation (DePalma, 1953).

The relationship between the functional end result and type of fracture *in the present series* is shown in Table XXIV and Fig. 10. The most striking feature was the high incidence of unsatisfactory results for comminuted fractures involving the joint. It should be noted that this group included only cases with severe joint involvement. Fractures with less serious involvement of the joint were classified in groups II B and II D. The classification of these fractures was flexible in the present series and is undoubtedly also subject to variation in the different studies published earlier.

In groups II A and II B, where dorsal angulation was the sole primary deformity, the incidence of impaired function was 13.5%, in groups II C and II D, where the fracture had been grossly displaced, 20%. The amount of primary displacement appeared to have little effect on the end results.

Fracture of the Ulnar Styloid Process

Although the majority of authors have regarded this component of the fracture as entirely insignificant for either the length of convalescence or the end result, there are several notable exceptions.

Haglund (1914) stated that fractures which include injury to the ulnar styloid process require considerably longer time to heal, frequently as much as 6 months, whereas patients without this complication are usually fully recovered after 6 weeks. Bange (1921) observed that this injury in many cases leads to instability of the distal radio-ulnar joint and consequent loss of function. Ghormley and Mroz (1932) made allowance for injuries to the ulnar styloid process in classifying their fractures. They observed that tenderness and pain over this area often persists for a long time. McAusland (1957) also remarked upon this symptom, which he considered due to poor healing of the ulnar collateral ligament.

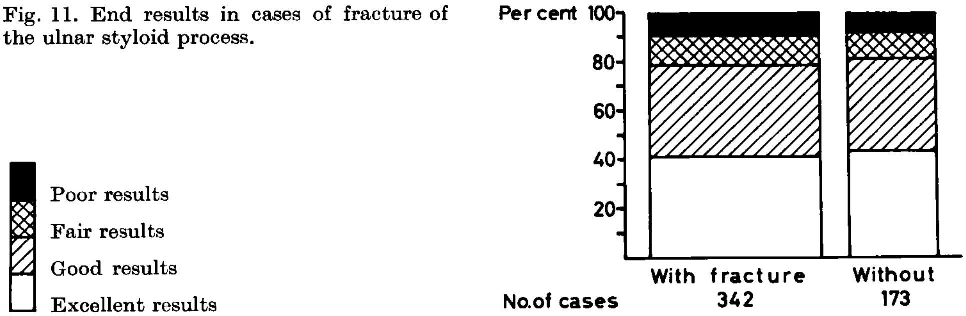
TABLE XXV. *Incidence of Fractures of the Ulnar Styloid Process.*

	Type of Fracture						
	II A	II B	II C	II D	II E	III	Undifferentiated
Incidence of fractures of the ulnar styloid process	64/123	25/39	151/216	51/68	28/32	6/13	17/24
Per cent	52	64	70	75	87.5	46	71

Table XXVI. *End Results in Cases with Fracture of the Ulnar Styloid Process.*

	No. of cases	%	Percentage distribution in series without fracture
Excellent results	140	*41*	*43*
Good results	128	*37.5*	*38*
Fair results	41	*12*	*11*
Poor results	33	*9.5*	*8*
Total	342	*100*	*100*

Fig. 11. End results in cases of fracture of the ulnar styloid process.



In the present series, fracture of the ulnar styloid process was a feature in a total of 342 cases (66.4%). In 60 cases the fracture passed through the tip of the styloid process, so that it was practically avulsed. The incidence of the injury is given in Table XXV. The functional end result in cases with fracture of the ulnar styloid process did not differ from the results in the remainder of the series, as illustrated by Table XXVI and Fig. 11. This feature of the fracture was of no consequence for the ultimate function.

The Anatomical End Result

The effect of the anatomical end result on the ultimate function of the wrist is one of the central problems in the clinical management of fracture of the distal radius. The importance attached to this factor not only to a great extent determines the individual surgeon's standards of reduction and fixation, but decides his entire approach to the initial treatment of the fracture.

Earlier studies reflect widely varying opinions regarding the effect of residual deformity on the functional end result.

According to one group of authors, there is a clear connection between persistent deformity and impaired function. Representative of this group are the following authors. Rosenbach (1902) observed in a series of 22 patients with severe deformity no single case where function had been completely restored. Of 168 patients without deformity, on the other hand, function was unimpaired in 150 and regarded as fair in the remaining cases. Hobart and Kraft (1931) stated without reservation that a poor anatomical result has an unfavourable effect upon the prognosis, an opinion which was shared by Hitzrot and Murray (1921), Grosby and Trick (1929), Cornell (1935), White (1940), Mayer (1940), Gartland and Werley (1951), Sirbu and Collof (1951), Walker (1952), McAusland (1957), and Glock, Mackel, and Brown (1957). Whereas Walker in his series observed several cases with residual symptoms despite normal appearance of the wrist, Taylor and Parsons (1937) believed that excellent function can be expected in all cases where normal anatomical relationships have been restored. Bacorn and Kurtzke (1951) observed in a series of compensation cases that the degree of disability increased in direct proportion to the amount of residual deformity. This appraisal was based only on the clinical appearance of the wrist, as no roentgenographic evaluation was made.

The following authors were rather undecided in their appraisal of this factor. Gurd (1937) believed that deformity in itself does not necessarily predispose to loss of function, unless it is so severe that it involves dislocation of the ulna. Höjensgaard (1945), although advocating adequate reduction, questioned whether poor anatomical results are very important. Hölund (1957) concluded that deformity influences the frequency of residual symptoms where young and middle-aged patients are concerned, but is of no importance to patients over 60 years of age.

A third group of authors, finally, have attributed only limited importance to deformity as a contributory factor to poor functional results. Böhler (1933) claimed that good anatomical and cosmetic results can be expected if the fracture shows no tendency towards axial displacement, whereas good functional but poor cosmetic results are obtained in fractures with radial shortening. Kotrnetz and Geiringer (1937) were of the opinion that accurate reduction, although it should be attempted, is no absolute condition for satisfactory function. Nissen-Lie (1939) found incorrect anatomical relationships persisting in more than $^5/_6$ of all cases with primary displacement of the fracture, but observed clinical symptoms due to this deformity only in a few cases. Pilcher (1917) and Cox and Meyer (1951) likewise concluded that in the great majority of cases deformity is no impediment to entirely satisfactory functional results. Cassebaum (1950) found in a series of 81 cases excellent functional results, even in cases where the anatomical result was less satisfactory. In his opinion, adequate reduction shortens the period of convalescence but is of no importance for the functional end result.

TABLE XXVII. *End Results in Relation to the Degree of Residual Deformity.*

	Degree of residual deformity								Total no. of cases
	None		Slight		Moderate		Severe		
	No.	%	No.	%	No.	%	No.	%	
Excellent results	74	*60*	107	*54*	33	*20*	0	*0*	214
Good results	39	*31*	62	*31*	80	*49*	14	*52*	195
Fair results	7	*6*	19	*10*	28	*16*	7	*26*	61
Poor results	4	*3*	9	*5*	26	*15*	6	*22*	45
Total	124	*100*	197	*100*	167	*100*	27	*100*	515

Another point of interest is to establish which type of deformity must be regarded as most detrimental to function. Most of the authors who have expressed an opinion on this point consider either shortening or radial deviation the crucial deformity, partly because these cause a loss of contiguity of the distal radio-ulnar joint (Crosby and Trick, 1929; Rogers, 1944; Milch, 1950; Hoffman, 1953; Mason, 1953; among others).

In direct contrast to this, Poulsen (1906) believed radial deviation often impossible to correct but regarded this of minor importance for the functional end result.

Residual dorsal angulation has been considered important by Edwards and Clayton (1929), Bankart (1929), Madsen (1949) and Wiklund and Müllern-Aspegren (1956). The last two studies mention that residual angulation should not exceed 5 degrees if a satisfactory functional result is to be expected. Hobart and Kraft (1941) put the maximum amount of dorsal angulation that is still acceptable at 90 degrees and claimed that more severe deformity almost always produces pain and causes impaired function. Milch (1950) claimed in contrast to this that too much importance has always been attributed to dorsal angulation in the treatment of these fractures.

Fig. 12. End results in relation to the degree of residual deformity.

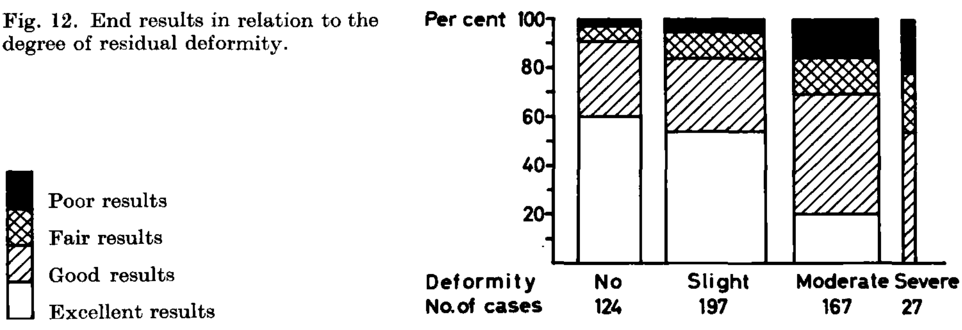


TABLE XXVIII. *Incidence of Fair and Poor Results in Relation to Dorsal Angulation and Shortening.*

	Incidence of fair and poor results			
	No dorsal angulation	Slight dorsal angulation	Moderate dorsal angulation	Severe dorsal angulation
Shortening:				
None	11/124 (= 9 %)	3/51 (= 6 %)	7/25 (= 28 %)	2/3 (= 67 %)
Slight	15/81 (= 18 %)	10/65 (= 16 %)	15/45 (= 33 %)	0/1 (= 0 %)
Moderate	8/37 (= 22 %)	12/34 (= 35 %)	12/26 (= 46 %)	3/7 (= 43 %)
Severe	2/3 (= 67 %)	3/7 (= 43 %)	2/3 (= 67 %)	1/3 (= 33 %)

Concerning *the present series* the two questions raised in the foregoing are illustrated in Tables XXVII and XXVIII and Fig. 12.

Table XXVII shows the end result in relation to the degree of residual deformity which was rated according to the same principles as in Table XV. The functional end result appeared to decline with increasing deformity.

Table XXVIII shows the incidence of unsatisfactory (fair + poor) functional results in relation to the two types of deformity, dorsal angulation and shortening.

Loss of function was observed in 9% of the cases without any residual deformity. The incidence was no higher for cases with only slight dorsal angulation. Dorsal angulation was therefore of no consequence as long as it did not exceed 100 degrees, but a larger amount of dorsal angulation caused a rapid decline of the functional results.

In contrast to dorsal angulation, even slight radial shortening as the sole residual deformity caused the incidence of unsatisfactory results to rise from 9% to 18%.

Even severe deformity was frequently no impediment to good functional results. Of the 27 cases where either severe dorsal angulation or severe shortening persisted, function was found to be satisfactory in 14 cases (52%).

Satisfactory reduction proved to be no guarantee for a satisfactory functional end result while on the contrary severe deformity in the majority of cases was found to be compatible with satisfactory function.

Injuries to the Distal Radio-Ulnar Joint

Two types of injuries to this joint can be distinguished:

(1) Injuries to the soft tissues surrounding the joint resulting in instability of the joint, and

(2) Loss of contiguity of the joint surfaces due to deformity of the distal end of the radius.

Anatomical aspects. The distal end of the radius presents a shallow articular surface, which means that the soft tissues surrounding the joint play a decisive role in stabilizing the joint. The head of the ulna is connected with its surrounding structures by the interosseous membrane, the radio-ulnar articular capsule, the triangular disk, the ulnar collateral ligament, the volar and dorsal radio-ulnar ligaments, the dorsal and volar carpal ligaments, and the pronator quadratus muscle.

It was thought of interest within the scope of this study to analyze which of these structures is the most essential to the stability of the joint. To this end, five wrists from autopsy specimens were dissected.

It was found that when the disk was merely disrupted at its ulnar attachment by the smallest possible incision, mobility of the ulnar head increased only very little. When either the dorsal or the volar radio-ulnar ligament was cut at the same time, however, the ulnar head became extremely unstable. When all soft tissues except the thin capsule and the disk were removed, no instability could be demonstrated. It would seem that damage to the disk is essential in causing increased mobility, but that marked instability only results following simultaneous rupture of one of the radio-ulnar ligaments. These findings are in close agreement with those reported by Mitchell (1922) and Lippmann (1937). Milch (1942), on the other hand, regarded the ulnar collateral ligament as the essential structure for the stability of the joint.

Injuries to the soft tissues surrounding the joint are probably very common complications to fracture of the distal radius with only slight displacement of the distal fragment. Mayer (1940) produced a break in the radius at the typical site of fracture by means of a Gigli saw and found that dorsal displacement occurred only when the ulnar styloid process with the insertion of the disk had been avulsed. A supination deformity, on the other hand, could result even if the triangular ligament remained intact. Pickard (1927) likewise maintained that only slight backwards and upwards displacement could occur as long as the disk was undamaged. Rupture of the disk can occur either at its ulnar or radial insertion, or through the fibers of the disk itself. Of these alternatives, avulsion of the disk at its ulnar insertion in combination with fracture of the ulnar styloid process is probably by far the most common.

Hultén (1928) studied the normal variations that can appear in the configuration of the distal radio-ulnar joint due to prominence of the ulna. In 61% of a series of 400 normal cases he could not observe any difference in length between the ulna and the radius, in 13% the ulna was shorter by 1 mm, in 5.5% by 2 mm, in 2% by 3 mm, and in 0.3% by 4 mm. The ulna was 1 mm longer than the radius in 10%, 2 mm longer in 4%, 3 mm longer in 1%, 4 mm longer in 0.7%, and 5 mm longer in 0.5%. In the limited number of cases where both hands were examined, the same type of variation was found on both sides, although sometimes the difference in length was more pronounced on one side.

REVIEW OF EARLIER CLINICAL STUDIES

Injuries to the distal radio-ulnar joint have been widely discussed, but no agreement exists regarding their significance for the final results.

Instability of the joint as an immediate consequence of fracture of the distal radius was already remarked upon by Colles (1813). Residual loss of stability due to poor healing has been observed and commented upon by numerous later authors. Worthy of note is Mitchell's (1922) observation that various degrees of instability must be distinguished. In his opinion severe symptoms result if the head of the ulna is free to glide out of the ulnar notch of the radius, thus permitting recurrent complete dislocation, whereas mere increased mobility of the ulnar head in the notch, a laxity, is of less consequence.

Cases of *recurrent complete dislocation* following fracture of the distal radius have been reported by Eldridge (1932) and Birch-Jensen (1951), among others. Bette (1957) claimed it to be a fairly common complication following so-called typical fractures. Dislocation not connected with a fracture is more often reported; Wallinheimo (1942) found a total of 93 cases of this type described in the literature.

Laxity of the head of the ulna has been reported as a common complication by Thon (1906). Bange (1921) reported a number of cases where laxity was an impediment to strenuous manual work. Lippmann (1937) found residual laxity in almost every 9th case in his series. He regarded this complication as due to injuries incurred at the time of fracture which sometimes refuse to heal despite accurate reduction. In his opinion the most typical feature of this complication is the infinite variety of the symptoms caused by it. Taylor and Parsons (1938) suggested that injuries to the triangular cartilage may well be the decisive factor for the prognosis of fractures of the distal radius; their classification of the fractures takes this factor into account. Their point of view has been supported by Mayer (1940).

Fixed displacement of the head of the ulna in the volar direction was regarded as the cause of poor results by Cochrane (1929). Edwards and Clayton (1929), on the other hand, considered this an extremely rare deformity. The characteristic displacement caused by these fractures implies a secondary volar displacement of the ulnar head in relation to the radial fragment, but such a deformity is as a rule automatically corrected on reduction of the other components of the fracture.

Loss of contiguity of the joint has been mentioned by Darrach (1913) who considered it of major importance for the final results. In a later publication, however, Darrach (1927) observed that severe loss of contiguity with complete disruption of the joint appeared to cause fewer symptoms than if the joint surfaces remain partly in contact. In his opinion the most common symptom is a defect of pronation and supination.

Ehalt (1931) regarded shortening causing subluxation of the radio-ulnar joint as a significant complication. The same opinion has been expressed by Hammond (1949), Cox and Meyer (1951), and Mason (1953). Kiær (1950) reported radial shortening exceeding 3 mm as a common finding in cases with persistent symptoms for a long time after injury. He believed that the capsule and the disk in the radio-ulnar joint contain factors stimulating pain which are activated by an unsatisfactory configuration. Hoffmann (1953) regarded radial deviation and disruption of the radio-ulnar joint as an important cause of poor results. Milch (1942) coined the expression "derangement about the wrist" to describe the typical symptoms in a group of patients with prominence of the capitulum ulnae, palpation tenderness over the ulna, weakness, pain on motion, and crepitus. He observed a varied roentgenologic picture in these cases.

Saikku (1953), on the other hand, reported a case where radial shortening amounted to 7 mm and where the clinical result was satisfactory. He observed that it is still discussed whether this factor is of any real consequence. Patrick (1946) drew attention to the fact that fibrosis and adhesions resulting from injuries to the capsule and the ligament obliterate the joint space with restricted and painful pronation and supination as a consequence. Schneck (1929), on the other hand, believed contracture and fibrosis of the pronator quadratus muscle to be the most common cause of restriction of these movements.

Platt (1932) and Gartland and Werley (1951) considered injuries to the radio-ulnar joint of only minor importance for the end result.

As a final observation, it can be mentioned that in the majority of earlier studies these injuries have not been subjected to a separate analysis.

ANALYSIS OF THE PRESENT SERIES

Laxity. In a total of 77 cases in the present series a distinct laxity could be palpated in the radio-ulnar joint. The incidence of this complication is shown

TABLE XXIX. *Incidence of Laxity in the Distal Radio-Ulnar Joint.*

	Type of Fracture						
	II A	II B	II C	II D	II E	III	Undifferentiated
Incidence of cases with laxity	20/123	5/39	37/216	10/68	1/32	2/13	2/24
Per cent	16	13	17	15	3	12	8

TABLE XXX. *End Results in Cases with Laxity in the Radio-Ulnar Joint.*

	No. of cases	%	Percentage distribution in series without laxity
Excellent results	8	*10*	*47*
Good results	37	*48*	*36*
Fair results	18	*24*	*10*
Poor results	14	*18*	*7*
Total	77	*100*	*100*

in Table XXIX. It was proportionately distributed over the various fracture types, with the exception of the group of comminuted fractures which included only one case. This suggests that severe fragmentation may decrease the strain on the triangular cartilage at the time of injury. The fact that one-third of all cases are found in association with fractures of type II A and II B, furthermore, indicates that a relatively slight displacement suffices to cause damage to the disk.

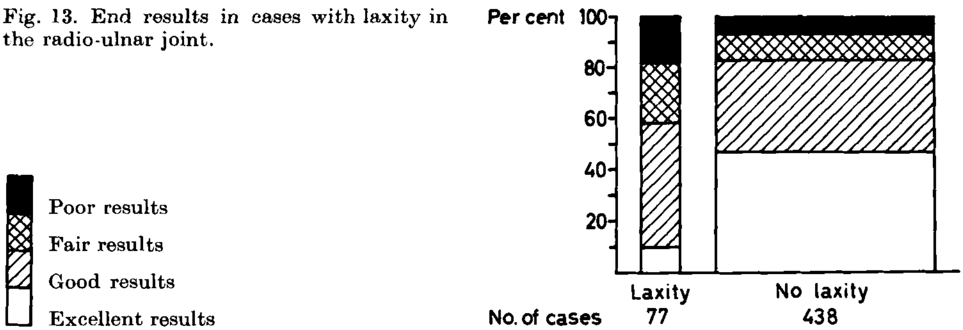
Fracture of the ulnar styloid process was a feature in 48 cases of this group (64.2 %), a frequency which agreed with that in the total series.

The anatomical end result was found to be somewhat less favourable than in the total series on roentgen examination; perfect reduction was achieved in 13 %, slight deformity persisted in 33 %, moderate deformity in 47 %, and severe deformity in 7 %.

Posttraumatic causalgia was present in 20 % of this subgroup, as against 15 % in the total series.

The functional end result for this group is shown in Table XXX and Fig. 13. Loss of function was found in 42 % of the cases. Although the anatomical end result was somewhat less satisfactory than in the total series, this was compensated by the lower incidence of comminuted fractures in this group. The clinical result was unquestionably less satisfactory than could have been expected

Fig. 13. End results in cases with laxity in the radio-ulnar joint.



A

B

C

Fig. 14. Woman aged 64. Marked palpable laxity in the radio-ulnar joint at follow-up. *A*. Pre-reduction roentgenogram. *B*. Follow-up roentgenogram 7 years after injury. Straight position of the hand. *C*. Diastasis in the radio-ulnar joint produced by extreme ulnar deviation of the hand.

under the circumstances. Laxity of the distal radio-ulnar joint appeared to be a complication with a detrimental effect on the final results.

The subjective symptoms contributing to the poor results were varied, but the picture in this respect did on the whole not differ from that observed in the total series. A slight difference could be observed in that weakness of the wrist in this group was an even more predominant symptom, reported by 52 of the 61 patients with subjective symptoms. Inability to bear weights with the hand in supination was particularly common. Other subjective symptoms were pain on weight-bearing, in many cases localized to the radio-ulnar joint, pain following exertion, decreased resistance to strain, and spontaneous pains. The frequency of these symptoms agreed with that in the total series. A loss of pronation or supination was found in 10 cases, but the defect was uniformly

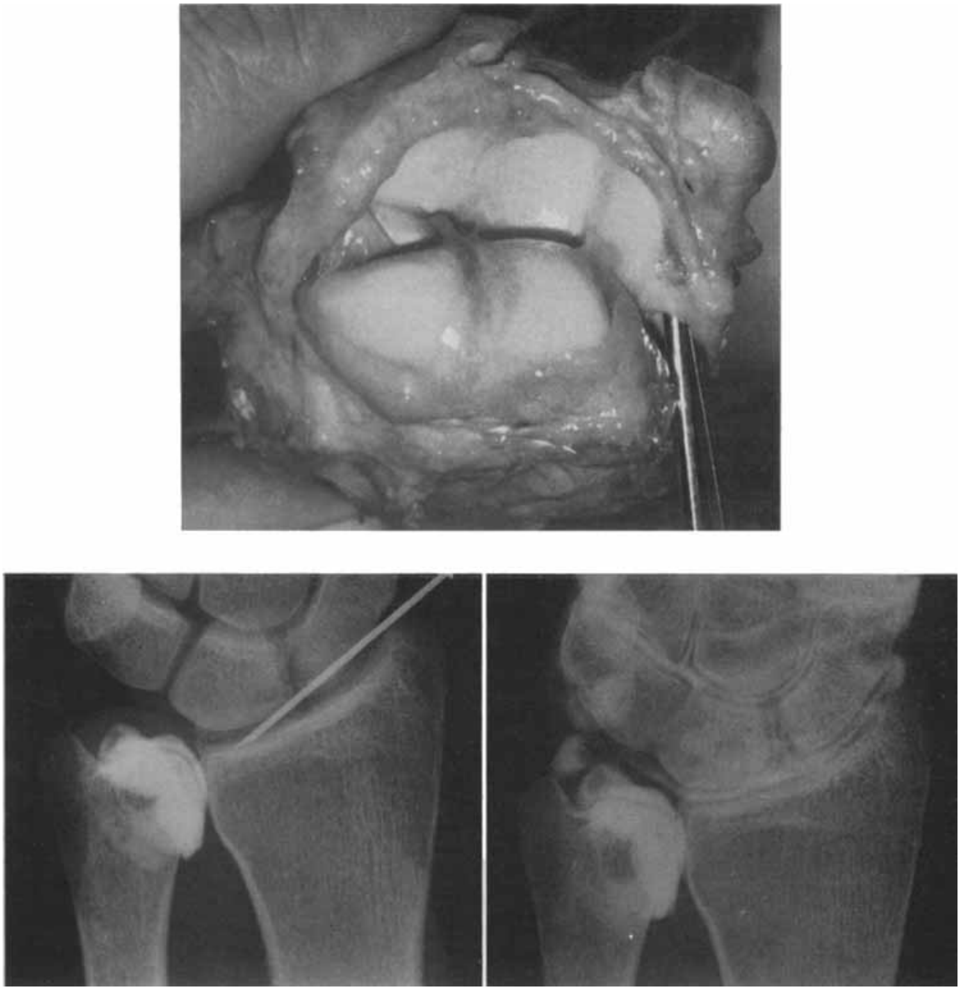


Fig. 15. Arthrograms showing normal aspects of the radio-carpal and the radio-ulnar joint in an autopsy specimen. The dissected joint has a normal disk.

slight and in no instance exceeded 15 degrees. Sixteen patients reported tenderness to palpation over the capitulum ulnae and the radio-ulnar joint space.

Roentgenologic signs of instability in the radio-ulnar joint. As laxity of the distal radio-ulnar joint appeared to have a moderate but unmistakable effect on the clinical result, it might be of interest to establish the possibilities of roentgenologic diagnosis of this complication. The obvious feature to expect in such cases is widening of the joint space between the radius and ulna, a diastasis of the same type as often seen in the ankle joint following fractures and sprains involving injury to the ligaments and capsule.

Numerous instances of such a diastasis in the radio-ulnar joint have been reported, but statistics of its incidence are scarce. Cornell (1935) reported an incidence of 17% in a series of 156 cases. Any statistics of the incidence of this complication are probably of doubtful value, however, since it is difficult to determine how much importance should be attached to a possible widening of the joint space. A certain amount of diastasis can sometimes be observed even under normal conditions, and an accurate evaluation is furthermore hampered by the difficulty of obtaining exact roentgenograms, since the deformity of the distal end of the radius which often results from the fracture makes it impossible to establish any standard projections.

An increased diastasis in comparison with the opposite side was observed in only 18 of the 77 cases (23%). The significance of this finding was further decreased by the fact that identical roentgenograms were obtained in cases where there was no sign of weakness of the radio-ulnar joint. In 25 cases where the clinical examination had indicated instability, the wrist was roentgenographed in extreme ulnar or radial deviation in order to see whether a diastasis could be provoked in this way, thus providing irrefutable evidence of laxity. It succeeded in only 3 of the 25 cases (Fig. 14).

Arthrographic examination of either the radio-ulnar or the radio-carpal joint was made in 20 cases with clinical evidence of instability, after which the findings were compared with arthrograms obtained in normal cases. 1–1 $^1/_2$ cc of umbradil was injected from the dorsal side. It was found that only a true frontal view supplied information of any interest.

In the dissected specimen shown in Fig. 15, the course of the disk and its ulnar insertion at the base of the ulnar styloid process are clearly visible. The arthrographic examination was primarily useful in permitting a study of this latter detail. The normal contrast defect at the base of the ulnar styloid process could generally not be observed in cases with laxity; the contrast ran out around the ulnar styloid process or, in cases where this was not consolidated, under the fragment (Fig. 16). These changes, which could not be observed in any of the normal cases, suggested either a break at the ulnar insertion of the disk or avulsion of this insertion together with the fragment of the ulnar styloid process. In two cases, where the capitulum ulnae was extremely loose, the contrast ran freely from the radio-ulnar into the radio-carpal joint and any contrast defect representing the disk could not be observed (Fig 17). Lang (1942), among others, observed that fissures in the disk are common, but in the present instances the arthrogram indicated severe rupture of the triangular ligament.

The information obtained on arthrographic examination was on the whole of little value.

Fig. 16. Woman aged 65. Marked palpable laxity in the radio-ulnar joint at follow-up. Arthrogram in the radio-ulnar joint. No defect representing the ulnar insertion of the disk is visible.

Loss of contiguity. Loss of contiguity of the distal radio-ulnar joint was in all cases associated with residual deformity of the distal end of the radius. It was predominantly caused by, and in all cases combined with, radial shortening. Loss of contiguity could best be evaluated by comparing both sides for possible distal prominence of the ulna. Loss of contiguity due to severe dorsal angulation was more difficult to evaluate. In the present series, ulnar prominence amounting to at least 4 mm on comparison with the opposite side was found in 98 cases.

It has already been shown (Table XXVIII) that shortening was associated with a less satisfactory functional result. It was considered of interest to determine whether this effect could be related to a loss of contiguity rather than to the type of shortening which is mainly due to a decrease of the normal radial tilt of the articular surface. To this end, a comparison was made between the functional end results in cases with only shortening and in the 98 cases with shortening and simultaneous loss of contiguity of the joint. Table XXXI shows that the incidence of unsatisfactory results was 10–12% higher in cases where the contiguity of the joint was lost.

A similar appraisal was made of the end results in cases where contiguity of the joint was retained, involving comparison of the end results in cases with shortening with those without shortening. The purpose of this latter comparison was to evaluate the effect of shortening not associated with a loss of contiguity on the functional result. From Table XXXII it can be seen that the effect of this factor varied. This suggests that much of the detrimental effect which radial shortening appears to have on the functional end results is bound up with a loss of contiguity of the distal radio-ulnar joint.

Among the 98 cases with loss of contiguity of the joint, pronation and supination were restricted in 26% as compared to 12% in the total series. As a rule, the loss of motion was slight. In all other respects, the clinical picture agreed with that in the total series.

A A

B C

D

Fig. 17. Woman aged 67. Marked laxity in the radio-ulnar joint at follow-up. *A*. Pre-reduction roentgenogram. *B*. Follow-up roentgenogram. There is a distinct diastasis present in the radio-ulnar joint in comparison with the uninjured wrist (*D*). *C*. Arthrogram in the radio-ulnar joint. The contrast medium is seen escaping towards the radio-carpal joint. The characteristic defect produced by the disk is absent.

TABLE XXXI. *Incidence of Unsatisfactory Functional Results in Relation to Loss of Contiguity of the Radio-Ulnar Joint in Cases with Shortening.*

	Incidence of unsatisfactory results	
	None or slight dorsal angulation	Moderate or severe dorsal angulation
No loss of contiguity	32/166 ... 19%	16/44 ... 33%
Loss of contiguity	18/61 ... 29%	17/37 ... 45%

TABLE XXXII. *Incidence of Unsatisfactory Functional Results in Relation to Shortening in Cases without Loss of Contiguity of the Radio-Ulnar Joint.*

	Incidence of unsatisfactory results	
	None or slight dorsal angulation	Moderate or severe dorsal angulation
No shortening	14/175 ... 8%	9/28 ... 32%
Slight, moderate or severe shortening	36/166 ... 19%	16/48 ... 33%

Posttraumatic Causalgia

Spontaneous pains of varying severity, edema, and swelling of the fingers complicating the posttraumatic course and often resulting in loss of motion have been remarked upon as a factor of significance by numerous earlier authors. Their interpretation is so varying, however, that it is difficult to compare data from different studies.

LeBreton (1915) described 8 cases of "arthritis" following fracture of the distal radius, in a few of which roentgenologic changes were observed in the interphalangeal joints. Four of the patients became permanently disabled. Pilcher (1917) discussed soft-tissue injuries as a common complication to fracture of the distal radius and regarded them as an essential factor for the final result. Hansen (1926) reported a series of cases handled by the Danish Workman's Compensation Board, where severe rigidity resulted despite perfect reduction of the fracture, in his opinion due to a "dystrophy". Pickard (1927) likewise regarded stiffness of the hand as the most detrimental effect of these fractures, but contended that the complication in most cases is due to over-long and too extensive immobilization and less frequently the result of a posttraumatic vasomotor disturbance. Kotrnetz and Geiringer (1937) regarded posttraumatic vascular disturbances as a highly important factor for the end result. They attempted to decrease the incidence of this complication by delaying reduction

TABLE XXXIII. *Incidence of Posttraumatic Causalgia.*

	Type of Fracture						
	II A	II B	II C	II D	II E	III	Undifferentiated
Incidence of cases with posttraumatic causalgia	8/123	6/39	20/216	12/68	4/32	3/13	0/24
Per cent	9	16	9	18	12	23	0

of the fracture until at least 24 hours had passed. Rosen (1947) found in a series of 280 cases 10 instances of posttraumatic dystrophy. Knapp (1952) divided soft-tissue injuries into posttraumatic fibroses and, as he described it, posttraumatic sympathetic reflex dystrophies. He regarded the former type of injury as a major cause of poor results and agreed with the majority of authors that active finger exercises are imperative in abolishing edema. Hoffman (1953) found signs of so-called Sudeck's atrophy in 10 of his 35 cases early in the posttraumatic course. Two of these cases had poor functional end results.

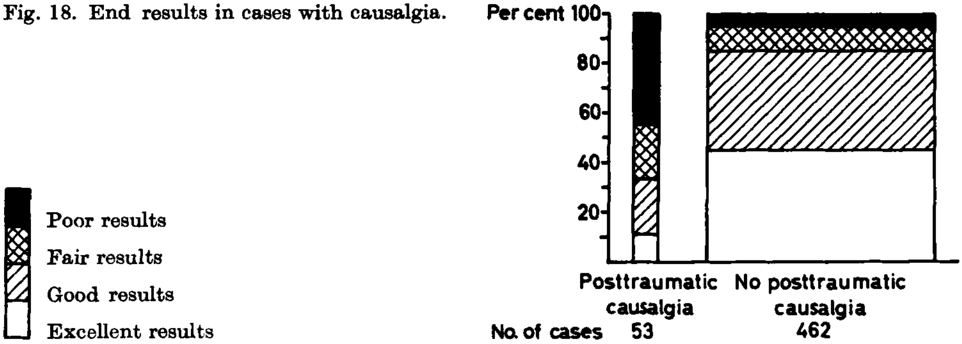
In the follow-up examination of *the present series,* it was difficult to define exactly in which cases complications of this type had been present. Only one case was identified as a classical example of Sudeck's atrophy. This was a 68 year old woman with moderate primary displacement of the fracture, who was left with a completely disabled hand due to finger stiffness and intense tenderness to palpation.

Fifty-three patients reported that the posttraumatic course had been complicated and protracted due to spontaneous pains over the wrist and forearm. The pain frequently interfered with sleep and required analgesics. The records showed that in the majority of these cases considerable swelling and stiffness

TABLE XXXIV. *End Results in Cases with Causalgia.*

	No. of cases	%	Percentage distribution in series without causalgia
Excellent results	6	*11*	*45*
Good results	12	*22*	*39*
Fair results	12	*22*	*11*
Poor results	23	*45*	*5*
Total	53	100	*100*

Fig. 18. End results in cases with causalgia.



of the fingers had been noticed during the posttraumatic course, for which physical therapy had been instituted. Shoulder stiffness and pain over the shoulder joint had also been observed in a few cases.

It seemed justified to combine all these cases into one group under the heading "cases with posttraumatic causalgia". This designation avoids an opinion about the uncertain genesis of these symptoms.

Table XXXIII shows the incidence of cases with posttraumatic causalgia. Their proportional distribution over the different fracture types showed no appreciable variation. The clinical end result in the group with posttraumatic causalgia is shown in Table XXXIV and Fig. 18. The functional results in this group were extremely poor with unsatisfactory function of the wrist in 67% The posttraumatic symptoms were therefore to some extent permanent.

It has been suggested, by Hölund (1957) among others, that repeated attempts at reduction with the additional trauma this implies, may increase the risk of these posttraumatic symptoms. Of the 53 cases in the group with posttraumatic causalgia, reduction had been repeated once or more in 12 cases (22%); in the total series this had occurred in 77 cases (16.6%). This factor did not appear to have any significance in this series.

Length of Follow-Up

The term "length of follow-up" refers to the time elapsed between injury and follow-up examination. No information can be found in the literature on the effect of this factor on the functional end result.

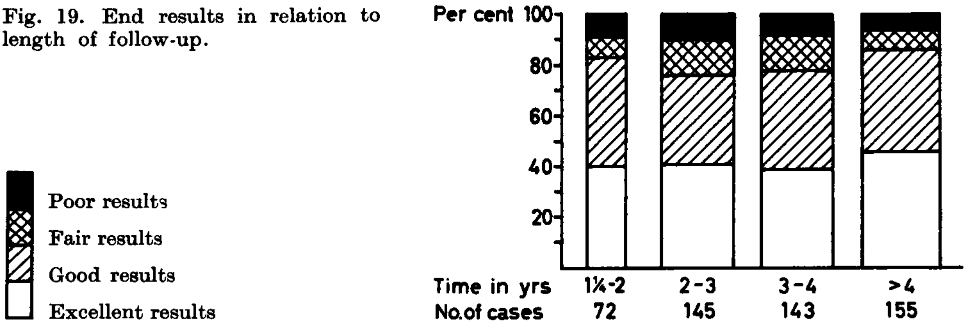
In the present series the patients were examined at intervals during the period between 1954 and 1957. The length of the follow-up period varied from 1 $^1/_4$ to 8 years, with an average of 3 years and 9 months.

The functional end results in relation to the length of follow-up are shown in Table XXXV and Fig. 19. The different types of fracture were equally re-

TABLE XXXV. *End Results in Relation to Length of Follow-Up.*

	Years								Total no. of cases
	1¼–2		2–3		3–4		>4		
	No.	%	No.	%	No.	%	No.	%	
Excellent results	28	*40*	59	*41*	56	*39*	71	*46*	214
Good results	31	*43*	49	*35*	52	*37*	63	*40*	195
Fair results	6	*8*	20	*14*	23	*16*	12	*8*	61
Poor results	7	*9*	17	*10*	12	*8*	9	*6*	45
Total	72	*100*	145	*100*	143	*100*	155	*100*	515

Fig. 19. End results in relation to length of follow-up.



presented throughout the entire follow-up period. The incidence of unsatisfactory results was somewhat higher in the group observed 2–4 years after injury (24 %) than in the groups examined less than 2 years (17 %) or more than 4 years (16 %) after injury. No definite tendency towards variation of the results could be discerned and it must be concluded that length of follow-up within the present limits had no significant effect on the functional end result. Although some patients reported that function of the wrist had improved several years after injury, these instances were too few to change the general impression to any significant degree.

Arthritis

Earlier studies provide only sparse and highly contradictory information regarding the incidence of arthritis following fracture of the distal radius.

Lilienfeldt (1907) and Lambrinudi (1938) believed arthritis to occur but rarely after this type of injury. Their opinion was shared by both Ehalt (1935) who in a series of 492 compensation cases did not observe a single instance of posttraumatic arthritis, and Kotrnetz and Geiringer (1937) who found appreciable arthritis in only slightly more than 1 % of their series.

TABLE XXXVI. *Incidence of Arthritis.*

	Type of Fracture						
	II A	II B	II C	II D	II E	III	Undifferentiated
Incidence of cases with arthritis	0/123	4/39	1/216	6/68	14/32	2/13	1/24
Per cent	0	10	0.5	9	44	12	4

In contrast to these authors, Cornell (1935) reported a 53% incidence of arthritis from a series in which the follow-up period varied from 3 months to 19 years, with an average of 16 months. Gartland and Werley (1951) observed several cases of arthritis on follow-up examination 18 months after injury. Fagge (1929) and Chandler (1950) both believed that fractures involving the radio-carpal and radio-ulnar joints usually lead to arthritis of varying severity. Grosby and Trick (1929), Watson-Jones (1929) and Mason (1954) stressed arthritis in the distal radio-ulnar joint as a common finding. Edwards and Clayton (1929) and Cassebaum (1950) contended that pre-injury arthritis can influence the final results.

In the present series clear evidence of arthritis in the form of sclerosis, osteophytic changes, and narrowing of the joint space was present in a total of 30 cases (5.7%). In 35 more cases only minute osteophytic changes were observed. This was not considered sufficient evidence on which to base a diagnosis of arthritis. Another 3 cases with arthritis were excluded for the reason that the changes dated from before the injury.

Table XXXVI shows the incidence of cases with posttraumatic arthritis. In the group of fractures with severe involvement of the articular surface the incidence approached 50%, whereas only a few cases were found in the remaining groups. In 5 cases the changes were mainly restricted to the distal radio-ulnar joint.

It was remarkable that the incidence of arthritis in the groups with type II B and type II D fractures was not higher than 10% despite the joint involvement of these fractures.

Unsatisfactory functional results were found in 6 (43%) of the 14 cases with arthritis in group II E, a lower proportion than in the total group. Of the remaining 13 cases with arthritis, the functional results were unsatisfactory in 5 (38%).

The number of cases with clear evidence of posttraumatic arthritis was slight and hardly permitted any definite conclusions regarding the effect of this complication on the functional end result.

In 27 cases arthritic changes were found in other parts of the carpal skeleton. Generally these had already been observed at the time of injury. In 19 cases the changes were located in the metacarpophalangeal joint of the thumb, and in 9 of these they were bilateral. In 5 cases the joint distal to the navicular bone was involved, in 2 cases in both hands. Osteophytic changes in the radial styloid process of the uninjured wrist were observed in 2 cases. In no single instance could these changes be definitely connected with subjective symptoms.

STATISTICAL ANALYSIS

The need of a more detailed analysis

In the first part of this chapter, an attempt has been made to estimate the effects of the various relevant clinical features on the functional end result. On the basis of this analysis, in which one factor at a time was correlated with the functional end result, some slightly correlated or entirely uncorrelated factors were eliminated as in all likelihood unimportant in this connection. These factors were age, sex, fracture of the ulnar styloid process, and the length of the follow-up period. Some other factors, on the other hand, appeared to be closely correlated with the functional end result. Fractures of type II E, residual deformity, symptoms suggestive of causalgia setting in early in the posttraumatic course, and evidence of laxity in the distal radio-ulnar joint on follow-up examination coincided with such a marked increase in the incidence of unsatisfactory functional results that a connection might reasonably be suspected.

Although the ordinary procedure in clinical follow-up studies, the method of correlating one factor at a time with the variable represented by the functional end result, often has the disadvantage of eliciting correlations that are difficult to interpret, as is illustrated by the following example.

Table XXX shows the incidence of unsatisfactory results to be 42% in the group where palpable laxity in the radio-ulnar joint was a feature, as against 17% in the group without laxity. Does this suffice to conclude that this factor clearly influences the functional result? This is questionable, since it is possible that residual dorsal angulation, another of the factors that appeared to influence the functional result (Table XXVIII), is essential in producing such laxity, implying a strong mutual correlation between these factors. Under these circumstances it may conceivably be the residual deformity which is mainly responsible for the detrimental effect on the functional end result, whereas the correlation between functional end result and laxity may be entirely or partly spurious.

From a therapeutic point of view the following two questions are more relevant:

1. Can measures directed towards overcoming laxity, for instance, surgical correction, be expected to have a favourable effect on function in cases with residual dorsal angulation?

2. Can a similar effect on the functional result also be expected in cases without dorsal angulation?

A first approach to an answer to these questions can be obtained by comparing the cases with and without laxity with respect to the incidence of unsatisfactory results *separately* for the cases with dorsal angulation and for those without this type of deformity.

In the preliminary analysis, cases without laxity were found to have a more favourable prognosis than those with laxity (17% unsatisfactory results as against 42%). An analysis directed towards eliciting the finer distinctions implied in questions (1) and (2) can be expected to give one of the following alternative answers:

A. Neither under the circumstances mentioned in (1) nor in those mentioned in (2) can any effect of the laxity be demonstrated. This would indicate that dorsal angulation is the actual factor responsible for the difference obtained in the preliminary analysis, proving the correlation between laxity and functional end result to be spurious, indicating that laxity has *no* effect.

B. Laxity is found to have approximately the *same* effect under either set of circumstances. At best, this effect can show good agreement with that estimated in the preliminary analysis (42%–17%) but it is conceivable that it will be of a different order of magnitude.

C. The effect of the laxity is found to be of an entirely *different* order of magnitude under the circumstances mentioned in (1) when compared with those mentioned in (2).

A more detailed analysis can therefore elicit finer distinctions in the results.

Dorsal angulation is only one of the factors, however, which conceivably might be important in connection with laxity. Shortening and type of fracture might also have a bearing on laxity. These are interesting factors in their own right, since the preliminary analysis has indicated that they influence the functional end result. From a therapeutic point of view it might also be of interest to know whether correction of laxity can be expected to influence the functional results favourably both in cases with and in cases without posttraumatic causalgia.

In order to consider all these factors, which are mutually correlated, all relevant factors are listed in Table XXXVII in every possible combination, and for every combination the incidence of unsatisfactory end results is given. An analysis based on this table is more likely to succeed in eliciting genuine effects than the preliminary analysis which runs the risk of producing mainly

TABLE XXXVII. *Incidence of Unsatisfactory End Results for Different Factor Combinations.*

Factor combination	Type	Da*	S*	C*	L*	Total no. of cases	No. of Fair & Poor Results	%
1	ABCD	0	0	0	0	136	4	2.9
2	E	0	0	0	0	2	1	50
3	ABCD	1	0	0	0	20	3	15
4	E	1	0	0	0	0	0	—
5	ABCD	0	1	0	0	140	13	9.3
6	E	0	1	0	0	12	5	41.7
7	ABCD	1	1	0	0	46	10	21.7
8	E	1	1	0	0	9	5	55.6
9	ABCD	0	0	1	0	7	3	42.9
10	E	0	0	1	0	2	1	50
11	ABCD	1	0	1	0	3	3	100
12	E	1	0	1	0	0	0	—
13	ABCD	0	1	1	0	19	11	57.9
14	E	0	1	1	0	1	1	100
15	ABCD	1	1	1	0	3	3	100
16	E	1	1	1	0	5	5	100
17	ABCD	0	0	0	1	15	4	26.7
18	E	0	0	0	1	0	0	—
19	ABCD	1	0	0	1	4	3	75
20	E	1	0	0	1	0	0	—
21	ABCD	0	1	0	1	26	9	34.6
22	E	0	1	0	1	1	0	0
23	ABCD	1	1	0	1	17	7	41.2
24	E	1	1	0	1	0	0	—
25	ABCD	0	0	1	1	1	0	0
26	E	0	0	1	1	0	0	—
27	ABCD	1	0	1	1	0	0	—
28	E	1	0	1	1	0	0	—
29	ABCD	0	1	1	1	7	6	85.7
30	E	0	1	1	1	0	0	—
31	ABCD	1	1	1	1	2	1	50
32	E	1	1	1	1	0	0	—

* Factor notations: Da = 1, Moderate or severe dorsal angulation; Da = 0, No or slight dorsal angulation; S = 1, Slight, moderate or severe shortening; S = 0, No shortening; C = 1, Causalgia present; C = 0, Causalgia absent; L = 1, Laxity present; L = 0, Laxity absent.

spurious correlations. This more detailed analysis can furthermore be useful in checking whether the preliminary analysis has been reliable.

In order to simplify the presentation the factors have been abbreviated as indicated in the footnote to Table XXXVII. These abbreviations will be used throughout the remainder of this chapter. In addition, the factors have been divided into two categories as follows. For every factor the relative frequency of unsatisfactory (fair + poor) results has been studied earlier in this chapter (cf. Tables XXII/XXXVI). Table XXIV shows no essential difference in this frequency between fracture types II A, II B, II C, and II D. These types have therefore been aggregated into one category which we intend to compare with type II E (column 2). Type III fractures are not considered in view of the small number of patients with this type of fracture. As to Da, a marked difference in frequency of unsatisfactory results existed between, on the one hand, cases with no or slight deformity and the remaining cases with moderate or severe deformity (Table XXVIII). In the former, the degree of Da has therefore been denoted as 0, in the latter category as 1 (column 3). Analogically, cases without S have been denoted as 0 and cases with slight, moderate, or severe S as 1 (column 4). The presence of L or C has been denoted as 1, their absence as 0.

Data on sex, length of follow-up, fractures of the ulnar styloid process, and arthritis have not been included in the table, as these factors according to the preliminary analysis seem to be irrelevant for the functional result.

The following example illustrates how to read the table. From line 13 in the table we read that there are 19 cases belonging to one of the fracture types II A, II B, II C, or II D exhibiting S and C, but without moderate or severe Da and without L. We furthermore find that the functional result for 11 of these 19 cases, i.e. 57.9%, is unsatisfactory.

Statistical Methods

For the following analysis we have chosen to use the technique of standard weighting. This technique is related to, although not identical with, partial correlation analysis. The standard weighting technique is illustrated by the following example where cases Da = 1 and cases Da = 0 are compared with respect to the frequency of unsatisfactory functional results, while the alternative categories of fracture type, S, C, and L are taken into consideration. In the first instance, we select the cases with fracture type II A–D and for which S = 0, C = 0 and L = 0 (cf. Table XXXVII). These cases are divided into two groups Da = 0 (line 1) and Da = 1 (line 3). The relative frequency of unsatisfactory results is 15% for Da = 1 and 2.9% for Da = 0 and the difference is 15% − 2.9% = 12.1%. Next we select the cases for which S = 1, C = 0, L = 0. The corresponding difference is computed by means of line 7 and line 5: 21.7% − 9.3% = 12.4%. We proceed in the same way and obtain the following differences, denoted as d_i:

Factor combination				Difference in %: d_i
Type	S	C	L	Cases Da = 1 versus cases Da = 0
II A–D	0	0	0	15.0 − 2.9 = 12.1
II A–D	1	0	0	21.7 − 9.3 = 12.4
II A–D	0	1	0	100.0 − 42.9 = 57.1
etc.				

Weighting system

Each of these differences indicates the magnitude of the effect of Da on the functional end result after the other factors possibly affecting the functional result have been taken into account (eliminated). The differences vary with the factor combination. This may be due to random errors, since several subgroups include only a small number of cases. In applying a significance test, an aggregation by constructing a weighted mean of the differences is advisable: $\Sigma w_i d_i / \Sigma w_i$, where w_i denotes the weights.

The choice of weights is somewhat arbitrary. In this study we have chosen w_i directly proportional to the sum of the cases in the two subgroups to which the difference refers (Table XXXVIII). This weighting system seems to be the most appropriate from a clinical point of view.

This weighted mean summarizes in one single value the effect of Da on the functional end result considering some other relevant factors.

TABLE XXXVIII. *Illustrating the Standard Weighting Procedure.*

Incidence of Unsatisfactory End Results for Cases with and without Dorsal Angulation. Comparison for Every Combination with Other Relevant Factors.

Class	Percentage incidence of unsatisfactory end results		Differences	No. of cases in subgroup		Weights*	
	With dorsal angulation (Da = 1)	Without dorsal angulation (Da = 0)		Da = 1	Da = 0		
i	P_i^1	P_i^0	$P_i^1 - P_i^0 = d_i$	n_i^1	n_i^0	$n_i^1 + n_i^0 = w_i$	$d_i w_i$
1	15	2.9	12.1	20	136	156	1887.6
2	21.7	9.3	12.4	46	140	186	2306.4
3	100	42.9	57.1	3	7	10	571.0
4	100	57.9	42.1	3	19	22	926.2
5	75	26.7	48.3	4	15	19	917.7
6	41.2	34.6	6.6	17	26	43	283.8
7	50	85.7	−35.7	2	7	9	−321.3
8	55.6	41.7	13.9	9	12	21	291.9
9	100	100	0.0	5	1	6	0
Total						472	6863.3

* These weights can be derived from the column "Total no. of cases" in Table XXXVII.

$d_i = P_i^1 - P_i^0$, the percentage difference between group Da = 1 and group Da = 0 with respect to unsatisfactory functional results.

The table includes 9 factor combinations, denoted as class 1–9 (cf. table on page 87). P_5^1 for instance, expresses the percentage incidence of unsatisfactory functional results in the group Da = 1 and belonging to class i = 5. $n_5^1 = 4$ expresses the total number of cases in the subgroup for which Da = 1, i = 5.

The standard weighted mean calculated from the table is $\Sigma d_i w_i / \Sigma w_i = 6863.3/472 = 14.5$.

TABLE IXL. *Standard Weighted Differences.*

	Standard weighted[a] difference (per cent)	Mean error corresponding to this difference (per cent)	Critical ratio. Significant judgement	Confidence interval (95% level) approx. = standard weighted difference ± 2 mean error
A				
Dorsal angulation With versus without	14.5	4.32	3.36***	14.5 ± 8.6
Shortening With versus without	6.5	3.20	2.03*	6.5 ± 6.4
Causalgia With versus without	46.8	7.67	6.10***	46.8 ± 15.3
Laxity With versus without	23.9	5.91	4.04***	23.9 ± 11.8
Fracture type II E versus II ABCD	37.2	14.28	2.61**	37.2 ± 28.6
B				
Dorsal angulation With versus without	13.5	4.51	2.99**	13.5 ± 9.0
Shortening With versus without	6.8	3.68	1.85	6.8 ± 7.4
Laxity With versus without	22.8	5.78	3.94***	22.8 ± 11.6
C				
Age. 31–65 years versus > 65 years	− 1.7	8.40	− 0.20	− 1.7 ± 16.8
Sex. Men versus women	1.5	6.78	0.22	1.5 ± 13.6
Time of follow-up < 2 yrs versus > 4 yrs	− 2.2	9.30	− 0.24	− 2.2 ± 18.6
Fracture type. II A + II B versus II C + II D	− 2.6	3.48	− 0.75	− 2.6 ± 7.0
Fracture of the ulnar styloid process With versus without	− 1.3	3.15	− 0.41	− 1.3 ± 6.3

[a] The standard weighted differences refer to the percentage differences with respect to unsatisfactory end results between the compared groups.

Note that the standard weighted mean itself gives no new information; all relevant differences can be read from the table (column d_i). However, if we intend to reach a summarizing evaluation of the importance of Da to the functional result, we have to combine the varying differences into one single value.

In Table XXXVIII cases Da = 1 are compared with cases Da = 0 with respect to the functional end result, using standard weighted means. In the same way the other factors have been dealt with in Table IXL. This table also presents mean errors, significance analyses, and confidence intervals.

From Table A we find that significant differences are obtained for all these factors, although the difference between cases S = 1 and S = 0 is not equally convincing as for the remaining factors.

Significance analysis (confidence interval)

If an observed difference between two percentages (or two means) is of a magnitude such that the probability P of obtaining a difference at least as great as the observed value is greater than 0.05 (where the null hypothesis is assumed to hold), then that observed difference is said to be *non-significant.*

If $0.01 < P \leqslant 0.05$ the difference is said to be (*probably*) *significant* and is marked *.

If $0.001 < P \leqslant 0.01$ the difference is said to be *significant* and is marked **.

If $0.001 \geqslant P$ the difference is said to be (*highly*) *significant* and is marked ***.

Only ordinary two-tailed significance tests have been applied.

The error (in %) in the standard weigthed mean in comparing Da = 1 and Da = 0 is calculated approximately according to the following formula:

$$\sqrt{\frac{\Sigma P_i\,(1-P_i)\;(n_i^1+n_i^0)^2\;\left(\dfrac{1}{n_i^1}+\dfrac{1}{n_i^0}\right)}{(\Sigma\,(n_i^1+n_i^0))^2}}$$

where

$$P_i = \frac{n_i^1\,P_i^1 + n_i^0\,P_i^0}{n_i^1+n_i^0}$$

and P_i^1, P_i^0, n_i^1, and n_i^0 are defined as in Table XXXVIII.

An analogous formula is used when computing the error in the standard weighted mean in comparing S = 0 and S = 1, C = 0 and C = 1, etc.

Table B differs from Table A in that the weights have been chosen in another way. In Table B, for instance, when comparing cases Da = 1 and Da = 0, the number of cases Da = 1 have been chosen as weight for every factor combination (n_i^1 in Table XXXVIII). Since the results in Table B and Table A agree rather well, the choice of weights does not seem to be very important. The significance test underlines the uncertainty of the above-mentioned significant difference between S = 1 and S = 0.

Table C presents comparisons with respect to those factors, age, sex, length

Table XL. *Comparison between the Expected and Observed Percentage of Unsatisfactory End Results*

(Factor combinations as in Table XXXVII)

Factor combination	Total no. of cases	Observed percentage	Expected percentage	Residual
1	136	2.9	2.9	Bas
2	2	50	40	10
3	20	15	17	− 2
5	140	9	9	0
6	12	42	46	− 4
7	46	22	24	− 2
8	9	56	61	− 5
9	7	43	49	− 6
10	2	50	87	− 37
11	3	100	64	36
13	19	58	56	2
14	1	100	94	6
15	3	100	71	29
16	5	100	108	− 8
17	15	27	27	0
19	4	75	41	34
21	26	35	33	2
22	1	0	70	− 70
23	17	41	48	− 7
25	1	0	74	− 74
29	7	86	80	6
31	2	50	95	− 45

of follow-up and fractures of the ulnar styloid process, which, according to the preliminary analysis in the first part of this chapter, were not important. A division into factor combinations has been made as in Table XXXVII. Within each factor combination patients aged 31–65 years are thus compared with patients over 65 years of age. A weighting system analogical to that used in Table A is applied. Table C confirms that the preliminary conclusions hold; not the slightest tendency towards differences can be discerned.

Table IXL A supplies only one value for every factor indicating its effect on the functional end results. The same applies to Tables B and C. These standard weighted differences, however, do not provide an answer to the questions set out under (1) and (2) on page 85. An answer to such questions can be obtained as follows.

We start out from the figures for the frequency of unsatisfactory functional end results obtained in Table XXXVII. These observed values are compared in Table XL with the expected values, obtained in the following way. We choose as a basis factor combination 1 in Table XXXVII and we put the expected value equal with the observed value = 2.9%. For factor combination 2 the expected value is obtained by adding 2.9 to the standard weighted difference with respect to unsatisfactory results between Type II E and Type II A–D found in Table IXL A, i.e. 37.2%. The expected value is then 2.9% + 37.2% = 40.1%. For factor combination 3 we add to the basis 14.5 i.e. the standard weighted difference between Da = 1 and Da = 0. Then we proceed in the same way, using Table IXL A as illustrated by Table XL.

If the standard weighted differences between L = 1 and L = 0, S = 1 and S = 0, etc. were the same for each subgroup, the percentages of unsatisfactory functional end results, which are given in the column for expected values, should roughly agree with the observed values.

The residual, i.e. the difference between the observed and the expected frequency, amounted to 10 per cent or more only in some very small subgroups (groups including at most 4 cases). In the remaining groups (including 5 or more cases) the residuals were never larger than 8%. The fact that the residuals are small indicates that there is no interaction between the factors affecting the functional result, i.e. that the standard weighted differences for every one of the factors given in Table IXL represent the effect of this factor regardless of which other factors are combined with it. This implies that answer B to the two questions posed on page 85 appears to be the most accurate.

CONCLUSIONS

As could be expected in a clinical study of this type, it proved rather difficult to define to what extent various possible factors had influenced the functional end result. No one clinical factor could be shown to have had a uniformly decisive effect on the functional result. In the majority of cases an interaction of factors could be conceived as the cause of unsatisfactory clinical results.

A preliminary analysis, in which the functional result was correlated with one factor at a time, gave the following information.

Sex and age did not appear to have any clear significance. While it was true that the results were more favourable in the youngest age groups under 30 years and less favourable in the eldest group over 70 years, the number of cases in these groups was too small to permit any definite conclusions. Fractures of the ulnar styloid process were of no consequence for the ultimate function. Clear evidence of arthritis was present in only a few cases, mainly following comminuted fractures involving the articular surface. The effect of this complication on the final results was difficult to evaluate in these cases, and because of its low incidence this factor had only minor significance. Variations in the length of follow-up, i.e. the time elapsed between injury and follow-up examination, did not influence the frequency of unsatisfactory results.

On the basis of this preliminary analysis, the remaining factors which could be considered to influence the functional result were defined as type II E fractures, residual deformity of varying severity consisting in either shortening or dorsal angulation, laxity in the distal radio-ulnar joint, and posttraumatic causalgic symptoms.

As has been said before, in the majority of cases several of these factors were in evidence in varying combinations. Under those circumstances the preliminary analysis did not suffice if spurious correlations were to be avoided and significant relationships elicited.

A more thorough statistical analysis was therefore made using the method of standard weighting. This analysis provided statistical proof which on the whole confirmed the observations resulting from the preliminary appraisal. One additional feature of particular interest was elicited. In the most favourable subgroup where none of the factors detrimental to function was in evidence (line 1, Table XXXVII), the incidence of unsatisfactory results was 2.9 % as against 20.5 % in the total series. This low incidence indicates that the analysis succeeded in eliciting all the factors that were essential in producing a loss of function.

As regards type of fracture, is was found that comminuted fractures involving the joint surface had less favourable results than the other types. This fracture type only made up 6 % of the total series, so that quantitatively it was a factor of minor significance.

The preliminary analysis suggested that the degree of primary displacement might have some slight significance. The incidence of unsatisfactory results in type II A and II B fractures with merely dorsal angulation was 13.5 % as against 20 % for type II C and II D fractures with more severe primary displacement. These figures were found to be without significance in the statistical analysis. The increased incidence of redisplacements in types II C and II D was not sufficiently high nor the redisplacements severe enough to cause a clear decline of the results. The results in the small group of fractures with volar displacement were less favourable than in the total series.

An important factor was roentgenologic evidence of residual deformity. This was mainly due to the high incidence of cases with such defects. If residual dorsal angulation amounted to 100 degrees, the increase in the incidence of unsatisfactory results was clearly significant, whereas in cases with residual shortening of 3 mm or more it was probably significant. On the other hand, in the majority of cases (52 %) even severe deformity was found to be compatible with satisfactory function of the wrist.

Residual laxity in the distal radio-ulnar joint significantly affected the functional end result in the relatively small group (15 % of the total series) where it was a feature. Complete dislocation of the ulnar styloid could in no instance be observed and is evidently a rare complication. Among the cases where a roentgenogram in the frontal view showed loss of contiguity of the joint, the incidence of impaired function was higher than in cases where the contiguity of the joint had been retained. Such a loss of contiguity is mainly caused by shortening of the radius and it is possible that the detrimental effect of radial shortening must mainly be ascribed to the changes it causes in the radio-ulnar joint. Severe dorsal angulation also produces a loss of contiguity of the distal radio-ulnar joint which might possibly be the direct cause of residual symptoms also where this type of deformity is concerned.

Pain, finger swelling or stiffness setting in early in the posttraumatic course proved in a small group of patients (10 % of the total series) to be of such a permanent character that the ultimate function of the hand was affected. Unlike the other factors, this factor could often not be objectively evaluated on follow-up examination and its appraisal was necessarily entirely dependent upon the information supplied by the patient, although in several cases the presence of residual symptoms permitted a reconstruction of the history. The genesis of such symptoms is difficult to explain. Suggestive of a circulatory disturbance as the underlying cause was the fact that 20 % of the patients in this group within a few days after injury again consulted a doctor because of finger swelling and pressure of the plaster. In the remaining part of the total series, this had occurred in 2 %. Even if signs of a typical Sudeck's atrophy were found in only one case on follow-up examination, it is possible that the majority of these symptoms were neurogenous and originated from the sympathetic nervous system.

Chapter 9

FREQUENCY OF THE VARIOUS FACTORS IN A SERIES OF PATIENTS RECEIVING DISABILITY COMPENSATION

It appears from the analysis of a routine clinical series of distal radius fractures described in the preceding chapter that the functional end result depends on certain factors connected with type of fracture, posttraumatic course, anatomical end result, and injuries to the distal radio-ulnar joint. If this analysis is to be considered reliable, these factors must inevitably play an even larger rôle in a series consisting exclusively of cases where the clinical end result has been so unsatisfactory that the patients have been left more or less disabled. Fracture of the distal radius is a relatively innocuous injury, however, as has been made clear in the foregoing chapters, and it is therefore difficult to collect a sufficient number of such cases from a routine series. A series selected from the files of an insurance company, where the cases rating disability compensation are gradually sifted out from the cases reported, should be able to clarify this point. In view of these considerations, the present study was supplemented by analysis of a series selected from the files of the Swedish State Insurance Board.

MATERIAL

After examining the records of all patients who at any time during the period between 1945 and 1954 had received disability compensation because of a fracture of the forearm, only those cases were selected where fracture of the distal radius had been the sole injury, in order to avoid distortion of the final results due to the possible influence of other injuries to the same limb. The Swedish Insurance Board considers a case eligible for compensation only if the total working capacity of the patient has been reduced by at least 10 per cent as compared to that of a healthy subject in the same age group. An evaluation of this kind is obviously highly subjective, but for an innocuous injury like fracture of the distal radius, a substantial loss of function of the injured wrist and hand is required. In the routine series, function was only in a few cases so poor that it made the patient eligible for disability compensation.

A total of 346 patients were found to have received compensation for disability due to fracture of the distal radius during the relevant period. In 117 cases, the compensation period did not exceed six months. After one year, 170 patients were still receiving compensation, and annuities lasting for more than two years after injury were paid to 134 patients. A gradual decrease in the number of disabled cases could consequently be observed as the period of observation grew longer. During the first years after injury, this was no doubt in many cases related to a clinical improvement in the function of the injured wrist. On the other hand, no continuing improvement of the clinical result could be observed in the routine series during the observation period which could be surveyed. The improvement of the patients' condition evidenced by the insurance statistics of the State Insurance Board, which continued for more than a year after injury, must to a considerable extent be ascribed to what in insurance terms is called "adaptation''. This implies the patient's ability to improve his working capacity by continuous training, despite the handicap any loss of function implies, and thus compensate the reduction in his income, which in many cases from the insurance point of view is the essential ground for awarding compensation. Adaptation may be achieved in various ways, for instance by employing special suitable tools, by letting the uninjured limb assume some of the more strenuous movements, or by other similar measures.

Of the original group of 346 cases entitled to compensation during the period between 1945 and 1954, 89 patients were left on examination of the records in 1958 who either continued to receive disability compensation or had been awarded an annuity for life. These cases could be regarded as ideally suited for an investigation into the factors which contributed to the disability. The records of these patients were minutely scrutinized. Information about the initial treatment was in this series collected from many different sources and was often incomplete. Roentgen examination had not been performed in 7 cases. To some extent the data contained in the records could be supplemented by studying the information contributed by the surgeon responsible for the initial treatment. In all cases detailed certificates of disability were available, made out either when a permanent annuity was settled or when continuation of disability compensation came up for revision. Fifty-one patients were called in for a follow-up examination, including roentgen examination of both wrists, in order to obtain more complete information.

RESULTS

Evaluation of the results in the "disability series" thus selected was based on the same factors as for the clinical analysis of the routine series. The material was too heterogeneous, however, to permit a statistical analysis.

Age and sex. The age and sex distribution in the total series of 346 patients originally receiving disability compensation is shown in Table XLI. The un-

TABLE XLI. *Age and Sex Distribution of the Total Series of Compensation Cases.*

	Years						Total no. of cases
	15–25	26–35	36–45	46–55	56–65	66–75	
Men	9	19	32	52	32	12	156
Women	—	4	12	68	84	22	190
Total	9	23	44	120	116	34	346

TABLE XLII. *Age and Sex Distribution of a Series of 89 Permanently Disabled Patients.*

	Years						Total no. of cases
	15–25	26–35	36–45	46–55	56–65	66–75	
Men	2	6	6	14	8	7	43
Women	0	0	1	17	19	9	46
Total	2	6	7	31	27	16	89

usually large proportion of men, as compared with the figures found in the routine series, must be ascribed entirely to the fact that housewives, the category by far the most liable to incur this type of injury, did not enjoy any insurance benefits during the relevant period and consequently as a group are excluded from a series of compensation cases.

The distribution of cases over the different age groups, on the other hand, agreed very well with that in the routine series. This tended to confirm the impression left from analysis of this factor in the routine series, that age did not significantly influence the clinical end result with respect to function, but the lack of exact information about the age distribution in the total female population resorting to the State Insurance Board during the relevant period did not warrant any definite conclusions.

Table XLII gives the age and sex incidence in the series of permanently disabled patients. The incidence in the age group between 66 and 75 years was high. It was uncertain to what extent this should be ascribed to clinical causes or regarded as due to technical insurance considerations. It seems likely, however, that as any adaptation could scarcely be counted on for these elderly patients, permanent annuities were awarded more generously in such cases.

Type of fracture. The type of fracture could be ascertained in 82 of the 89 cases. In the remaining cases no roentgen pictures were available. The type of

TABLE XLIII. *Distribution of Fracture Types in the Series of Permanently Disabled Patients.*

	Type of Fracture							Total no. of cases
	II A	II B	II C	II D	II E	III	Undiffer-entiated	
Men	5	2	8	2	23	1	2	43
Women	9	1	20	6	4	1	5	46
Total	14	3	28	8	27	2	7	89
%	*16*	*3.5*	*31.5*	*9*	*30*	*2*	*8*	*100*

fracture was determined according to the same principles as in the routine series. In some cases the initial roentgen pictures were not available, but post-reduction or follow-up pictures permitted determination of the fracture type.

Table XLIII illustrates the incidence of the different fracture types. Comminuted fractures involving the joint, which in the routine series comprised somewhat more than 6% of all cases and made up 22% of unsatisfactory results, in this series represented almost one-third of the 89 cases. Probably largely due to the poor prognosis inherent in these fractures, a contributory cause may have been that this type of fracture is more common in men than in women and consequently in the present series was over-represented, due to the unusually large proportion of men. It was remarkable that 20% of the cases of permanent disability were due to fractures with negligible displacement not involving the joint. The group with "poor" functional results in the routine series showed approximately the same incidence of these "harmless" fractures.

Anatomical end result. The cases were classified according to degree of deformity in the same way as the routine series. Evaluation of this factor was possible in 66 cases. The results, shown in Table XLIV, were clearly less favourable than in the routine series, with an incidence of 64% moderate and severe deformity, as against 37% in the routine series.

Of the 42 cases of moderate or severe deformity, 29 were largely due to gross redisplacement, whereas in the remaining cases reduction had been unsatisfactory. In 4 cases with severe deformity, a corrective osteotomy was attempted at a later stage.

Arthritis. This factor could only be evaluated in the cases subjected to follow-up examination. The period of observation varied from 4 to 14 years. In 15 of the 51 cases, relatively severe changes were observed, but in some instances these dated from before the injury. In 13 of the 15 cases of arthritis, fractures

TABLE XLIV. *Anatomical End Results in 66 Cases with Permanent Disability.*

	No. of cases	%	Percentage distribution in routine series
No or insignificant deformity	10	*15*	(*24*)
Slight deformity	14	*21*	(*39*)
Moderate deformity	27	*41*	(*32*)
Severe deformity	15	*23*	(*5*)

with severe joint involvement had been present. In only two cases was arthritis observed following an uncomplicated fracture.

Distal radio-ulnar joint. A distinct laxity of this joint could be palpated in 7 of the examined patients (13%). In 3 cases this injury had been decisive for the outcome and the permanent disability which resulted. The following case is a fairly representative example of this group:

—*EB (Injury 1954, Annuity 96850), Woman, 55 years old.*

Patient slipped on an icy road and received the impact of the fall with her arm held behind her. This resulted in a fracture one cm proximal to the radio-carpal joint, running into the distal radio-ulnar joint. Slight dorsal displacement. No fracture of the ulnar styloid process. Reduction under local anaesthesia with satisfactory results. Some redisplacement occurred during the postreduction course and the final roentgen examination showed a dorsal angulation of more than 100 degrees. Immediately on removal of the plaster fixation, the patient complained of pain, tenderness and crepitations over the ulnar aspect of the wrist. The symptoms did not regress and have made the hand completely useless. An annuity based on 25% disability was awarded. On follow-up examination 4 years after injury, instability of the radio-ulnar joint was marked and the patient complained of intense tenderness on palpation over the capitulum ulnae. Supination caused the capitulum ulnae to subluxate palmarwards, subsequent pronation restored it to its normal position with pain and crepitation. After these movements there was prolonged pain. Roentgen examination showed a distinct diastasis in the joint, which increased on pronounced radial deviation (Fig. 20). The patient used a fixation bandage continuously.

This case served to illustrate two points that have been put forward earlier. Serious damage to the soft tissues stabilizing the distal radio-ulnar joint may occur even if the fracture is not appreciably displaced. Severe symptoms result only if the capitulum ulnae is considerably dislocated. Mere laxity causes only slight impairment of function.

Of the remaining two cases, the fracture had in one instance been of the same harmless type, in the other it had been grossly displaced.

Causalgia. On this point, the records provided information for all 89 cases of permanent disability. In 26 cases (30%), 20 women and 6 men, a highly typical posttraumatic reflex dystrophy had developed after reduction. Fourteen of the patients in this group were given a follow-up examination; in the remaining cases the records gave such exact information that the diagnosis was clear. In 20 cases, a typical "stiff hand" resulted, with marked loss of motion in fingers and wrist. These "Sudeck" symptoms were found to result from all types of fracture. They were the main cause of disability in the group of "harmless" fractures with satisfactory anatomical end results.

These 26 cases of Sudeck's atrophy, which presented the entire characteristic syndrome, were relatively clearly distinguished from the remaining cases. A common factor for the entire group was nevertheless that the postreduction course had been longer than usual, due to stiffness, swelling and pains of a less typical nature.

Nerve injuries. Permanent nerve lesions resulting in loss of sensation and muscle atrophy were observed in 5 of the 89 cases (5.6%). In 2 cases the damage was limited to the ulnar nerve, in 1 case both the median and radial nerve were injured, and in the fourth case a paresis involving the entire arm was present, due to the brachial plexus being damaged at the time of injury. In two more cases the initial records indicated that the immediate posttraumatic symptoms might have been due to injury of the median nerve, but no objective evidence of such damage could be found on follow-up examination.

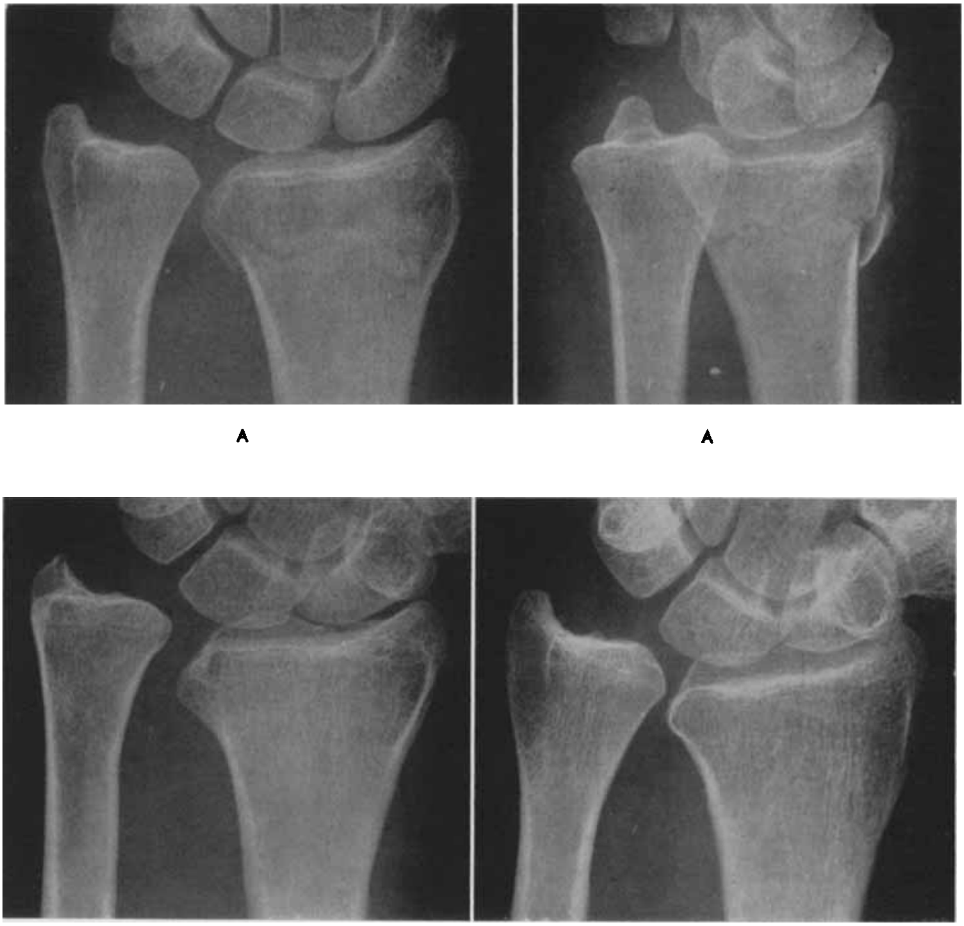
In two cases the fracture had been uncomplicated and did not leave any deformity, so that the nerve injury in these instances must be regarded as an essential factor for the final result.

SUMMARY

The primary aim of this analysis of a series of disabled patients was to test the reliability of the conclusions resulting from the preceding analysis of factors influencing the final results in the routine series. On the whole, these conclusions can be said to have been confirmed.

The proportion of clear posttraumatic reflex dystrophies, however, was larger in this series of patients with strongly impaired function, and residual symptoms causing severe loss of motion were present in every 4th case. This explained why permanent disability was found in a considerable number of cases following a harmless fracture with either entirely satisfactory anatomical results or only can be said to have been confirmed.

The anatomical end result was nevertheless decidedly less favourable than in the routine series, which suggests that this factor in the present series, too, was an important, although not decisive, cause of functional impairment.



A A

B C

Fig. 20. Woman aged 55. Fracture with slight primary displacement resulting in disability due to recurrent dislocation of the capitulum ulnae. *A*. Pre-reduction roentgenogram. *B*. Follow-up roentgenogram 4 years after injury. Clearly increased diastasis in the radio-ulnar joint in comparison with the uninjured wrist (C).

The same was true for type of fracture. Comminuted fractures had in this series an incidence of 30% as against 6% in the routine series.

A contributory cause to disability not represented in the routine series was in some cases recurrent dislocation of the distal radio-ulnar joint, in a few other cases severe nerve injuries.

The age and sex incidence in this series of compensation cases did not differ from that in the hospital series, but men were over-represented due to technical insurance causes.

Chapter 10

SOME PRACTICAL CONCLUSIONS FROM THE INVESTIGATION

In considering the question of how effective the treatment of fracture of the distal radius is, a review of the literature and the results of the present study established the following salient points.

Perfect cosmetic and functional results were found in 41% of the present series. Function of the wrist was affected by residual symptoms in over 20% of all cases, although this functional impairment had considerable practical importance in only about 10%.

It is dubious if these results can be considered an improvement over the first therapeutic results published around the turn of the century.

An appraisal of these figures depends on the point of view one assumes. On the one hand, they may be regarded as distressing evidence of inadequacy in treating what is often considered the most harmless and most easily approached fracture of the human skeleton. On the other hand, the results may be considered relatively satisfactory for a fracture close to a joint which in most cases causes severe crushing of the cancellous bone and often directly involves two articulations of highly specialized function.

Wiklund and Müllern-Aspegren (1956) fixed the annual number of distal radius fractures treated at the out-patient departments of Stockholm's communal hospitals at 500. If the total population resorting to these hospitals is put at 750,000 and the fracture assumed to have the same incidence in the provinces as in the capital, the annual number of cases in Sweden may roughly be estimated at 5000, of which between 400 and 500 can be expected to leave an appreciable and permanent impairment of function. Although these figures are mere approximations, they serve to give some idea of the order of magnitude of the problem. From whichever point of view one appraises the final results, these figures warrant the suggestion that the methods of treatment may need to be improved.

In considering possible ways of approaching this problem, one must take into account both the factors responsible for residual symptoms and the varying significance that should be attached to them. The present follow-up study has provided some information on these points.

The important factors were found to be roentgenographic and clinical evidence of residual deformity, comminution of the fracture involving the radial articular surface, posttraumatic causalgia, and injuries to the distal radio-ulnar joint resulting in chronic instability. None of these factors were decisive for the final result, however, and measures directed at any single one of them must consequently be expected to have only a limited effect.

The most effective approach would probably be to aim at improving the anatomical end result. While it is true that the functional result was satisfactory in about 60% of cases with moderate or severe residual deformity, the incidence of these cases was as high as 32%. As a purely quantitative factor, the anatomical end result, with respect to both radial shortening and dorsal angulation, would seem to be of considerable importance.

It follows that accurate reduction is an important factor. Exact anatomical reduction, while not providing an absolute guarantee, affords at least some protection against redisplacement. In addition to restoring the normal angulation of the articular surface and the normal length of the radius, it is important to correct the position of the distal fragment so that the fracture surfaces are in perfect apposition.

To achieve such a perfect reduction, repeated attempts may be necessary. Although it could not be confirmed in the present study, several authors have suggested that the resulting additional trauma may increase the incidence of posttraumatic causalgia. These posttraumatic syndromes with pain, swelling and stiffness of the fingers, unquestionably have an adverse effect on the final results. In order to avoid this risk while still ensuring an adequate reduction, it would seem that the earlier-mentioned extension technique with so-called Chinese finger-stalls introduced by Caldwell (1930) might be worth a trial, in any case for fractures where reduction tends to be difficult. This is particularly true of comminuted fractures involving the joint, the results of which with the technique used in the present investigation were unsatisfactory. The method suggested by Freese (1949) and Hudson and Rusnack (1958), which involves resection of the capitulum ulnae in order to facilitate reduction, will seldom be indicated.

It is clear that a dorsal plaster splint affords no absolute protection against redisplacement and hardly can be expected to do so, because of the crushing of the cancellous bone. The literature provides only sparse, and to some extent contradictory, data about the advantages to be expected from more extensive plaster fixation which includes the elbow. Some authors believe that no form of external fixation is completely effective in preventing redisplacement if the cancellous bone has been crushed (e.g. Poulsen, 1906). Nevertheless, in the present series, where a dorsal plaster splint was the standard fixation, the redisplacements that occurred were not very severe and their adverse effect on the final results was uncertain. This means that more radical methods, such as skeletal traction or internal fixation in combination with various forms of plaster fixation, are justified only in exceptional cases, although they should be considered as an alternative method, in particular in the management of comminuted fractures.

Adequate reduction, with, in particular, correction of radial deviation and restoration of the integrity of the radio-ulnar joint, has been mentioned as a first condition for preventing instability in the joint (Mason, 1953). As ulnar instability often results from fractures with slight primary displacement that leave very little deformity, it would seem that accurate reduction does not provide sufficient prophylaxis. A circular plaster cast, extending above the elbow and effectively preventing pronation and supination during immobilization, is regarded as a particularly valuable protection against instability. It is uncertain whether union is better encouraged by fixation with the hand in palmar flexion and ulnar deviation (Taylor and Parsons, 1938; Mayer, 1940) or in supination (Lippman, 1937), as the authors do not present any end results to support their viewpoint. The essential point is immediate diagnosis in cases where the instability is so severe that there is a risk of recurrent dislocation of the capitulum ulnae. If possible, the stability of the capitulum ulnae should be tested during reduction. If it is found to be very loose, the fixation should be made to include the elbow and the condition should be followed until the fracture has healed.

The possibilities of arresting a posttraumatic causalgia once it has appeared seem to be limited. Gentleness in reducing the fracture and adjustment of the bandage if swelling of the fingers is noticed can do much towards preventing its occurrence. For the same reason, one must insist upon the patient performing the prescribed active exercises. Patients presenting clear symptoms of this type should be hospitalized, since this complication is a major cause of permanent and severe disability. Although the effect of cervical sympathetic blocks or infiltration of painful and tender areas in the fracture site with local anaesthetics is often slight, these remedies should nevertheless be tried. It is essential that complaints about pain and signs of increased temperature and finger swelling during immobilization not be disregarded. Although circulatory disturbances as a cause of finger swelling with the technique of immobilization used in Sweden are bound to be less common than the causalgic symptoms due to involvement of the sympathetic nerve system, the possibility of such disturbances should not be neglected.

CORRECTION OF RESIDUAL DEFORMITY

A variety of operative methods have been recommended in the literature for correction of residual deformity. Some of these are directed at restoring both the normal length and appearance of the distal radius and the integrity of the distal radio-ulnar joint. In addition, various techniques have been presented for correction of instability in the radio-ulnar joint.

As Speed and Knight (1945) emphasized, such plastic surgery should be planned on an individual basis depending on the type of deformity to be corrected. If there is no appreciable shortening, a corrective osteotomy may suffice, but if the radius must be restored to its normal length, bone grafting becomes necessary. The method adopted by Durman (1937) and Campbell (1937) appears to be suitable in the majority of cases. A graft taken from the distal end of the ulna, after this has either been chiseled off or resected, is shaped to fit the particular deformity to be corrected and wedged into the osteotomy.

For correction of a persisting defect of pronation and supination, resection of the distal end of the ulna is one of the most common methods. This operation has been associated with the name of Darrach since his introduction of the method in 1913. A few isolated cases had earlier been described by Moore (1880), Lesser (1887), and Lauenstein (1887). Good results with the method have been reported, among others by Boyd and Stone (1944), and by Dingman (1952).

Another operation for correction of this deformity, in which part of the ulna is resected but the capitulum ulnae is left intact, is ascribed to LeFort and Cololian (1918). Ingebrigtsen (1955), who introduced the method in Scandinavia, emphasized the importance of performing this resection above the pronator quadratus muscle.

The methods most widely used for correction of instability in the radio-ulnar joint are resection of the ulna and various forms of tendon and fascia transplantation to replace the injured soft tissues (Milch, 1928; Henschen, 1938; Hill, 1939; Liebolt, 1953; Bette, 1957). Lengenhager (1950) believed it sufficient to merely suture the dorsal and volar ligaments. Hultén (1949) has recommended arthrodesis for patients doing heavy manual work.

It is clear from the foregoing that there is a wide choice of methods for operative treatment. Making the right selection among these methods and a satisfactory amount of technical skill in performing the operation are important points, but equally important is the decision what indications justify surgical intervention. The present study permits some conclusions on this point. Primarily, one should consider that good function is found in the majority of cases despite sometimes considerable deformity; severe impairment of function is found in a mere fraction of these cases. It is certainly necessary to preclude the possibility of other factors besides anatomical deformity being responsible for poor function, before resorting to surgical intervention. If a posttraumatic causalgia can be suspected to lie behind a loss of motion or a painful condition, it is hardly to be expected that surgical correction of deformity will have any effect. A detailed history which includes information about the posttraumatic course may be helpful in reaching a decision. Equally little effect must be expected from operative correction in cases with severe comminution of the carpal articular surface. An exception must be made in the rare cases of arthritis in the radio-ulnar joint, when resection of the capitulum ulnae is always indicated.

Another point of importance is that, for several reasons, sufficient time should be allowed to pass before operative correction is attempted. For one thing, in several cases in the present series it was found that function improved and painful conditions disappeared spontaneously as long as one year after injury. In addition, the soft tissues must be allowed to heal completely, while a third reason it that physical therapy given for some time prior to the operation may improve results. Operative correction should never be attempted within the first 6 months and rarely within the first year after fracture. The only exception is made in the rare cases where instability in the radio-ulnar joint is so severe that the capitulum ulnae dislocates.

A point which has been discussed in the literature (Campbell, 1938) is whether deformity without an appreciable loss of function is sufficient indication for operative correction, but this problem is not bound to have much practical interest where Swedish patients are concerned.

Summing up, it can be said that operative correction should be made to depend upon the following conditions:

(1) The deformity must be severe,

(2) Sufficient time must have elapsed after injury,

(3) The patient's history must make no mention of signs that could be interpreted as posttraumatic trophic disturbances or nerve injuries,

(4) There must be no comminution of the articular surface or arthritis of the radio-carpal joint,

(5) Operative correction of radio-ulnar instability is only indicated if it is so severe that the capitulum ulnae is displaced out of the ulnar notch.

On these indications, the cases in which operative correction is justified are few. Of the 51 disabled patients included in the follow-up examination, open correction could have been attempted in no more than 8 cases with any hope of success.

Arthrodesis may be considered in cases where an impairment of function can be mainly ascribed to arthritis. In the remaining cases, where operative correction would be futile, the only alternative is provided by various types of bandages. This form of treatment is worth a trial. In the series of compensation cases, most of the patients who had been fitted with a fixation bandage thought it effective and used it continuously.

Chapter 11

GENERAL SUMMARY

Concerning fractures of the distal end of the radius, one might say, that although this lesion has been the subject of intensive studies, both clinical and experimental, as to its treatment, prognosis and even importance for almost 150 years, a general agreement on many aspects of the problem has yet to be attained. Against this background, the present study was designed with two objects in view:

1. by means of a follow-up examination to analyze a large series of patients treated by routine methods;
2. on this basis to evaluate the effect of various factors on the functional end result by clinical and statistical methods.

A total of 515 fractures were included in the follow-up examination. In view of the random selection of the cases, they could be regarded as representative of a typical surgical out-patient population treated by routine methods. As fissure fractures and fractures without appreciable displacement hardly can be considered to constitute a therapeutic problem, only those cases were included in which a clear displacement of the distal fragment had occurred. With a few exceptions, treatment had uniformly consisted of immediate reduction under local or general anaesthesia followed by immobilization with the hand in mid-position by means of a dorsal plaster splint for an average period of 35 days.

According to the severity of the displacement and the degree of involvement of the radial articular surface, the following types of fractures were distinguished:

Fractures with merely dorsal angulation	123 cases.
Fractures with merely dorsal angulation involving the joint but without comminution of the articular surface	39 cases.
Fractures with dorsal displacement of the distal fragment	216 cases.
Fractures with dorsal displacement of the distal fragment involving the joint but without comminution of the articular surface	68 cases.
Fractures with dorsal displacement of the distal fragment and comminution of the articular surface	32 cases.

Fractures with volar displacement of the distal fragment	13 cases.
Undifferentiated fractures	24 cases.

The follow-up study included an appraisal of the immediate results of treatment on the basis of the available hospital records, the information supplied by the patients on follow-up examination, and the prereduction and postreduction roentgenograms.

The subsequent evaluation of end results was made from 15 months to 8 years after injury, with an average follow-up period of 3 years and 9 months.

The roentgenologic evaluation of residual deformity was based on measurement of both the angle created by the radial articular surface and the long axis of the radius (dorsal angulation) and the proximal displacement of the radial styloid process (shortening).

As an immediate result of treatment, exact reposition of the distal fragment and perfect apposition of the fracture surfaces was achieved in every other case.

An appreciable amount of redisplacement, implying a loss of the original reduction amounting to 10 degrees with respect to dorsal angulation and to 4 mm for shortening, occurred in 28%, but in only 7% it could be considered severe (dorsal angulation exceeding 20 degrees, shortening of 10 mm). The incidence of redisplacements was somewhat higher both in elderly people, in the group with severe primary displacement of the fracture, and in cases where reduction had not been exact. This did not imply that perfect reduction constituted any guarantee against a loss of position.

Fifty-three patients reported causalgia, a symptom complex combining lingering pains, finger swelling and stiffness which had set in early in the post-traumatic course.

As regards the end results, 236 patients (46%) reported on follow-up examination residual symptoms of varying severity. The most common symptom was a sensation of weakness in both the hand and wrist, followed in frequency by pains on and following exertion.

On the basis of the roentgenologic evaluation, the anatomical end results were classified as perfect in 24%. Slight deformity (dorsal angulation of 91–100 degrees, shortening of 3–6 mm) persisted in 39%, moderate deformity (dorsal angulation of 101–115 degrees, shortening of 7–11 mm) in 32%, and severe deformity (dorsal angulation exceeding 115 degrees, shortening of more than 11 mm) in 5%. Roentgenologic evidence of slight deformity generally did not involve any changes in the appearance of the wrist; the cosmetic end results were considered satisfactory in 60%.

Loss of motion of varying severity was observed in 48%; in the majority of cases it was slight and did not exceed 20 degrees in the dorsal or volar direction on comparison with the opposite hand. Frequently it had gone unnoticed by the patient.

A palpable laxity in the distal radio-ulnar joint was found in 77 cases (15%).

Evidence of nerve injuries was rarely found.

On the basis of the follow-up findings, the end results were classified as follows, with the emphasis put on function of the wrist:

Excellent results. Unimpaired function of the wrist. No subjective symptoms. No deformity. Slight loss of motion not exceeding 15 degrees accepted.	214 cases (41.5%)
Good results. Unimpaired function of the wrist. Negligible subjective symptoms. Deformity accepted if not producing subjective symptoms.	195 cases (38%)
Fair results. Function of the wrist less satisfactory for strenuous or more specialized movements. Most pre-injury activities possible. Severe loss of motion accepted if not associated with subjective symptoms.	61 cases (12%)
Poor results. Working capacity diminished or general way of life affected. Cases with continuous pain.	45 cases (8.5%)

The next question to be considered was to what extent various clinical factors had contributed to this functional end result. The factors included in this analysis were age, sex, type of fracture, residual deformity consisting in dorsal angulation or shortening, posttraumatic causalgia, fracture of the ulnar styloid process, arthritis, length of follow-up, and laxity in the distal radio-ulnar joint.

In the first instance, each of these factors was correlated separately with the functional end result. On the basis of this preliminary analysis age, sex, length of follow-up, and fracture of the ulnar styloid process could be eliminated as being of negligible significance, whereas unmistakable evidence of arthritis was present in such a small number of cases that the clinical significance of this factor was difficult to evaluate. Residual deformity, causalgia, fractures involving comminution of the articular surface, and laxity in the distal radio-ulnar joint, on the other hand, appeared to be correlated to the functional end result. However, in a considerable number of cases with impaired function several of these factors were in evidence in varying combinations. The possibility of an interaction between these factors, which might imply that the correlations found in the preliminary analysis were partly spurious, could therefore not be excluded. This meant that a more detailed statistical analysis was needed if any reliable conclusions were to be drawn.

Such an analysis was made using the technique of standard weighting. It succeeded in establishing statistically significant correlations between the functional end result and certain of the examined factors, and confirmed that the factors eliminated in the preliminary analysis had no significance. On the whole, the statistical analysis corroborated the findings of the preliminary analysis.

It permitted the following conclusions:

1. Prognosis was less favourable for fractures with comminution of the articular surface than for other types of fracture.
2. Residual deformity increased the risk of impaired function.
3. Posttraumatic causalgia was to some extent permanent with consequent loss of function.
4. Residual laxity in the distal radio-ulnar joint implied increased risks of impaired function.

In order to estimate the effect of these factors in cases with severe chronic disability, finally, the study included an analysis of a series of compensation cases, i.e. patients who as a consequence of fracture of the distal end of the radius either had received disability compensation over a long period of time or had been awarded an annuity for life. The results of treatment in this group were less favourable than in the group classified as "poor results" in the routine series. The study of this series of compensation cases included 89 cases.

On the whole, this analysis tended to confirm the earlier conclusions. The incidence of cases with residual deformity was higher in the compensation series, while fractures with comminution involving the joint had an incidence of 30% as against 6% in the routine series. A feature of particular interest was the high frequency (30%) of posttraumatic symptoms suggestive of Sudeck's atrophy.

Additional factors contributing to chronic disability not encountered in the routine series were, among others, recurrent dislocation of the ulnar head and severe nerve lesions.

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