SECOND EDITION

RECONSTRUCTIVE PLASTIC SURGERY

VOLUME SIX

THE HAND AND UPPER EXTREMITY

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RECONSTRUCTIVE PLASTIC SURGERY

Principles and Procedures in Correction, Reconstruction and Transplantation

VOLUME SIX

THE HAND AND UPPER EXTREMITY

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Edited by J. William Littler, M.D.

Part Three

THE HAND AND UPPER EXTREMITY

EDITED BY J. WILLIAM LITTLER, M.D.

CHAPTER 68

SURGERY OF THE HAND: INTRODUCTION

J. WILLIAM LITTLER, M.D.

An extensive historical survey is not to be presented here, but rather some introductory remarks on the various factors that have consolidated an interest in surgery of the hand, and the principles that sustain it as a regional specialty. While it is obvious that deliberately concentrated effort will force progress in a particular area beyond the expected rate, there are special reasons inherent in the nature and structure of the hand itself and in its practical and emotional significance to the individual which have focused the attention of many surgeons on this region.

From ancient times the unique functional and psychologic attributes of the hand have been recognized. Certainly a symbolic significance as well as a fearful act of courage was demonstrated when Caius Mucius* thrust his right hand into a brazier of glowing coals before the Etruscan king Porsena to prove the steadfastness of his purpose.† It is said that Julius Caesar during the Gallic wars ordered the thumbs of captured warriors to be amputated that these mutilated men might survive as examples to their countrymen, yet be unable effectively to bear arms again.* Ablation of the hand as a punishment for serious crime, in some societies, has stood not far below decapitation in severity of sentence.

When clinical medicine bloomed and physical diagnostic measures became refined, astute physicians appreciated that the hands might bear mute testimony to both physical disease and mental perturbation. In the Orient practitioners had to rely entirely upon this and other peripheral sources of information since the more intimate anatomy was not allowed their scrutiny. With the Darwinian era the interrelationships of religion, philosophy and science received lengthy consideration and, as applied to the hand, formed the basis of Sir Charles Bell's fascinating and brilliant work (1833), *The Hand; Its Mechanism and Vital Endowments as Evincing Design.*† With the concentrated effort on comparative anatomy in the

*Thereafter known as Scaevola, or the left-handed man.

†Even so current French idiom expresses surety of purpose—"J'en mets ma main au feu!"

*Caesar ordered the thumbs of enemies captured in Uxellodunum cut off to render them ineffective as warriors. Similarly in the Peloponnesian War the same practice is cited, carried out by the Athenians upon the oarsmen of hostile galleys before these prisoners were sent home. (Hyrtl, J.: Lehrbuch der Anatomie des Menschen. Zwanzigste Anflage. 2nd Ed. Wien, 1889.)

†Treatise IV of the Bridgewater Treatises on the Power, Wisdom and Goodness of God as manifested in the Creation.

nineteenth century came the realization that the hand is not far advanced in the evolutionary scheme, and that greater perfection lies in the brain which directs it.

As the technical aspects of surgery matured, men aspired to success in repairing the more refined mechanisms of grasp. The relatively high level of disability occasioned by hand injury focused, and even forced, a greater surgical interest in the processes of composite tissue healing and demanded more refined techniques in dealing with these intricate structures, particularly in tendon repair. The investigations of Biesalski (Berlin, 1910) laid the groundwork for successful tendon grafting. Additional experience came from German clinics, and Leo Mayer continued these basic studies in the United States, where Kanavel, Bunnell, Koch, Mason, Allen and others also took up the subject.

The highly significant studies of Kanavel concerning the fascial, retinacular and synovial arrangements in the hand established an anatomic basis for proper placement of incisions to gain safe and adequate drainage of infection, both in those pre-antibiotic days and later. His study of congenital anomalies and his definition of the "position of function," so well known yet still so often neglected, are further great contributions. Continuing this school of regional surgery, Koch and his associates in Chicago long have promulgated the basic attitudes of Kanavel, emphasizing meticulous care of wounds and the conservation of function through maintenance of proper position and by sound planning of the reconstructive effort. In New York, Auchincloss extended the developmental anatomic studies of the vascular, fascial and tendon systems, and Cutler (1942), sensing a need, correlated various surgical viewpoints in his volume devoted to the hand, the first in this country, preceded only by the work of Iselin (1933) in France.

The decision of the Army Surgeon General, orthopedist Norman Kirk, during World War II to treat hand casualties at centers of regional specialization not only gave impetus to a great educational process but also, in assuring highest standards of care, established the hand surgeon as master of all aspects of the region. The unqualified success of the program was due largely to its over-all supervision, which happily fell to Sterling Bunnell (Fig. 68-1); his comprehensive book, then just published, was taken by the Army as a text.* Through his untiring

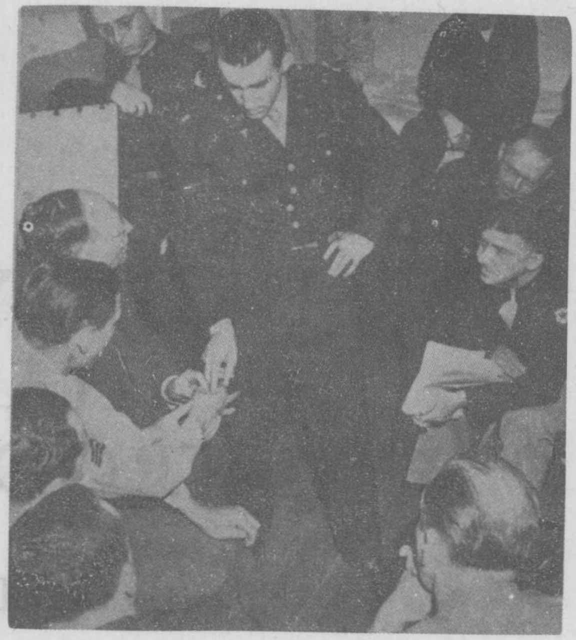

FIGURE 68-1. Dr. Sterling Bunnell, civilian consultant, at the Cushing General Hospital (1946). His sustained effort toward the improvement of hand care was one of the great medical contributions of World War II.

devotion, skill and learning, Bunnell was able to inspire a nucleus of general, neurologic, orthopedic and plastic surgeons who developed the available techniques and created a regional specialty. Since that time other wars, the ever-present traumatic lesions in a mechanized society, tumors and congenital anomalies have maintained demand for hand surgeons, have offered a challenge to their skill and tested fully their powers of imagination and ingenuity.

This specialty requires a precise anatomical and functional knowledge of the forearm and hand, an appreciation of central nervous control, an awareness of the sensitive relationship of the hand to the individual's personality, and its importance to his economic state. In reality this regional endeavor represents only a segmental interest in the broad field of reconstructive surgery. It is special only to a degree for, as in other fields, its purpose is to preserve and restore function. But a particular and refined surgical attitude, somewhat akin to that which pertains in ophthalmology, is necessary for the best management of the complex structure of the hand. To a degree, man unquestionably accepts his primitive but supremely adaptive hand as he does all parts of his body, but when the hand is wounded, he suffers far more than pain, especially the artisan or professional indi-

*The history of these enterprises is recounted in the official Army history edited by Bunnell (1955).

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vidual whose hands provide livelihood and express the creativity that springs from the mind. The personality, which depends so much on physical appearance and a capacity to perform, is deeply affected by a severe hand injury. Great concern and careful management are essential if the local disability is not to be compounded by emotional scars. It is the teleologic aspect, or rather the predictable consequence of injury, especially with deeply incised wounds, which is so important in the reduction of disability.

The chief concern of the surgeon is to aid and direct the reparative process, but too often we see excessive and unnecessary secondary disability result from inappropriate or overzealous intervention in the primary phase of treatment. It has been said that the first person caring for an injured hand will determine the ultimate state of its usefulness. Initially, a hand injury constitutes a nonvital wound, and other serious injuries demanding precedence may complicate the therapeutic situation. The wounded hand then must be treated as simply as possible, but in a manner conducive ultimately to a good functional result.

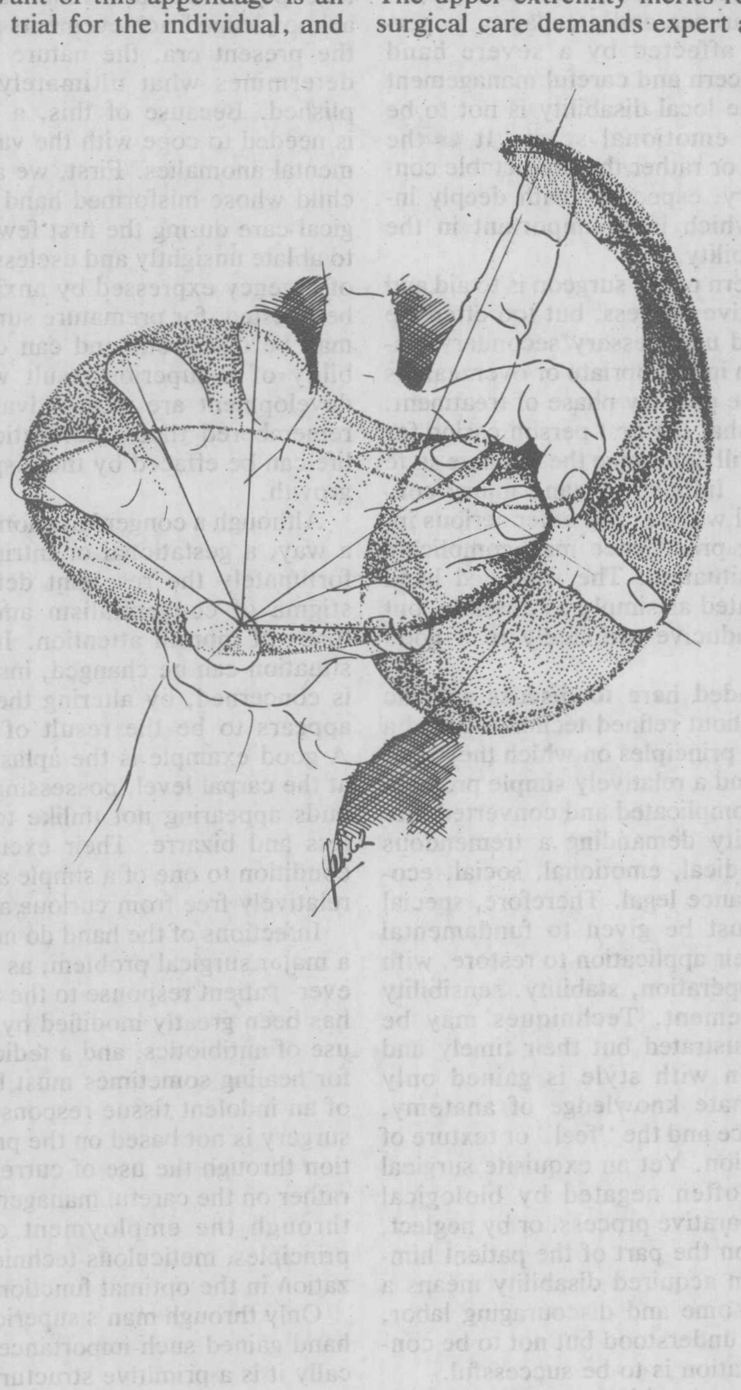
It is not intended here to discuss specific methods, but without refined techniques and a knowledge of the principles on which they rest, treatment fails, and a relatively simple problem may readily be complicated and converted into a serious disability demanding a tremendous expenditure—medical, emotional, social, economic and perchance legal. Therefore, special consideration must be given to fundamental principles and their application to restore, with the patient's cooperation, stability, sensibility and useful movement. Techniques may be described and illustrated but their timely and skillful execution with style is gained only through an intimate knowledge of anatomy, through experience and the "feel" or texture of tissues in dissection. Yet an exquisite surgical performance is often negated by biological failures in the reparative process, or by neglect, perhaps willful, on the part of the patient himself. To some, an acquired disability means a respite from tiresome and discouraging labor, a situation easily understood but not to be condoned if rehabilitation is to be successful.

Among the many problems encountered by the hand surgeon are those of congenital deformity. The active distress and even guilt suffered by sensitive parents can be assuaged only through a sympathetic understanding on the part of the physician who must first console and, when possible, give hope for future restoration. Today so much is expected from reconstructive surgery by an informed, or misinformed, public that specialized care is mandatory. Despite the acknowledged achievements and resources of the present era, the nature of the deformity determines what ultimately can be accomplished. Because of this, a basic philosophy is needed to cope with the variegated developmental anomalies. First, we are dealing with a child whose misformed hand rarely needs surgical care during the first few years other than to ablate unsightly and useless parts. The sense of urgency expressed by anxious parents must be resisted, for premature surgical intervention may be disastrous and can destroy the possibility of a superior result when growth and development are more advanced. It must be remembered that a correction made in early life can be effaced by the disparity imposed by growth.

Although a congenital anomaly represents, in a way, a gestational or intrinsic accident, unfortunately the resultant deformity bears the stigma of congenitalism and may become a focus of morbid attention. In many cases the situation can be changed, insofar as the public is concerned, by altering the defect so that it appears to be the result of external trauma. A good example is the aplastic hand, arrested at the carpal level, possessing five rudimentary buds appearing not unlike toes, but functionless and bizarre. Their excision converts the condition to one of a simple amputation stump, relatively free from curious attention.

Infections of the hand do not often constitute a major surgical problem, as in the past. However patient response to the various organisms has been greatly modified by an indiscriminate use of antibiotics, and a tedious surgical battle for healing sometimes must be waged because of an indolent tissue response. Reconstructive surgery is not based on the prevention of infection through the use of current antibiotics, but rather on the careful management of all tissues, through the employment of basic surgical principles, meticulous technique and immobilization in the optimal functional position.

Only through man's superior intellect has the hand gained such importance, for phylogenetically it is a primitive structure. It is a mechanism open to observation and so free of the mystery and of the awe imposed by the obscurity of the brain and the viscera. The hand, like the eye, is a capital structure, but it is not generally accorded the degree of respect evoked by the intricacy and special sensibility of the visual apparatus. Yet, the hand is a sensitive and most practical servant of the brain, faithfully supporting man's tedious works and his creative efforts. Want of this appendage is an enduring and sore trial for the individual, and in our society, despite automation, manual disabilities still generate a major economic burden. The upper extremity merits refined study—its surgical care demands expert attention.



CHAPTER 69

SURGICAL ANATOMY OF THE HAND

ROBERT A. CHASE, M.D.

The unique functional capacity of the human hand has been extolled by anatomical observers since the dawn of medical history. As a functional puppet it responds to the desires of man; its motor performance is initiated by the contralateral cerebral cortex. The conscious demands relayed to the hand and forearm from the central nervous controlling mechanism are sent as movement commands. At the subconscious levels, such a movement command is broken down, regrouped, coordinated, and sent on as a signal for fixation, graded contraction, or relaxation of specific muscular units. The degree of contraction or relaxation is then modified by relayed evidence that the motion created is that desired by the organism. The modifying factors arrive centrally from the multiplicity of sensory sources such as the eye, peripheral sensory end organs, and muscle or joint sensory endings. The surgeon planning reconstructive surgery on the upper extremity must be aware not only of the complex anatomy of the hand and arm but also of the physiologic interplay of balanced muscular functions under the influence of complex central nervous coordination. The maintenance of physiologic viability by the central and peripheral circulatory and lymphatic systems must also concern the reconstructive surgeon.

THE SKELETON AND ITS NEUROMUSCULAR APPARATUS

In any anatomical study of the hand and forearm, one thought should be kept in mind as one delves into morphologic detail of each structure—that physiologic hand function knows no such specialization as the dissected mechanical categories into which we fit our fragments of anatomic knowledge. Natural function knows only a summation of actions as expressed in phenomena such as grasp, pinch, push, pull or release. A study of single muscle or tendon function is an anatomical and not a physiologic study. It is essential to recall that the muscular unit never functions alone but is a cooperative contributor to hand posture, fixation or motion by its fixed or varied contraction or relaxation with its antagonists, protagonists, and modifiers.

Architecture. The ability of the hand to resist and create powerful gross action, combined with its capacity to perform intricate fine movements in multiple planes, reflects the masterful construction of its supporting architecture. Reducing the hand to its supporting skeleton and its restraining ligaments reveals

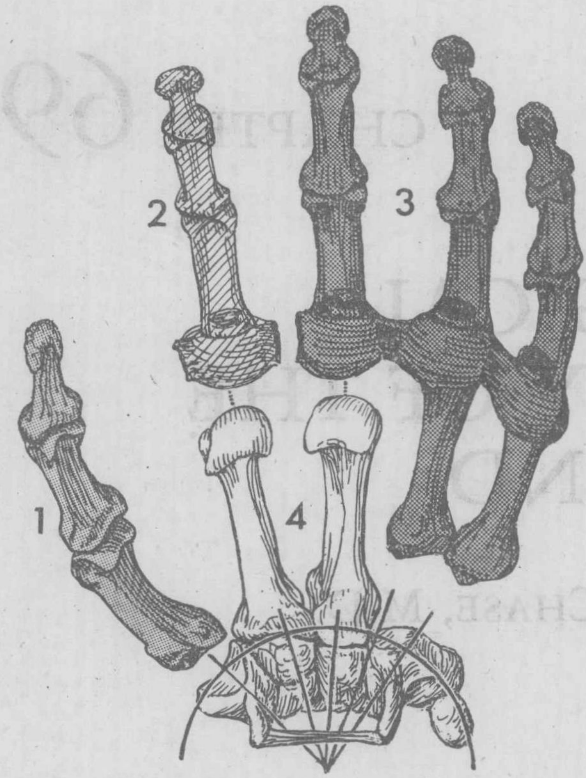


FIGURE 69–1. Exploded view of functional elements of the hand. The hand is a composite of four elements of descending order of specialization: *1,* The thumb and its metacarpal with wide range of motion at the carpometacarpal saddle joint. *2,* The index digit with its independence of function in several planes. *3,* The third, fourth, and fifth digits with metacarpals 4 and 5 work as a unit on the ulnar aspect of the hand. *4,* The fixed unit or backbone of the hand, consisting of the carpals with the fixed transverse carpal arch and the central, second and third metacarpals forming a fixed longitudinal arch projecting from the carpus. (After Littler.)

the architectural basis for its varied function. A study of the range of joint motions in the hand and forearm with all motor elements removed discloses the full range and limitations which the skeleton imposes on hand function.

The hand skeleton is divisible into four elements of descending order of specialization (Fig. 69–1):

1. The *thumb* and its *metacarpal* with a wide range of motion at the carpometacarpal joint. Five intrinsic muscles and four extrinsic muscles are specifically influential on thumb positioning and activity.

2. The *index finger* with independence of action within the range of motion allowed by its joints and ligaments. Three intrinsic and four extrinsic muscles allow such digital independence.

3. The *long, ring, and little fingers with metacarpals* 4 *and* 5. This unit functions as a stabilizing vise to grasp objects for manipulation by the thumb and index finger or in concert with the other hand units in powerful grasp.

4. *The fixed unit of the hand consisting of the second and third metacarpals and the distal carpal row.*

THE FIXED UNIT OF THE HAND. The distal row of carpal bones forms a solid architectural arch with the capitate bone as a keystone. The articulations of the distal carpals with one another, the intercarpal ligaments, and the important volar carpal ligament (flexor retinaculum) maintain a strong, fixed transverse carpal arch. Projecting distally from the central third of this arch are the fixed central metacarpals, the second and third. Littler has called this "the fixed unit of the hand." It forms a fixed transverse arch of carpal bones and a fixed longitudinal arch created by the anatomical convexity of the metacarpals. As a stable foundation this unit creates a supporting base for the three other mobile units. This central beam moves as a unit at the wrist under the influence of the prime wrist extensors (extensor carpi radialis longus and extensor carpi radialis brevis) and the prime wrist flexor, the flexor carpi radialis. These major wrist movers insert on the second and third metacarpals. Thus the fixed central unit is positioned for activity of the adaptive elements of the hand around it.

THE ADAPTIVE HAND ELEMENTS. The distal row of carpal bones constitutes a fixed transverse arch. At the level of the metacarpal heads the transverse arch of the hand becomes mobile, which is possible because the first metacarpal moves through a wide range of motion at the saddlelike carpometacarpal joint. The loose capsular ligaments and the shallow saddle articulation between the first metacarpal and the greater multangular allow circumduction of the mobile first metacarpal. Its range of motion is checked by these capsular ligaments and by its attachment to the fixed hand axis through the adductor pollicis, the first dorsal interosseous, and the fascia and skin of the first web space. The mobile fourth and fifth metacarpal heads move dorsally and volarly in relation to the central hand axis by limited mobility at the carpometacarpal joints. These metacarpal heads are tethered to the central metacarpals by the intermetacarpal ligaments. The intermetacarpal ligaments unite adjacent metacarpophalangeal volar plates, which are an intimate part of the joint capsules.

When the head of the first metacarpal is

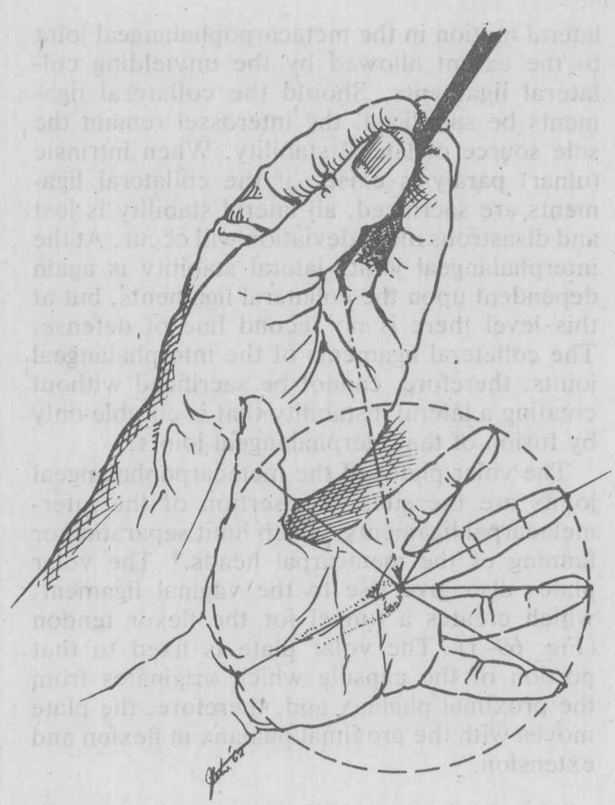


FIGURE 69–2. The anatomical center of the hand at the level of the third metacarpal head. The digit tips converge from the half-circle transverse metacarpal arch to form a cone, the base of which is at the anatomical center. With the fingers spread, the tips form equidistant radii from the anatomical center and a proximal projection of a similar radius falls at the wrist joint. The primitive thumb, in the absence of the distal phalanx, also falls an equal distance from the middle of the hand. The addition of the distal phalanx to the length of the thumb differentiates man from the primitive arboreal animals.

palmar abducted by thenar muscles innervated by the median nerve, and the fourth and fifth metacarpals are palmar abducted by the hypothenar muscles innervated by the ulnar nerve, a volar, concave, transverse metacarpal arch is created, approximating a semicircle. The mobile metacarpal heads are pulled dorsally by extrinsic extensor tendons when the thenar and hypothenar muscles relax. It is obvious that a flaccid paralysis of the intrinsic muscles of the hand in median and ulnar nerve palsy will produce a flattened or even reversed transverse metacarpal arch. The active production of a semicircular transverse arch by the thenar and hypothenar muscles creates the proper circumferential arrangement of the metacarpophalangeal joints for convergence of the fingers in flexion. In this position the fingers, flexing at the metacarpophalangeal joints only, converge, forming with the thumb a cone, the apex of which lies over the anatomical center of the hand (Fig. 69–2). A vertical line dropped from the apex of the cone to the center of its base will strike the third metacarpophalangeal joint. This point at the apex of the transverse metacarpal arch is the anatomical center of the hand. With the fingers fully abducted, the tips form radii of equal length from the anatomical center of the hand. The same radius projected proximally falls at the wrist joint (Figs. 69–2 and 69–3).

The most important single motor operating the central hand beam at the wrist level is the extensor carpi radialis brevis. It works against gravity, positioning the pronated hand into extension. In the absence of any other motors it pulls the central third metacarpal into extension, making it the apex of the passively created transverse metacarpal arch.

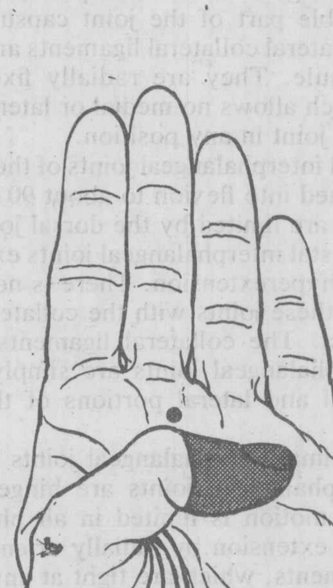


FIGURE 69–3. The thumb, in the absence of the distal phalanx, forms a radius from the anatomical center of the hand equal to that of the other digits.

The Metacarpophalangeal Joints. Lateral activity in the metacarpophalangeal joints in the denuded skeleton with only ligaments intact is limited by the reinlike collateral ligaments. These ligaments are loose and redundant while the metacarpophalangeal joints are in extension and hyperextension, allowing maximum medial and lateral deviation. As the metacarpophalangeal joint is flexed, the cam effect of the eccentrically placed ligaments and the epicondylar bowing of the collateral ligaments result in tightening and strict limitation of lateral mobility (see Fig. 73-6). Fingers that have been fixed in extension during periods of healing have had the stage set for collateral ligament shrinkage and locking of the metacarpophalangeal joints in hyperextension.

The Interphalangeal Joints. The proximal interphalangeal joint can be pushed to 120 degrees of flexion or 30 degrees beyond the right angle, but extension usually cannot be carried beyond 5 degrees hyperextension because of the ligamentous volar plate, which is an inseparable part of the joint capsule. The medial and lateral collateral ligaments are a part of the capsule. They are radially fixed in a manner which allows no medial or lateral deviation of the joint in any position.

The distal interphalangeal joints of the fingers can be pushed into flexion to about 90 degrees before they are limited by the dorsal joint capsule. The distal interphalangeal joints extend to 30 degrees hyperextension. There is no lateral mobility in these joints with the collateral ligaments intact. The collateral ligaments of the distal interphalangeal joints are simply thickened medial and lateral portions of the joint capsule.

The proximal interphalangeal joints and the distal interphalangeal joints are hinge joints; any lateral motion is limited in all phases of flexion and extension by radially oriented collateral ligaments, which are tight at any angle. The metacarpophalangeal joints, by contrast, allow motion through several axes. The capsule, including the collateral ligaments and volar plate, is quite lax, allowing medial and lateral deviation, flexion, extension, and thereby circumduction and a small degree of distraction. In the absence of other sources of stabilization, upon cutting the collateral ligaments the metacarpophalangeal joint becomes a flail, unstable mechanism. Nature, fortunately, has created another source of lateral stability—the interosseous muscles. By virtue of the selective variable pull, the interossei normally influence lateral motion in the metacarpophalangeal joint to the extent allowed by the unyielding collateral ligaments. Should the collateral ligaments be sacrificed, the interossei remain the sole source of lateral stability. When intrinsic (ulnar) paralysis exists, if the collateral ligaments are sacrificed, all lateral stability is lost and disastrous ulnar deviation will occur. At the interphalangeal joints lateral stability is again dependent upon the collateral ligaments, but at this level there is no second line of defense. The collateral ligaments of the interphalangeal joints, therefore, cannot be sacrificed without creating a lateral instability that is curable only by fusion of the interphalangeal joints.

The volar plates of the metacarpophalangeal joints are the sites of insertion of the intermetacarpal ligaments, which limit separation or fanning of the metacarpal heads.* The volar plates also give rise to the vaginal ligament, which creates a tunnel for the flexor tendon (Fig. 69-1). The volar plate is fixed to that portion of the capsule which originates from the proximal phalanx and, therefore, the plate moves with the proximal phalanx in flexion and extension.

The Wrist. The wrist joint is the site for major postural change between the arm beam and the working hand end piece. It has a multiarticulated architecture which creates a potentially wide range of motion in flexion, extension, radial deviation, ulnar deviation, and circumduction. The most extensive range of motion occurs at the radiocarpal joint. The distal radius presents a shallow articular surface that is concave from radial to ulnar extremes as well as in the dorsal to volar projection. Its articular junction with the distal ulna presents a concave surface in a third plane, which allows rotation of the radius around the ulna in supination and pronation. The hand rotates with the distal radius.

The navicular and lunate bones of the proximal carpal row form the convex articular counterparts of the concave distal radius for the major wrist articulation.

All four of the bones in the distal carpal row present articular surfaces for junction with

*The attachments of the deep transverse palmar ligament have been specifically noted by Haines (1951) as follows: "The pads, i.e., volar plates of adjacent digits, are attached together by the deep transverse ligaments of the palm, made of ordinary ligamentous tissue, . . . deep transverse palmar ligament or deep intermetacarpal ligament, the latter a most inappropriate term as the structure is not directly attached to the metacarpal bones."

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