atlas of HAND SURGERY

by Robert A. Chase, M.D.

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Preface

The principles of hand surgery have evolved to some extent from research investigation but in larger part from experience. Therefore, if we are to concern ourselves with the proper application of the principles of hand surgery, we must absorb everything in the milieu which may be relevant. Discussions with a mentor and participation with him in the care of patients are the basis for development of competence.

Experience is partly based on one's own attempts to apply surgical principles, but the attempts of others provide equally important knowledge. The principles themselves continue to be modified and improved upon by innovators in surgery—through experience. Since experience in surgery may be passed on by personal interchange with only a limited number of colleagues, the published word and diagram become very important in establishing the educational milieu alluded to above. The urge to record experiences personally participated in and the compelling desire to make available to colleagues some of the valued return of interchanges with my teachers and fellow students prompted the preparation of this atlas.

The excitement in surgery of the hand arises from the fact that each hand problem is different and requires the sequence of (1) thinking through the problem; (2) conceptualizing a course of action; (3) pursuing that course; and (4) assessing the results. This kind of clinical equivalent of research has generated the principles by which we function as hand surgeons.

The material presented in this atlas is based on case experiences. The case examples chosen exemplify fundamentals which may be applied in new combinations to fit the unique problems of any patient who presents himself with a surgical problem in the hand. I have used principles, notions and prejudices passed on to me by those with whom I have had the closest relationship in surgery of the hand, particularly Willie White, Bill Littler, Erle Peacock, Paul Brand, Don Laub and Harry Buncke. I am grateful to them for the occasional use from their experiences of a case example which perfectly exemplifies a principle.

This atlas is a reality in large part because of the enormous effort of Daisy Stilwell, whose drawings better than words depict principles and techniques which have proved useful in clinical experience. I am grateful for the talented hands, keen intellect and perseverance of my secretary, Mrs. Grace Lee, for her help in preparing the manuscript. Their capable hands have made my task of directing the project an easy one.

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General Principles

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Anatomy

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 a specific muscular unit. The degree of contraction or relaxation is then modified by relayed evidence that the motion created is that desired by the person. The modifying factors arrive centrally from a 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 anatomic 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 anatomic 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 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. (**A**)

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 *third, fourth, and fifth 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.

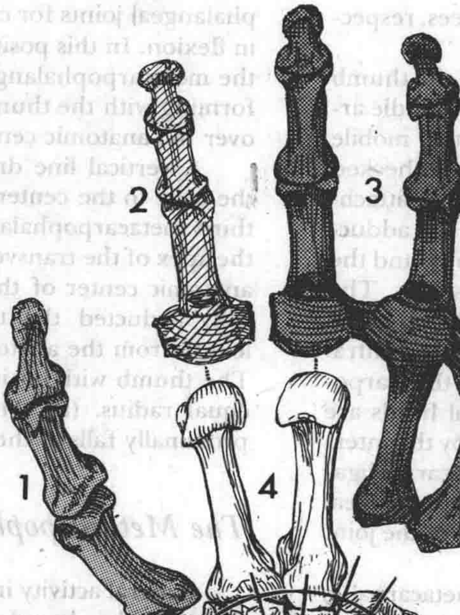
4. *The fixed unit of the hand consisting of the second and third metacarpals and the distal carpal row*

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 transverse 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 anatomic 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. (**B**)

The Adaptive Hand Elements

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 saddle-like carpometacarpal joint, and the fourth and fifth metacarpal heads move for-



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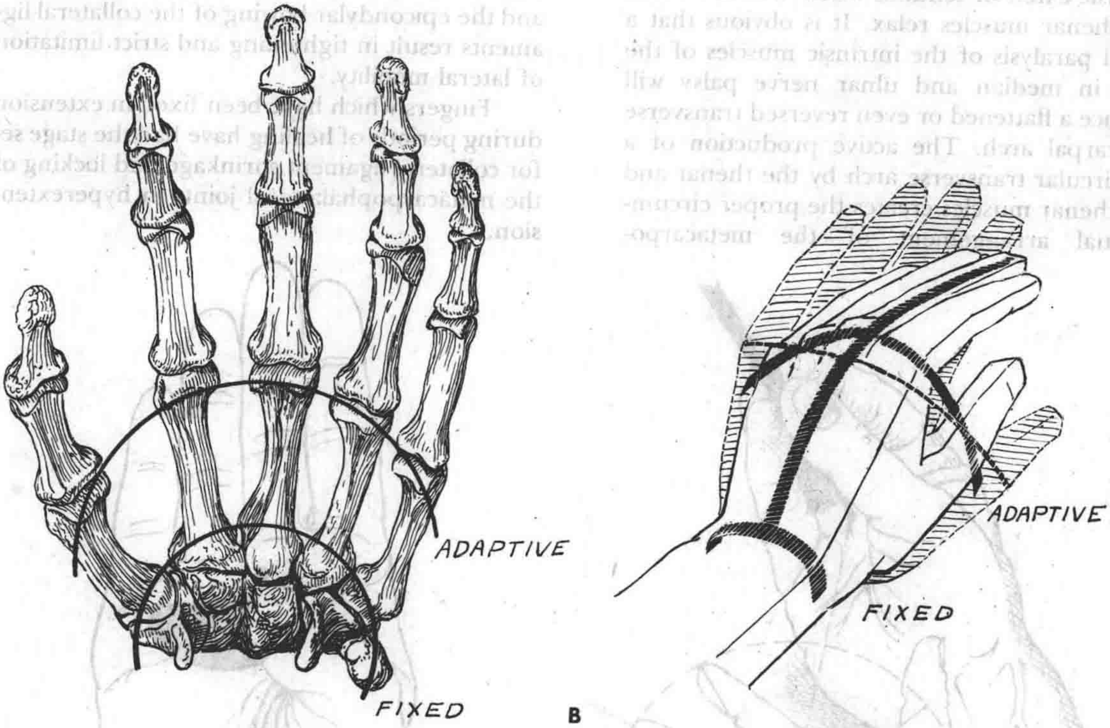


B

ward and back about 15 and 30 degrees, respectively.

The loose capsular ligaments of the thumb carpometacarpal joint with its shallow saddle articulation 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 dorsal and palmar 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 intimate parts of the joint capsules.

When the head of the first metacarpal is 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 palmar, 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 whose apex lies over the anatomic center of the hand. (**C**)

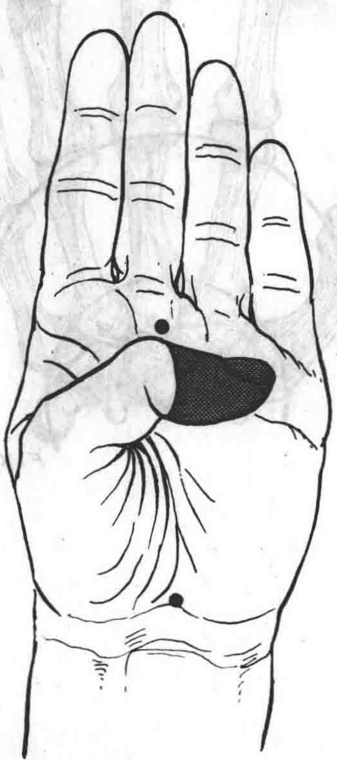
A vertical line dropped from the apex of the cone to the center of its base will strike the third metacarpophalangeal joint. This point at the apex of the transverse metacarpal arch is the anatomic center of the hand. With the fingers fully abducted the tips form radii of equal length from the anatomical center of the hand The thumb without its distal phalanx is a fifth equal radius. (**D**) The same radius projected proximally falls at the wrist joint.

The Metacarpophalangeal Joints

Lateral activity in the metacarpophalangeal joints in the denuded skeleton with only ligaments intact is limited by the reinlike collateral ligaments. (**E**) 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.

Fingers which 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.

C



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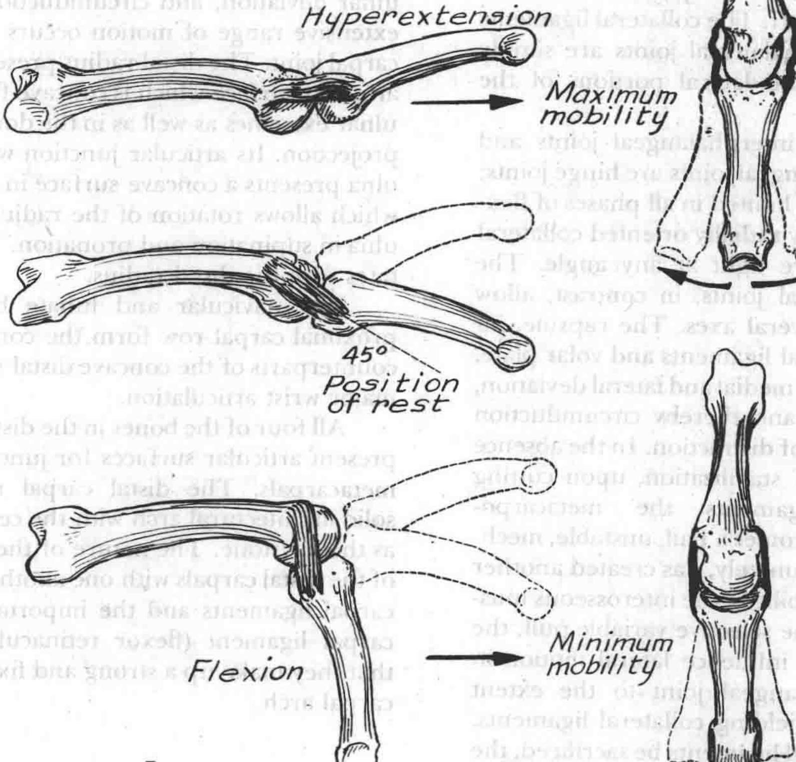

E

Adapted from Littler, in Converse: Reconstructive Plastic Surgery. Philadelphia, W. B. Saunders Company, 1964, Vol. 4, p. 1620.

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 of 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 of 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, in 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 correctable only by fusion of the interphalangeal joint or reconstruction of collateral ligaments.

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. 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 which is concave from radial to ulnar extremes as well as in the dorsal to palmar 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 metacarpals. The distal carpal row forms a solid architectural arch with the central capitate as the keystone. The nature of the articulations of the distal carpals with one another, and of the carpal ligaments and the important transverse carpal ligament (flexor retinaculum), is such that they make up a strong and fixed transverse carpal arch.

Skin Creases

The surgeon must know the relationship of skin creases and the underlying joints to plan precise placement of skin incisions for exposure of joints and their related structures. (**F**)

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*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."