Review Article

Surgical Exposures of the Wrist and Hand

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Abstract

The neurovascular anatomy of the carpus and hand is complex. Therefore, precise exposures are required to avoid iatrogenic injury. In general, dorsal exposures are more forgiving than volar exposures because major neurovascular structures lie on the volar aspect of the hand and fingers; however, volar, ulnar, and radial approaches to the carpal bones are also commonly used. Exposure of the metacarpals and phalanges is relatively straightforward by comparison. Exposure of the carpus and hand is also complicated by the dense and often superficial innervation network. Therefore, a thorough knowledge of the pertinent anatomy is required for safe surgical approaches to the wrist and hand.

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Dr. Zlotolow or an immediate family member serves as a paid consultant to OsteoMed; has received research or institutional support from Arthrex; and serves as a board member, owner, officer, or committee member of the American Society for Surgery of the Hand. Dr. Barron or an immediate family member has received royalties from and serves as a paid consultant to Extremity Medical. None of the following authors or any immediate family member has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Catalano, Ms. Purcelli Lafer, and Dr. Weidner.

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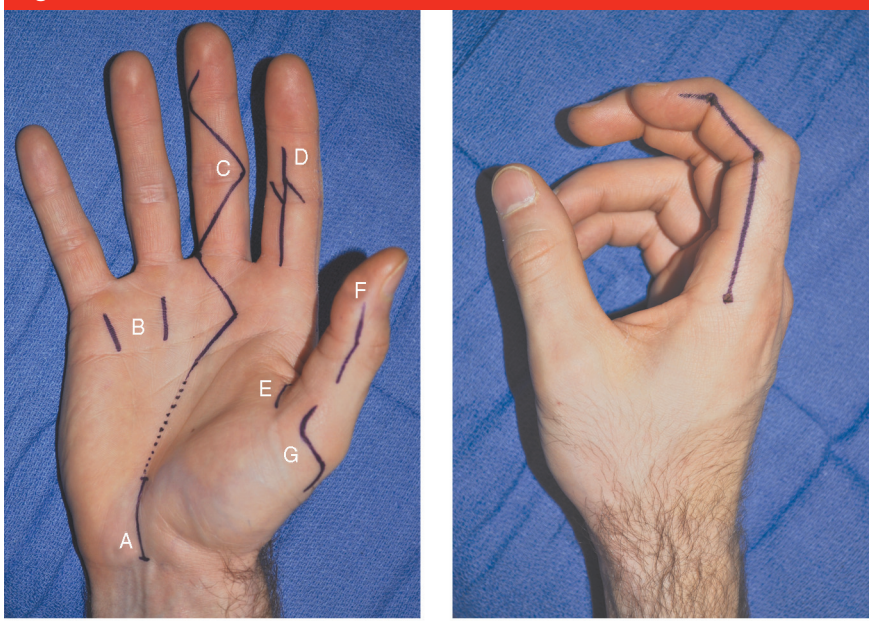
Neurovascular anatomy about the carpus and hand is complex and requires precise exposure to prevent iatrogenic injury. Several approaches can be used to access the carpus and the metacarpal (MC) and phalangeal joints.

Given the multiplanar motion of the wrist and hand, flexion creases at and distal to the wrist are more complex than those at the proximal joints. Littler[1] warned against placing incisions perpendicular to skin flexion creases to avoid longitudinal scar contracture and associated flexion deformities of the involved joints. Minimal tension is placed on an incision created within a flexion crease or at an oblique angle to a flexion crease, and this placement affords the best cosmetic result with minimal scar contracture (Figure 1). Some surgeons avoid placing incisions directly within a skin crease, citing concern for wound maceration, the paucity of subcutaneous fat in these areas, and the need to carefully evert the skin edges at closure.[2] On the dorsal side of the hand or finger axis, incisions may be created perpendicular to skin creases without fear of producing extension contractures.

Innervation

The complex, overlapping system of nerves is another complicating feature of wrist and hand exposures. The superficial branch of the radial nerve (SBRN) divides into a mean of four branches that are joined by the terminal branches of the lateral antebrachial cutaneous nerve. In an anatomic study of 20 cadavers, the authors reported that the lateral antebrachial cutaneous nerve joined with the SBRN to innervate the dorsoradial hand, the dorsum of the thumb and index fingers, and the radial aspect of the long finger in approximately one third of the specimens.[3] The ulnar half of the dorsal wrist is innervated by the dorsal sensory branch of the ulnar nerve (DSBUN), which originates 5 cm proximal to the ulnar styloid and crosses onto the dorsum of the wrist

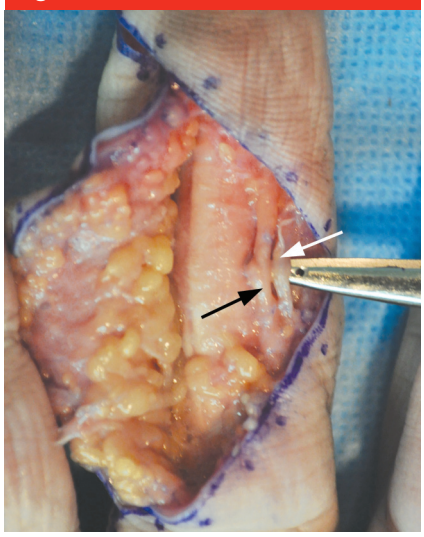
Figure 1



A B

A, Photograph demonstrating markings for several hand incisions. A, Standard mini-open carpal tunnel incision, measuring approximately 3.4 cm long. B, Standard longitudinal incision for A1 pulley release. C, Zigzag incision with apices at the flexor creases. One should avoid placing incisions perpendicular to flexion creases to prevent scar contracture, resulting in a longitudinal tether. D, Longitudinal digital incision broken up by a Z-plasty over the proximal interphalangeal flexion crease. E, Volar transverse incision made over the thumb flexion crease for trigger thumb release. F, Midaxial incision for exposure of the interphalangeal joint. G, Lazy S-shaped incision for exposure of the radial (or ulnar) aspect of the thumb metacarpophalangeal joint. **B,** The midaxial incision is created by joining the apices of the flexion creases of each joint. The midlateral incision lies just volar to this incision. The advantage of the midaxial incision is that the wound is tension free, which may produce a less visible scar.

Figure 2



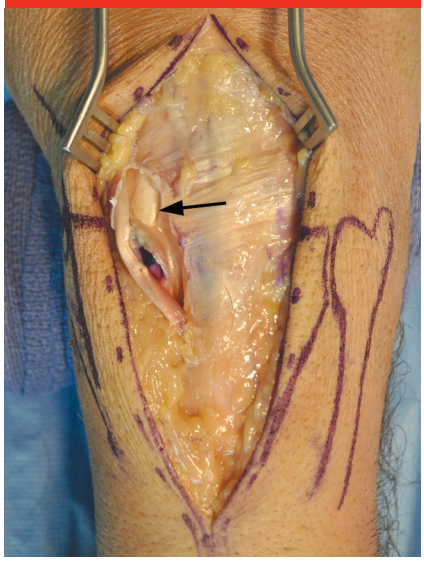
Intraoperative photograph demonstrating the digital artery (white arrow), which lies dorsal to the digital nerve (black arrow) in the finger.

at a range of 2.5 cm proximal to 2.5 cm distal to the styloid process.[4] In the dorsal hand, the DSBUN divides to form three or four branches that typically innervate the dorsum of the small and ring fingers and the ulnar half of the long finger. Both dorsal sensory nerves converge at the base of the third MC and can be injured during dorsal midline extensile approaches. Using the third carpometacarpal (CMC) joint as a reference, a proposed site for safe surgical incision lies just proximal to the joint, between 0.6 cm radial and 2 cm ulnar to the joint.[5]

Innervation of the volar skin is redundant and dense with some notable exceptions. The palmar cutaneous branch of the median nerve is a discrete branch of the median nerve that is responsible for cutaneous innervation of the proximal thenar eminence. This branch originates radialward from the median nerve 5 cm proximal to the distal wrist crease and travels along the ulnar aspect of the flexor carpi radialis (FCR) sheath before becoming subcutaneous at the base of the hand. Division of this nerve results in complete anesthesia of this discrete area and may lead to a painful neuroma. The skin overlying the hypothenar musculature is solely innervated by branches of the ulnar nerve that originate distal to the distal wrist flexion crease.

In the palm, the common digital nerves that arise from the median and ulnar nerves lie deep to the superficial volar arch and the common digital vessels. At the level of the metacarpophalangeal (MP) joint, the relationship is reversed such that the proper digital nerves come to lie volar to the proper digital arteries (Figure 2). The common digital neurovascular bundles traverse the volar aspect of the lumbricals, allowing for safe direct dissection to the flexor tendons and the MCs. The neurovascular bundles travel down the fingers via a triangular fibrous tunnel composed of the Grayson and Cleland ligaments and the flexor tendon sheath. The Grayson ligaments originate in the volar flexor sheath, pass volar to the neurovascular bundle, and insert into the skin, whereas the Cleland ligaments pass dorsal to the neurovascular bundle from the phalanges to the skin. The lateral digital sheath, which is formed by merging

Figure 3



Photograph of a cadaver showing the extensor pollicis longus, which has been transposed radially out of the third dorsal compartment. The arrow points to the extensor carpi radialis brevis tendon, which is located in the second dorsal compartment.

Figure 4

Photograph of a cadaver demonstrating a marking for a T-shaped arthrotomy drawn over the dorsal radiocarpal ligaments. A small cuff of capsular tissue is left attached proximally for later repair.

fibers of the spiral band and natatory ligament, is located lateral and parallel to the neurovascular bundle in the finger. Because of the rotation of the thumb relative to the plane of the other digits, the digital neurovascular bundle to the radial aspect of the thumb crosses the flexor tendon sheath obliquely near the level of the MP joint, and the radial digital nerve lies 2.19 mm beneath the dermis and 1.15 mm anterior to the radial sesamoid bone at the MP crease.[6] This digital nerve is at most risk of injury during midline volar dissection of the MP joint; the radial digital nerve to the index finger and the ulnar digital nerve to the small finger both cross the midline at the volar aspect of the MP joint and are at similar risk of injury. The common digital nerve to the fourth web space also crosses the small finger flexor tendon sheath, but the nerve crosses near the level of the mid palmar crease. Any incision or laceration in the region of the intersection of the thenar crease and the Kaplan cardinal line places the radial digital nerve to the index finger at risk of injury because the nerve lies in very superficial subcutaneous tissue.

Carpal Exposures

Dorsal Midline Approach

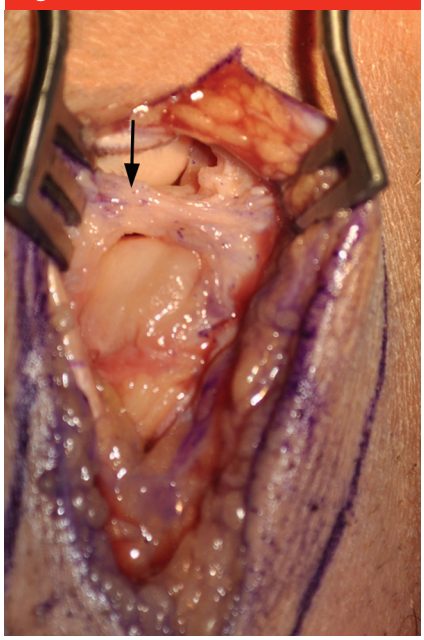
The dorsal midline approach is the utilitarian approach to the carpal bones. Except for the trapezium and the pisiform, all of the carpal bones, the triangular fibrocartilage complex (TFCC), and the second through the fifth CMC joints can be accessed through this approach. It can also be extended proximally along the Thompson approach to the radius, up the radial column of the humerus, and into an anterolateral exposure of the humerus. At the distal extent of the incision, care must be taken to preserve crossing branches of the superficial dorsal radial and ulnar nerves at the base of the third MC.

Supraretinacular flaps are elevated ulnarly and radially while achieving hemostasis of perforating cutaneous vessels that cross the retinaculum. The extensor pollicis longus is identified just ulnar to the Lister tubercle and is transposed out of its sheath by incising the roof of the third extensor compartment (Figure 3). Subperiosteal dissection is then performed ulnarly, reflecting the fourth extensor compartment. Further radial exposure can be achieved by reflecting the third and second dorsal compartments radially or, occasionally, by cutting the cortex directly deep to the third and second extensor compartments and reflecting the osteoretinacular flap radially.[7] Reflecting the compartments away from the midline exposes the dorsal radiocarpal (DRC) joint capsule and the dorsal intercarpal (DIC) and DRC ligaments.

Deeper exposure can be accomplished using a direct longitudinal or ligament-sparing approach. The direct longitudinal approach can be extended via an inverted T-shaped capsular incision made along the dorsal cuff of the distal radius and the dorsal radioulnar ligament (Figure 4). This provides access from the radial styloid to the TFCC and both carpal rows but does not provide access to the pisiform and trapezium.

In a ligament-sparing approach, the DRC and DIC ligaments are split along their fibers, and a V-shaped capsuloligamentous flap is elevated from the dorsal triquetrum. The proximal limb of the incision is made from the distal edge of the dorsal radius to the dorsal rim of the triquetrum in line with the fibers of the DRC ligament. The distal limb is created in line with the DIC ligament from the triquetrum to the scaphotrapeziotrapezoid joint, where the DIC inserts on the dorsal aspect of

Figure 5



Intraoperative photograph demonstrating the dorsal radioulnar ligment (arrow). It is important to avoid transection of this ligament when exposing the distal radioulnar joint (DRUJ) and/or triangular fibrocartilage complex to minimize postoperative DRUJ instability.

these three bones. The flap is reflected radially to expose the lunate, scapholunate joint, capitate head, and proximal pole of the scaphoid. Further radial exposure can be achieved by extending the proximal limb of the capsulotomy along the dorsal lip of the distal radius, preserving a small cuff of tissue for later repair.[8] The flap must be elevated carefully to avoid injury to the underlying interosseous ligaments.[9] If the surgical plan does not include scaphoid excision, the capsular attachment to the dorsal ridge of the scaphoid should be preserved to minimize the risk of devascularizing the proximal pole; however, this concern has not been validated clinically.[10,11]

Dorsoulnar Approach

The dorsoulnar approach provides direct exposure of the ulnar-sided proximal row of carpal bones and the underlying TFCC. Based on surgeon preference, the skin can be incised using longitudinal, zigzag, L-shaped or C-shaped incisions centered over the distal aspect of the distal radioulnar joint (DRUJ). Careful subcutaneous dissection is essential to avoid injury to the DSBUN. The extensor retinaculum can be divided either by opening the fifth extensor compartment longitudinally or by dividing the retinaculum between the fifth and sixth extensor compartments. If the fifth compartment is opened, the capsule can be exposed by opening the floor of the sheath[12] or by dividing the interval between the fourth and fifth extensor compartments.[13] The joint can then be exposed via careful dissection and capsulotomies performed proximal and distal to the TFCC.

One capsulotomy technique involves a three-limbed incision. The distal limb extends from the triquetrum to the distal end of the radius along the fibers of the DRC ligament and the midportion extends longitundinally along the radial portion of the distal radioulnar joint, while the proximal limb extends obliquely in an ulnar direction toward the proximal corner of the radioulnar capsule.[14] Care must be taken to preserve the dorsal radioulnar ligament to avoid postoperative DRUJ instability (Figure 5).

Volar Scaphoid Approach

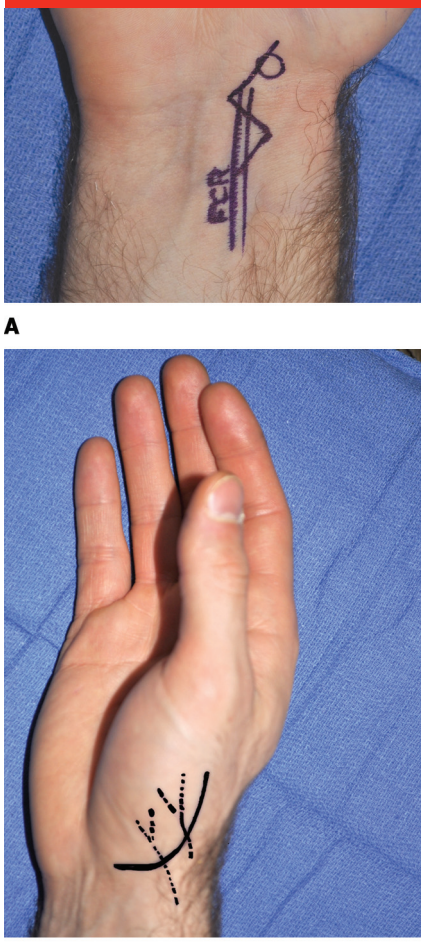
Popularized by Russe,[15] the volar approach to the scaphoid is commonly used for fixation of scaphoid waist fractures and nonunions. This approach has two major advantages over the dorsal approach: the ability to more effectively correct the humpback deformity associated with scaphoid nonunion, and the theoretical benefit of preserving the dorsal blood supply to the scaphoid.

We prefer to use a zigzag incision that is centered over the distal wrist crease and extends to the scaphoid tuberosity or a modified Wagner incision made along the glabrous and nonglabrous skin junction of the thumb to the proximal wrist crease (Figure 6). Cutaneous nerves from the SBRN are protected, and the superficial volar branch of the radial artery is retracted or ligated as necessary. The FCR sheath is opened, and the FCR tendon is retracted ulnarward. The floor of the FCR sheath and the thick capsule are then incised longitudinally. The radioscaphocapitate and long radiolunate ligaments can be incised for exposure of the waist and the proximal pole of the scaphoid.[16] When exposure of the distal pole is needed, such as for screw insertion, a volar radial transverse capsulotomy can be made in the scaphotrapezial (ST) joint. If possible, extensive dorsal and radial dissection of the capsule off the scaphoid should be avoided to preserve the blood supply to the distal pole.[10] The volar ligaments should be repaired anatomically upon closure.

Carpal Tunnel Approach

This approach is used for open carpal tunnel release and to manage perilunate dislocations and fractures of the hook of the hamate. A straight or curvilinear incision is begun at the distal wrist crease and extended 3 to 4 cm along the ring finger ray to the Kaplan cardinal line (Figure 7). Proximal extension of the incision must be made in an ulnar direction to avoid transection of the volar cutaneous branch of the median nerve. We prefer to preserve identifiable crossing nerves, but this was not shown to improve postoperative scar pain in a recent prospective randomized study.[17,18] The volar fascia is divided longitudinally, exposing the transverse carpal ligament. The hook

Figure 6



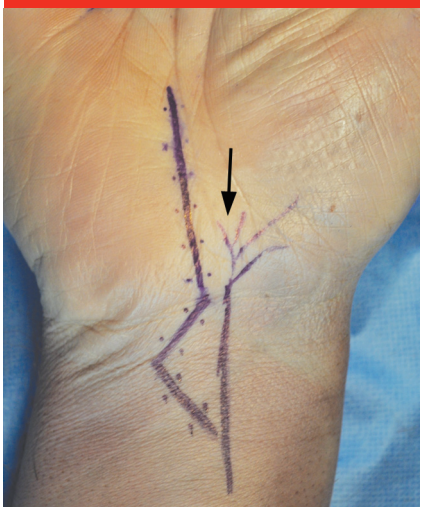
A

B

A, Photograph demonstrating markings for a zigzag incision, which provides a cosmetic scar and avoids the possibility of the longitudinal scar contracture that the authors feel occurs often with standard L-shaped incisions. The circle represents the distal pole of the scaphoid. **B,** Photograph of a right hand demonstrating the modified Wagner incision (solid line). The terminal branches of the superficial branch of the radial nerve are marked (dotted lines). The incision extends from the glabrous and nonglabrous skin interval to the proximal wrist crease and provides excellent exposure to the thumb metacarpal base and carpometacarpal joint. FCR = flexor carpi radialis

of the hamate should be palpable deep to the ulnar origin of the ligament. The transverse carpal ligament

Figure 7



Preoperative photograph of the right hand demonstrating markings for a standard longitudinal carpal tunnel incision. The distal forearm zigzag incision over the wrist flexion creases allows for an extended carpal tunnel approach. The path of the palmar cutaneous branch of the median nerve is also marked (arrow).

(TCL) is then divided, and the distal antebrachial fascia and the TCL are divided longitudinally to enter the carpal canal. The volar fat pad, which lies just distal to the distal edge of the TCL, is a reliable anatomic landmark beyond which dissection should not extend for routine carpal tunnel release.[19] The median nerve and flexor tendons are retracted radially to expose the floor of the canal. Repair of the TCL is not necessary.

Guyon Canal Exposure

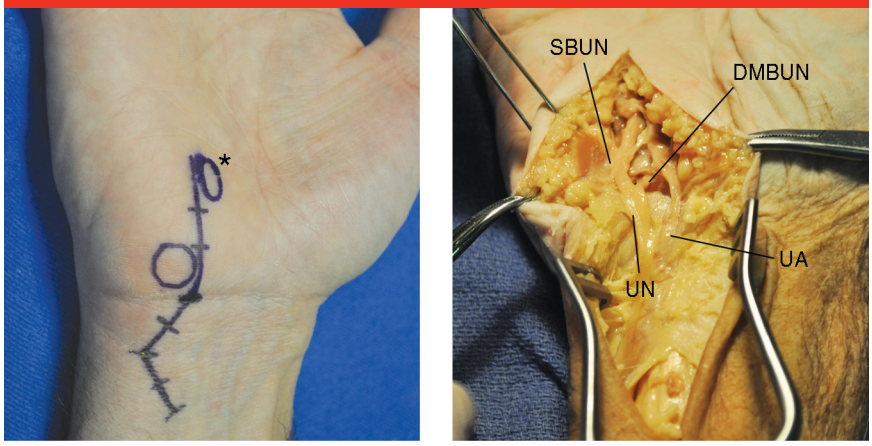
A separate volar ulnar approach (ie, Guyon canal exposure) provides exposure of the ulnar nerve and artery and can be used to address pisotriquetral arthritis and fracture and nonunion of the pisiform and the hook of the hamate. A zigzag incision is begun distally at the hook of the hamate and extends proximally just radial to the pisiform and crosses the distal wrist flexion crease (Figure 8). Subcutaneous dissection should be performed cautiously to protect the cutaneous branches of the ulnar nerve.[20] Distally, the palmaris brevis muscle and the volar carpal ligament are divided longitudinally, exposing the ulnar nerve and artery. Proximally, the distal antebrachial fascia is divided. The pisiform can be shelled out of the flexor carpi ulnaris tendon with a longitudinal incision, maintaining a periosteal cuff while protecting the ulnar neurovascular bundle. Deeper dissection to expose the motor branch of the ulnar nerve requires division of the fibrous arch at the origin of the hypothenar muscles. A small motor branch to the abductor digiti quinti courses just distal and ulnarward around the pisiform and must be protected during pisiform excision. The main motor branch hugs the distal aspect of the hook of the hamate as it travels radialward to innervate the interossei. Care must be taken to protect this nerve during excision of the hook of the hamate.

Exposure of the Carpometacarpal Joints

Basal Joint of the Thumb

Exposure of the CMC joint of the thumb for arthroplasty or fracture fixation can be achieved via a Wagner, a triradiate, or a straight dorsal approach. The Wagner approach begins as a skin incision at the base of the first MC and extends along the border of the glabrous and nonglabrous skin to the distal wrist flexion crease, curving ulnarly along the crease to the FCR tendon[21] (Figure 6, B). Branches of the SBRN are retracted; the largest and most important branch courses just radial and parallel to the distal limb of the incision. The thenar musculature is sharply elevated off the MC base, the

Figure 8



A B

A, Photograph of a right hand demonstrating markings for the volar ulnar exposure of the wrist. A zigzag incision with apices at the wrist flexion creases is marked. The distal circle (asterisk) represents the hook of the hamate, and the proximal circle represents the pisiform. **B,** Photograph of a cadaver demonstrating deep dissection into the Guyon canal, which reveals that the ulnar nerve (UN) is located ulnar to the ulnar artery (UA). The deep motor branch of the ulnar nerve (DMBUN) traverses radially and deep to the hypothenar muscles. SBUN = sensory branch of the ulnar nerve

CMC and ST joint capsules, and the trapezium and distal scaphoid bones. The thenar muscles are then retracted ulnarward to expose the entire trapezium to the level of the TCL origin. Often, a slip of the abductor pollicis longus (APL) inserts into the abductor pollicis brevis and must be divided for adequate exposure. This slip is tagged for later repair during closure, helping to reestablish ideal tension of the thenar musculature. Horizontal CMC joint capsulotomy provides excellent access to the CMC joint, but a longitudinal capsulotomy can be used, as well.

Exposure of the CMC joint of the thumb can also be achieved with a triradiate incision. Originally described by Pellegrini and Burton,[22] this incision is created by adding a dorsal limb that mirrors and extends opposite to the ulnar curve of the Wagner approach. Proponents of the triradiate approach cite the ability to mobilize and protect the radial artery as the major advantage over the Wagner approach.[23] The radial artery transitions from a volar to a dorsal structure through the anatomic snuff box within a fat pad directly over the radial aspect of the ST joint.

Some surgeons prefer a direct dorsal approach to the basal joint of the thumb, in which a longitudinal incision is made from the dorsal base of the first MC to the distal aspect of the radial styloid.[24] Branches of the SBRN are identified and protected. The APL and the extensor pollicis brevis (EPB) tendons are identified, and the interval between them is developed to allow access to the joint. The radial artery, which runs between the ST joint and the APL and EPB tendons, should be mobilized and protected. If necessary, this approach can be converted to a triradiate approach.

Fifth Carpometacarpal Joint

Dorsal hamate fractures and fracture-dislocations of the fourth and fifth CMC joints may require open reduction and internal fixation. The surgical approach is relatively straightforward, with a longitudinal or S-shaped incision centered directly over the dorsal aspect of the joint. Branches of the DSBUN are often encountered during subcutaneous dissection. The extensor digitorum communis and extensor digiti quinti tendons may need to be retracted radially for complete exposure. During subperiosteal dissection, care should be taken to preserve the insertion of the extensor carpi ulnaris tendon at the base of the fifth MC.

Exposure of the Metacarpals

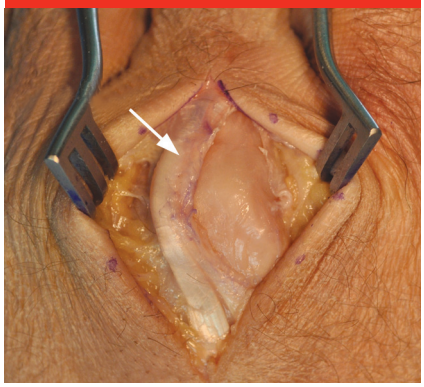
Typically, exposure of the MCs is performed via longitudinal dorsal incisions placed either directly over the bone or slightly ulnar to the fifth MC and radial to the second MC to facilitate placement of the hardware away from the extensor tendons. Branches of either or both the DSBUN and SBRN are encountered during subcutaneous dissection, depending on which MC is exposed. The extensor digitorum communis, extensor digiti quinti, and extensor indicis proprius tendons are identified and protected when necessary. Whenever possible, the authors prefer to place hardware either dorsoradial or dorsoulnar on the MC and to repair the periosteum and floor of the sheath to minimize tendon irritation and adhesion formation. If two adjacent MCs require exposure, a single longitudinal incision along the intermetacarpal space is used.

Exposure of the Metacarpophalangeal Joints

Dorsal Approach

The dorsal approach to the MP joint is optimal for MP joint arthroplasty and for management of injuries to the ex-

Figure 9



Intraoperative photograph demonstrating the dorsal approach to the metacarpophalangeal joint. Division of the ulnar sagittal band (arrow) reveals the dorsal capsule of the joint.

tensor hood as well as most intra-articular fractures of the MP joints. The incision can be made directly dorsal or curvilinear, with sharp dissection to the extensor hood. For collateral ligament injury, a dorsoulnar or dorsoradial lazy S-shaped incision can be used for repairs to the ulnar and radial collateral ligaments, respectively. The incision begins dorsally and extends longitudinally along the mid-dorsum of the finger. The cutaneous nerves travel ulnar and radial to the dorsum of the MP joint and are infrequently encountered. However, dorsal veins are often seen and should be preserved if possible. The extensor hood, which is composed of sagittal and oblique bands and traverses the extrinsic extensor tendons, is readily visible. Deeper exposure requires division of the ulnar sagittal band to retract the extensor tendon radialward (Figure 9). In the long and ring fingers, the radial sagittal band is weaker than the ulnar band, and there is a risk of tendon subluxation ulnarward with division of the radial band.[25] However, in the small finger, the tendon may subluxate radially with division of the ulnar sagittal band.

If only visualization of the MP joint is needed, the extensor tendon is split along the midline or retracted distally with a skin hook under the sagittal bands rather than by cutting the ulnar sagittal band. The dorsal MP capsule is divided longitudinally to expose the head of the MC, base of the proximal phalanx, and collateral ligaments. The sagittal bands should be repaired anatomically at the end of the procedure.

Volar Approach

Avulsion fractures of the MP collateral ligaments located at the base of the proximal phalanx can be exposed via a volar approach.[26] A zigzag incision in the palm is made centered over the MP joint, with a limb in the palm and a limb in the finger while crossing the MP joint flexion crease at a 90° angle. While the neurovascular bundles are protected, dissection is carried down to the A1 pulley. The A1 pulley is divided longitudinally, and the flexor tendons are retracted to expose the volar plate. The volar plate is divided longitudinally in the midsagittal line and retracted, exposing the MC head and the base of the proximal phalanx.

Thumb Approaches

Because of its unique orientation, the thumb MP joint can be exposed using volar, radial, ulnar, and dorsal approaches. The volar approach is used for MP joint capsulodesis and management of volar intra-articular fractures; this exposure is similar to the volar approach to the finger MP joints. The major differences between volar approaches to the thumb and fingers are that, in approaches to the thumb, the radial digital nerve crosses the surgical field; only one flexor tendon, the flexor pollicis longus, must be retracted; and the thenar musculature and the adductor attachments to the sesamoids may limit visibility. The dorsal approach to the thumb is similar to the dorsal approach to the finger MP joints; the only notable difference is that the extensor hood is divided between the extensor pollicis longus and EPB tendons (Figure 10).

The radial approach can be used for management of radial collateral ligament injuries and fracture fixation. A lazy S-shaped incision is made with the proximal limb extending along the radial aspect of the EPB and continuing volarly and obliquely along the skin creases. The distal limb extends along the volar aspect of the proximal phalanx. At least one branch of the SBRN is seen during subcutaneous dissection; it must be gently retracted to prevent painful neuroma formation. The abductor aponeurosis is incised sharply, and a small cuff is left dorsally for later repair.[27] Retraction of the aponeurosis exposes the radial collateral ligament and capsule. Access to the joint can be achieved with a capsulotomy in line with the collateral ligament fibers. Indications and surgical technique for the ulnar approach are similar to those of the radial approach except that the adductor aponeurosis is divided instead of the abductor aponeurosis.[28]

Exposure of the Phalanges

Dorsal Approach

The dorsal approach to the finger is typically performed using a midline or curvilinear incision. The dorsal veins should be preserved if possible. The extensor mechanism can be split longitudinally over the proximal or middle phalanges to gain access to the bone for fracture fixation. The extensor mechanism can also be elevated by incising the transverse retinacular ligaments at the proximal interphalangeal (PIP) joint and retracting the extensor mechanism

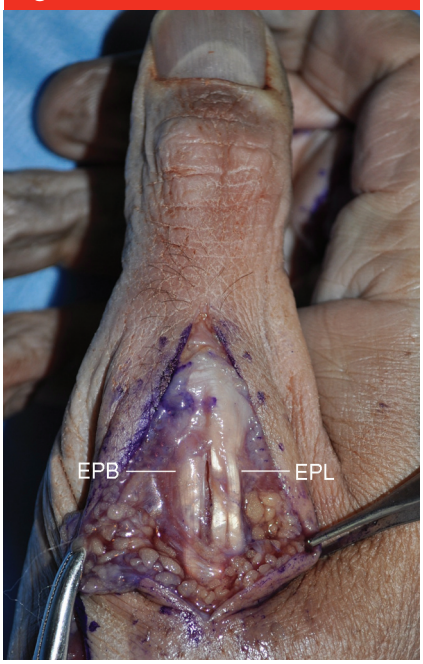
ulnarly or radially to allow access to the proximal or middle phalanges. Alternatively, an incision can be made between the central tendon and the lateral band for proximal phalangeal exposures.

Dorsal exposure of the PIP joint for fracture fixation or arthroplasty can be achieved using a tendon-splitting approach or the Chamay approach.[29] In the tendon-splitting approach, the central slip insertion is reflected while continuity with the periosteum is maintained. If the insertion is violated, it must be securely reattached through drill holes during closure. In the Chamay approach, the central tendon is divided at the level of the proximal phalanx, creating a tendon flap that is retracted distally based on an intact central slip insertion.[30] More recently, Mercer et al[31] described an approach in which a longitudinal incision in the extensor tendon can be repaired with side-to-side reapproximation using Ethibond sutures (Ethicon, Somerville, NJ).

Several incisions can be used for exposure of the DIP joint, including direct midline and zigzag, as well as H-, U-, L-, and Y-shaped.[32,33] Distal extension of these incisions must be made carefully to avoid injury to the germinal matrix and eponychial fold. In a cadaver study, the average distance from the terminal extensor tendon insertion to the proximal edge of the germinal matrix was found to be 1.2 mm.[34]

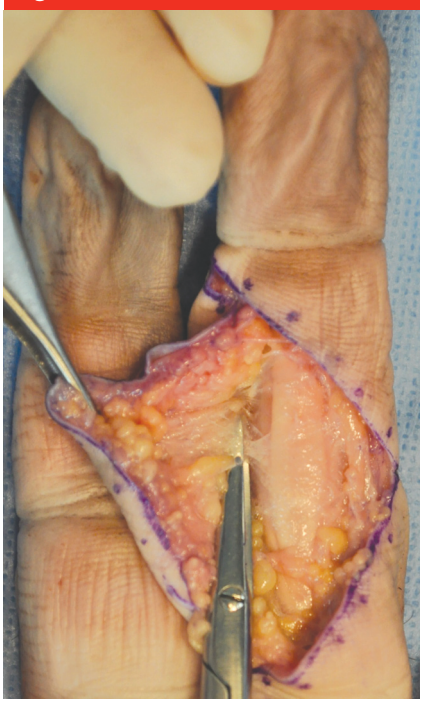
During dorsal exposures of the DIP joint, preservation of the terminal tendon insertion into the dorsal lip of the distal phalanx is crucial. The joint can be accessed via a capsulotomy in the interval between the collateral ligament and terminal tendon. For mallet fractures, exposure of the joint is obtained through the fracture plane with proximal reflection of the terminal tendon insertion on the fracture fragment.

Figure 10



Photograph of a cadaver demonstrating a dorsal incision over the metacarpophalangeal joint of the thumb, exposing the extensor pollicis brevis (EPB) and extensor pollicis longus (EPL) tendons. Deeper dissection involves splitting the dorsal capsule longitudinally between the tendons.

Figure 11



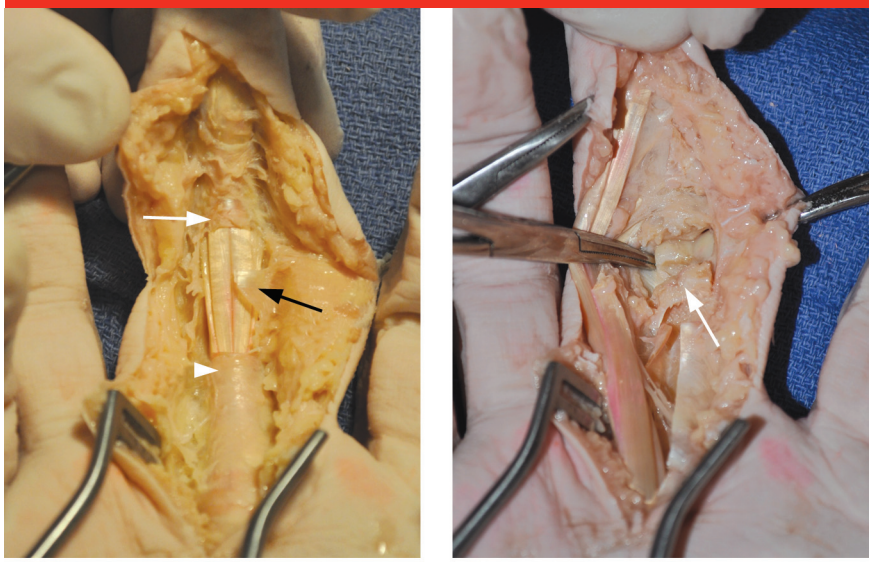
Photograph of a cadaver demonstrating superficial dissection of the proximal interphalangeal (PIP) joint. The Grayson ligament is located volar to the neurovascular bundle and is best identified about the PIP joint. Division of this thin fibrous structure exposes the digital nerve and artery.

Volar Approach

The most common approach to the digit is the volar zigzag approach described by Littler[1] and popularized by Bruner.[35] This approach is a combination of oblique incisions that meet at approximately 90° angles at the corner of the finger flexion creases (Figure 1). The neurovascular bundles are at greatest risk of injury at the corners of the flaps; therefore, deep skin incisions must be avoided. To minimize damage to the corners of the skin flaps, we prefer to place a 4-0 silk suture through the corner subcutaneously for retraction. Once the neurovascular bundle is identified at the corner, the flap is elevated superficial to the bundle and the flexor tendon sheath. At the base of each flap, the dissection can proceed through the Grayson ligament, which is a thin fibrous layer volar to the neurovascular bundle that is thickest at the level of the PIP joint (Figure 11). Dissection should be performed with care along the lateral aspects of the digits to protect the neurovascular bundles. The trifurcation of the digital nerve is encountered at the DIP joint and should be protected. With the flaps retracted, this approach affords excellent exposure of the pulley system, flexor tendons, and both neurovascular bundles.

The PIP and DIP joints can be accessed by releasing the A3 and A5 pulleys, respectively, and retracting the flexor tendon or tendons. Joint exposure can be achieved with longi-

Figure 12



A B

Photographs of cadavers demonstrating dissection of the proximal interphalangeal (PIP) joint. **A,** Exposure of the flexor tendon sheath involves elevation of C1, C2, and A3 pulleys (black arrow) and preservation of the A2 (arrowhead) and A4 (white arrow) pulleys. **B,** Volar exposure of the PIP joint requires retraction of the flexor tendons and elevation of the volar plate. In this case, the volar plate (arrow) has been retracted proximally and has been elevated distally from the base of the middle phalanx, and the proximal phalanx articular surface is seen clearly.

tudinal division of the volar plate along the midsagittal line or by releasing the volar plate proximally or distally. Release of the collateral ligaments is performed by placing a scalpel blade in the joint and turning the blade to become parallel to the phalanges while tightly hugging the base of the middle or distal phalanx, thereby detaching the insertion of each collateral ligament (Figure 12). With this release, the joint can be hyperextended to expose the entire articular surface of the interphalangeal (IP) joints for fracture fixation or IP joint arthroplasty.

Midaxial Approach

The midaxial line extends along the corners of the finger flexion creases from the fingertip just volar to the lateral nail fold to the interdigital web space, creating a straight line with the finger extended. When possible, exposure of the ulnar side of the index, long, and ring fingers as well as the radial side of the small finger is preferred to limit scar sensitivity. The term midlateral is often used erroneously to refer to the midaxial approach; however, the midlateral approach is slightly volar along the lateral midline of the digit (Figure 1). In the midlateral approach, the neurovascular bundle is directly below the incision. In the midaxial approach, the neurovascular bundle is located volar to the incision and, therefore, is at less risk of injury. In addition, the midlateral approach traverses the flexion creases at 90° angles, potentially resulting in flexion contracture.

When using the midaxial approach, the dorsal sensory branch of the digital nerve should be protected; it is encountered at the level of the proximal phalanx, often in line with the intrinsic contribution to the lateral band. Both the dorsal sensory nerve and the lateral band are retracted dorsally for exposure of the proximal phalanx. A relative internervous plane lies between the distal aspect of the proximal phalanx and the distal interphalangeal (DIP) joint as dissection proceeds distal to the dorsal sensory branch and proximal to the trifurcation of the digital nerve at the DIP joint. The incision can be extended into the palm using a volar zigzag incision. This approach allows exposure of the lateral phalanges, IP joints, and collateral ligaments for fracture fixation, ligament repair and/or reconstruction, and PIP joint arthroplasty. A midaxial approach may be helpful for access to the dorsal DIP joint between the collateral ligament and terminal tendon when the skin at the dorsal DIP joint is particularly thin.

Summary

Surgical exposures of the wrist and hand require precise planning because of the complex neurovascular anatomy, the dense and often superficial innervation network, numerous flexion creases, and cosmetic concerns. Dorsal approaches are typically more forgiving than volar approaches because the major neurovascular structures lie on the volar aspect of the hand and fingers. However, selection is ultimately based on the procedure and surgeon preference. The dorsal midline approach is a utilitarian approach to the carpal bones; almost all of the bones of the carpus can be exposed with this approach. Exposure of the MP joint of the thumb requires special consideration because of the unique anatomy and position of the thumb. Adherence to principles stated in this article and knowledge of the pertinent

anatomy is crucial to achieve optimal results.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 17 is a level I study. Reference 18 is a level II study. References 11, 14, and 22 are level III studies. References 8, 21, 26-28, and 33 are level IV studies. References 12 and 35 are level V expert opinion.

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