Osseous Structures of the Elbow

The elbow joint consists of three articulating bones—the humerus, the radius, and the ulna (Table 9.1). The humerus is a long bone that articulates at the shoulder proximally and the elbow distally. The humerus widens significantly at the distal articulation and provides a contact point for several important muscular origins. These contact points are also common sites for fractures, although the functional recovery from fractures is generally very good (1).

Table 9.1: General Information Regarding the Elbow.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
<td>3 bones: ulna, radius, and humerus</td>
</tr>
<tr>
<td>Number of dedicated</td>
<td>4 joints: humeroulnar, humeroradial, proximal radioulnar, and distal</td>
</tr>
<tr>
<td>joints</td>
<td>radioulnar</td>
</tr>
<tr>
<td>Range of motion</td>
<td>Normal ROM is +5° extension to 145° flexion and 75–85° pronation and</td>
</tr>
<tr>
<td></td>
<td>85–90° for supination</td>
</tr>
<tr>
<td>Nerve systems</td>
<td>Musculocutaneous nerve (C5-C7 nerve roots). Innervates the skin of lateral</td>
</tr>
<tr>
<td></td>
<td>forearm</td>
</tr>
<tr>
<td></td>
<td>Radial nerve (C5-T1 nerve roots). Innervates the extensor carpi radialis</td>
</tr>
<tr>
<td></td>
<td>longus, extensor carpi radialis brevis, brachioradialis, supinator, and</td>
</tr>
<tr>
<td></td>
<td>finger and wrist extensors. The radial nerve divides distal to the elbow</td>
</tr>
<tr>
<td></td>
<td>into the superficial branch (sensory only) and deep branch (which passes</td>
</tr>
<tr>
<td></td>
<td>through the supinator muscle and can be involved in radial tunnel</td>
</tr>
<tr>
<td></td>
<td>syndrome)</td>
</tr>
<tr>
<td></td>
<td>Median nerve (C6-T1 nerve roots). Innervates the wrist flexors, pronators,</td>
</tr>
<tr>
<td></td>
<td>flexor digitorum superficialis, lateral half of flexor digitorum profundus</td>
</tr>
<tr>
<td></td>
<td>and muscles of the thumb and lateral fingers</td>
</tr>
<tr>
<td></td>
<td>Ulnar nerve – (C8-T1 nerve roots). Innervates the flexor carpi ulnaris,</td>
</tr>
<tr>
<td></td>
<td>medial half of the FDP, and intrinsic muscles of the hand. Humeroulnar and</td>
</tr>
<tr>
<td></td>
<td>humeroradial joints and their surrounding connective tissues receive their</td>
</tr>
<tr>
<td></td>
<td>sensory innervation from C6-7 nerve roots</td>
</tr>
<tr>
<td></td>
<td>Proximal radioulnar joint and surrounding capsule receive their sensory</td>
</tr>
<tr>
<td></td>
<td>innervation from C7-7 nerve roots. (The distal radioulnar joint receives its</td>
</tr>
<tr>
<td></td>
<td>sensory innervation from C8)</td>
</tr>
</tbody>
</table>

The ulna provides the distal hinge joint articulation for the humeral ulnar joint (HUJ). The ulna is a long, thin bone with a posterior and proximal protuberance called the olcrenon that serves as an attachment site for the triceps and anconeus. Anteriorly, the coronoid provides stability during
movement. Distally, the ulna provides a thin contact with the wrist and a shared capsular articulation with the radiocarpal joint (2).

The radius provides the most substantial articulation with the wrist and a unique joint contact at the elbow. The concave radial head articulates with the convex capitulum, forming a modified hinge joint that has a considerable amount of pivoting movement. Distally, the radius broadens and provides a wide contact surface for wrist articulation.

**Osseous Structures of the Wrist**

Normally, 27 bones make up the wrist and hand complex. In some cases, sesamoid bones may increase the total of bones in the wrist (Table 9.2). There are eight carpal bones in the normal hand (Table 9.3). The proximal carpal row is made up of the pisiform, triquetrum, lunate, and scaphoid. The distal row consists of the hamate, capitate, trapezoid, and trapezium. Of the eight carpal bones, the pisiform functions less for support and articulation and is nearly entirely embedded within the tendon of the flexor carpi ulnaris. The scaphoid is a peanut-shaped bone and is the most commonly fractured carpal bone. Approximately 65 percent of the fractures occur at the “waist” of the scaphoid secondary to a poor blood supply. However, pole fractures actually take longer to heal, generally taking up to 20 weeks for proper ossification and stability (3).

<table>
<thead>
<tr>
<th>Concept</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
<td>24 bones: ulna and radius; 8 carpal bones, 5 metacarpals, 5 carpals, 5 phalanges, and humerus</td>
</tr>
<tr>
<td>Number of dedicated joints</td>
<td>4 joints: humeroulnar, humeroradial, proximal radioulnar, and distal radioulnar</td>
</tr>
</tbody>
</table>
| Range of motion of the wrist and hand | • Wrist flexion = 80–90°  
• Wrist extension = 70–90°  
• Ulnar deviation = 30–and45°  
• Radial deviation = 15°  
• Pronation = 85–90°  
• Supination = 85–90°  
• Finger flexion  
  MCP = 85–90° |
<table>
<thead>
<tr>
<th>Bone</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaphoid (navicular)</td>
<td>Proximal surface is convex to articulate with the concave distal radius. Is the most frequently fractured carpal bone secondary to its narrow &quot;waist.&quot; The scaphoid articulates with the radius and four carpal bones</td>
</tr>
<tr>
<td>Lunate</td>
<td>The lunate is the central bone of the proximal row. The proximal surface is convex to articulate with the concave distal radius. The distal surface is concave to accept the proximal concavity of the capitate. The bone plays an essential role for both wrist stability and mobility</td>
</tr>
<tr>
<td>Triquetrum</td>
<td>The triquetrum is a triangular bone that occupies the most ulnar position in the wrist. The bone is palpated medially during wrist radial deviation</td>
</tr>
<tr>
<td>Pisiform</td>
<td>The pisiform serves as an attachment for several muscles and ligaments and is the smallest carpal bone</td>
</tr>
<tr>
<td>Capitate</td>
<td>The capitate is the largest carpal bone and is the keystone of the distal row of carpal bones. The bone has a convex head (proximal end) that articulates with the deep concavity of the scaphoid and lunate. The bone is rigidly attached to the 3rd metacarpal to provide a strong central column in the hand</td>
</tr>
<tr>
<td>Trapezium</td>
<td>The trapezium is located at the base of the thumb. The bone forms a saddle joint with the 1st metacarpal (thumb) due to its sellar distal surface</td>
</tr>
<tr>
<td>Trapezoid</td>
<td>The trapezoid wedges between the capitate and the trapezium. The articulation with the 2nd metacarpal is the most stable articulation in the wrist.</td>
</tr>
<tr>
<td>Hamate</td>
<td>The hamate has a large hook, which (along with the pisiform) provides an</td>
</tr>
</tbody>
</table>
Osseous Structures of the Hand

There are five metacarpals in the hand, which are made up of 19 separate bones arranged in longitudinal order. Metacarpals are long, cylindrical bones that make up the palmar and dorsal aspect of the hand. The bones run from the carpal bones of the wrist to the articulation of the metacarpal phalangeal joint. Metacarpals 2 and 3 move very little, whereas metacarpal 1 exhibits liberal movement, allowing the thumb to oppose digits 4 and 5 (4).

Figure 9.1: The Bones of the Wrist and Hand

There are three phalanges (proximal, middle, and distal) for each finger and two for the thumb (proximal and distal). The phalanges are long and cylindrical, with each distal joint surface exhibiting a convex presentation. Each proximal structure exhibits a concave presentation lending to a hinge-type joint. The distal extremities are shorter and smaller than the proximal.

Summary

- Three primary osseous structures make up the elbow joint: the humerus, the radius, and the ulna.
• The osseous structures of the wrist include the proximal structures of the ulna and radius and the carpal bones; the proximal carpal row is made up of the pisiform, triquetrum, lunate and scaphoid. The distal row consists of the hamate, capitate, trapezoid and trapezium.
• There are five metacarpals in the hand and three phalanges for each finger and two for the thumb.

Ligaments, Interosseous, and Capsular Structures of the Elbow

The elbow is less stable with valgus stresses than with varus stresses, although instability is not common. When instability is present, it is normally associated with valgus stress, a product of functional torque upon the joint. To counter this consequence, the medial collateral ligaments of the elbow are stronger than the lateral collateral ligaments (5).

The medial or ulnar collateral ligaments include the anterior oblique and posterior oblique bundles and a transverse ligament (5). The anterior oblique bundle provides medial stability throughout flexion and extension. This ligament maintains the elbow against valgus instability to a greater extent than even the bony configuration of the olecranon (5). Morrey and An (6) suggested that the anterior oblique bundles provided the greatest stability to valgus forces of the ligaments of the elbow. The posterior oblique bundle provides medial stability in 60 to 135 degrees of flexion and extension, while the transverse ligament’s contribution is marginal (5).

The ulnar (medial) collateral ligament provides valgus stability (abduction) and is tightened in all positions of the elbow through influence of the anterior, posterior, and oblique (transverse) bands. The anterior band provides the greatest passive structure resistance to valgus force throughout the flexion and extension movements of the elbow (2). The anterior band originates on the medial supracondylar ridge of the humerus and inserts lateral to the coronoid process of the ulna (5). The transverse or oblique band provides medial stability at 60 to 135 degrees of extension to flexion movement. The transverse band originates on the distal-most aspect of the supracondylar ridge of the humerus, just distal to the humerus, and inserts on the proximal-lateral aspect of the coronoid process of the ulna (5). The posterior bundle of the medial collateral aspect of the elbow originates on the medial supracondylar ridge of the humerus and inserts just anterior to the lateral
aspect of the olecranon. The ulnar ligamentous complex is most stable at 110 degrees and also most lax at this range if the ligament is disrupted (2).

The lateral or radial collateral ligament originates from the lateral condyle of the humerus and inserts on the annular ligament, which encircles the head of the radius. The radial collateral ligament provides varus stability (adduction) but does not provide the same intensity of the stabilization as does the medial collateral structures (5).

The annular ligament of the elbow forms a ligamentous ring that encircles the head of the radius and a ligamentous attachment to the ulna. The annular ligament allows hinge-like motion, promotes rotation of the radial head with stabilization of its position to the ulna, and contributes partially to lateral stability of the elbow. The annular ligament also prevents lateral and inferior displacement of the radial head (5).

The capsule of the elbow that is prepositioned in extension contributes significantly to the stability of the elbow in distraction (6), and slightly for motions of varus and valgus forces. The contribution of the capsule for stability during flexion is nearly insignificant. Studies have shown that resection of the elbow capsule does not alter valgus or varus stability; however, resection of the medial and lateral collateral ligaments certainly affects stability (7).
Ligaments, Interosseous, and Capsular Structures of the Wrist and Hand

The palmar ligaments (volar wrist ligaments) are highly developed, stable, and have integrated with the volar plates in the fingers. The wrist ligaments originate from the radial styloid process and migrate in a distal and ulnar direction. These ligaments include the ulnar-sided capitohamate ligaments, the lunatrotiquetral ligaments, the ulnolunate ligament, and the ulnotriquetral ligament. The ulnotriquetral ligament and the ulnolunate ligament lie ulnarly, while the radiolunate, radioscapoid, and radioscapolunate lie radially (8).

Like the elbow, the capsule of the wrist is synovial and contiguous. The capsule contains the joints of the wrist but does not contain the multiple tendons of the fingers, which lie outside the capsule. The dorsal surface of the hand also demonstrates excellent stability. The superficial layers include the dorsal oblique radiotriquetral ligaments and the dorsal transverse intercarpal (trapezoid-triquetral ligament), while the deep layers include the scapholunate interosseous ligament and the unnotriquetral interosseous ligament. Each of the deep and superficial ligaments plays an important role during stabilization of the wrist (8).

Summary

- The ligaments of the elbow include the medial structures, the anterior oblique and posterior oblique bundles, and the transverse, lateral collateral, and annular ligaments.
- The capsule within the elbow is contiguous.
- The wrist consists of both medial and lateral ligaments as well as multiple interosseous ligaments between each carpal bone.
- The hand also consists of numerous ligaments that guide motion and provide structure to the hand and fingers.
- The capsule of the wrist is contiguous but does not contain the tendons of the wrist.

BIOMECHANICS

The Elbow

The center of rotation for sagittal movement of the elbow moves very little throughout flexion and extension physiological movements (9). This suggests that the humeroulnar joint (HUJ) is a simple hinge joint with only slight alterations of variability. Others have found up to 8 degrees of variability (10) with concurrent varus and valgus movements of 4 to 8 degrees in the coronal plane.
This movement is associated with the contribution of the capitellum and the freedom of varus and valgus translation during this motion.

Individually, the radial head can turn clockwise and counterclockwise. The axis of rotation for pronation and supination lies in an oblique plane between the ulna and the radius and passes through the interosseous membrane at the distal fourth of the ulna (9). During pronation, the radius moves both proximally and laterally, while the ulna concurrently internally rotates. During supination the ulna exhibits external rotation, while the radius moves distally and medially. Prepositioning of the elbow in pronation or supination alters the axis of the HUJ and humeroradial joint (HRJ), creating differences in the amount of force that is translated through the joint (9).

**Joints of the Elbow**

There are four primary joints of the elbow (Table 9.4). The two most proximal joints of the elbow, the HUJ and the HRJ, have two degrees of freedom: 1) flexion-extension at the HUJ, and 2) pronation-supination at the HRJ. The third joint, the proximal radio-ulnar joint (PRUJ) is enveloped within the same capsule as the HUJ and the HRJ. The theoretical movement patterns of the joints are described in Table 9.5.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humeroulnar</td>
<td>Synovial (hinged)</td>
<td>Articulation between the concave trochlear notch of the ulna and the convex trochlea of the humerus. Flexion tightens posterior fibers of the medial collateral ligament. Extension is stabilized by the anterior fibers of the medial collateral ligament. The olecranon process wedges into olecranon fossa</td>
</tr>
<tr>
<td>Humeroradial</td>
<td>Synovial (arthrodial-gliding)</td>
<td>Articulation between the fovea of the radial head and the rounded capitellum. It provides only minimal structural stability to the elbow. In full extension there is little contact</td>
</tr>
<tr>
<td>Proximal radioulnar</td>
<td>Synovial (trochoid or pivot joint)</td>
<td>Movement is limited to rotation; the joint is formed by a pivot-like process turning within a ring, or a ring on a pivot. In the proximal radioulnar articulation, the ring is formed by the radial notch of the ulna and the annular ligament; here, the head of the radius rotates within the ring</td>
</tr>
</tbody>
</table>
The convex head of the ulna fits into the shallow concavity formed by the ulnar notch of the radius and the articular disc. The disc is the triangular fibrocartilage. The disc is part of a larger set of connective tissues known as the triangular fibrocartilage complex. This occupies most of the space between the distal ulna and the ulnar side of the carpal bones. This disc is the primary stabilizer of the distal radioulnar joint.

**Table 9.5: Theoretical Open Pack, Close Pack, and Capsular Patterns of the Elbow.**

<table>
<thead>
<tr>
<th>Joint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humeroulnar</td>
<td>Open pack = 70° flexion and 10° supination</td>
</tr>
<tr>
<td></td>
<td>Close pack = supination</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion, extension</td>
</tr>
<tr>
<td>Humeroradial</td>
<td>Open pack = full extension and full supination</td>
</tr>
<tr>
<td></td>
<td>Close pack = flexion to 90°, supination 5°</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion, extension, supination, pronation</td>
</tr>
<tr>
<td>Proximal radioulnar</td>
<td>Open pack = 35° supination, 70° flexion</td>
</tr>
<tr>
<td></td>
<td>Close pack = 5° supination</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = equal limitations of supination and pronation</td>
</tr>
<tr>
<td>Distal radioulnar</td>
<td>Open pack = 10° supination</td>
</tr>
<tr>
<td></td>
<td>Close pack = 5° supination</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = pain at extremes of rotation</td>
</tr>
</tbody>
</table>

**Humeroulnar joint (HUJ)**

The HUJ is a hinge joint, demonstrating the primary movements of flexion and extension. The complete range of motion of the joint varies but generally exhibits 0 to 5 degrees of hyperextension to 135 to 150 degrees of flexion. The 5 degrees of hyperextension is considered normal and functional.

Extension is limited either by the olecranon process of the posterior articulation or by the anterior ligaments of the elbow. Occasionally, tightness in the origin and insertions of the anterior muscles may limit extension as well. Flexion is limited by the coronoid process of the elbow, soft tissue of the anterior forearm and biceps, and posterior and anterior ligaments.
When the elbow is fully extended and supinated, the forearm is angled slightly away from the long axis of the humerus. This angle is called the "carrying angle" and is a product of function and the fulcruming action of the biceps tuberosity. The head of the radius will translate medially during supination and laterally during pronation as a result of the fulcruming action of the biceps tuberosity of the radius (9).

**Humeroradial joint (HRJ)**

The articulation between humerus and radius is the HRJ. The articulation is hallmarked by the smooth junction of the convex capitulum of the humerus as the structure articulates with the top of the concave radial head. This biomechanical relationship allows for a spinning movement around the capitulum by the radial head during flexion, which contributes to flexion and extension and pronation and supination of the joint (9).

**Proximal Radial Ulnar Joint (PRUJ)**

The PRUJ is a pivot joint and consists of the articulations of the proximal one-third of the ulna and radius. The radius is attached to the ulna by the annular ligament, which assists in guiding the movement of pronation and supination. Normal pronation values are approximately 70 degrees of range of motion, whereas supination is approximately 85 degrees of range. During supination and extension, the radial head is displaced medially, allowing for an increased carrying angle. During pronation, the radial head translates laterally, promoted by the biceps tubercle as a pivot point and fulcrum.

The complex movements associated with elbow motion are manufactured by the collective movements of numerous muscles (Table 9.6). The biceps, brachioradialis, and brachialis provide the majority of torque for flexion. The anconeus and the triceps provide extension torque. Pronation is produced primarily from the pronator teres, while supination is produced by the supinator and the biceps. Damage to the muscle may lead to movement dysfunction and subsequent restrictions and impairments.
**Table 9.6: Muscles and Function of the Elbow and Forearm.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement and Function</th>
<th>Joint Motion</th>
<th>Spinal Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps brachii</td>
<td>Flexion and supination</td>
<td>Flexes arm and forearm, supinates hand</td>
<td>C5-C6</td>
</tr>
<tr>
<td>• Long head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Short head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachialis</td>
<td>Flexion</td>
<td>Flexes forearm</td>
<td>C5-C6</td>
</tr>
<tr>
<td>Triceps</td>
<td>Extension</td>
<td>Extends arm and forearm</td>
<td>C7-C8</td>
</tr>
<tr>
<td>• Long head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lateral head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Medial head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronator teres</td>
<td>Pronation and flexion</td>
<td>Pronates hand and flexes Forearm</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Supinator</td>
<td>Supination</td>
<td>Following pronation, supinator supinates the radius</td>
<td>C6</td>
</tr>
<tr>
<td>Flexor carpi radialis</td>
<td>Flexion, pronation, and radial deviation</td>
<td>Flex forearm and hand, aid in pronation and abduction of hand</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Palmaris longus</td>
<td>Flexion</td>
<td>Flexes hand and wrinkles skin of palm of hand</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Flexor digitorum superficialis</td>
<td>Flexion</td>
<td>Flexes phalanges, wrist, and forearm</td>
<td>C6,C7,T1</td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td>Flexion and ulnar deviation</td>
<td>Flexes forearm and hand, adducts hand</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Flexor pollicis longus</td>
<td>Flexion</td>
<td>Flexes thumb</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Flexor Digitorum Profundus</td>
<td>Flexion</td>
<td>Flexes phalanges</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Pronator quadratus</td>
<td>Pronation</td>
<td>Pronates hand</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Extensor carpi radialis longus</td>
<td>Extension and radial deviation</td>
<td>Extends and abduction the wrist</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Extensor carpi radialis brevis</td>
<td>Extension and radial deviation</td>
<td>Extends and abduction the wrist</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Extensor carpi ulnaris</td>
<td>Extension and ulnar deviation</td>
<td>Extends and adducts the hand</td>
<td>C6,C7,C8</td>
</tr>
<tr>
<td>Anconeus</td>
<td>Extension</td>
<td>Extends forearm</td>
<td>C7-C8</td>
</tr>
</tbody>
</table>
Figure 9.3: Forearm Muscles—Anterior View

Figure 9.4: Forearm Muscles—Posterior View
Summary

- The two most proximal joints of the elbow, the ulnohumeral and the radiohumeral, have two degrees of freedom, allowing flexion and extension as well as pronation and supination.
- The elbow also exhibits a small degree of varus and valgus motion during flexion and extension.
- Pronation requires the lateral translation of the radial head, while supination requires a medial translation of the radial head.
- Multiple muscles produce the complex active movements of the elbow, some contributing to movements in more than one plane.

The Wrist

Wrist motion is the summated movements of the collective joints of the wrist and is infinitely complex. This motion includes the intricate motions of the carpal bones and the movements with the distal aspect of the radius. Individual ranges of motion between the distal carpal bones range from as little as 6 degrees of flexion-extension, or radial-ulna deviation to as great as 12 degrees (11).

The carpal bones in the distal row generally move in concert more often than the carpal bones in the proximal row but do exhibit isolated movements. The reason the proximal row demonstrates greater isolated movements is that the carpal bones are less tightly bound to one another through ligamentous and capsular connections (12,13). In general, carpal bones within the distal row synergistically move with flexion and ulnar deviation during flexion and, conversely, with extension and radial deviation.

The proximal carpal bones that exhibit the greatest amount of movement are the scaphoid, which moves up to 80 degrees with respect to the radius (13), and the lunate and triquetrum, which move only slightly less (14). It is imperative to acknowledge that movement occurs in multiple planes, with respect to the radius and with respect to other carpal bones. For example, the scaphoid not only moves toward extension during wrist extension but also supinates and deviates into a radial direction (11). Wrist flexion promotes the combined movements of flexion, ulnar deviation and pronation of the scaphoid. In contrast, during extension, the lunate extends, pronates, and ulnarly deviates.
Range of motion is also dependent on the laxity of the intercarpal joints, the shape of the distal radius, the function of the **triangular fibrocartilaginous complex** (TFCC), and the ulnocarpal joint. Movements are always combined and very complex, and are dependent on a myriad of structures.

In summary, motion of the wrist is coupled and multiplanar. Movements such as flexion and ulnar deviation and extension and radial deviation occur concurrently and have a linear relationship. As much as 75 percent of ulnar and radial deviation is associated with flexion and extension movements (15). Additionally, pronation and supination of the elbow require pronation and supination contributions from the wrist (16). The mean degree of movement of pronation and supination that originates at the wrist is 17 degrees respectively for both (16).

**Joints of the Wrist**

The global movements of the wrist and hand include flexion and extension with normative values of 80 to 90 degrees of flexion and 75 to 80 degrees of extension. Thirty-five degrees of ulnar deviation and 20 degrees of radial deviation are considered normal as is metacarpal phalangeal flexion and extension of 135 and 25 degrees, respectively. Adduction and abduction values are 20 to 25 degrees, respectively, and proximal interphalangeal flexion and extension values are 115 and 0 degrees, respectively. Finally, distal interphalangeal extension and flexion demonstrate 0 to 90 degrees of movement.

Although there are numerous joints of the wrist and hand, each joint is synovial and contributes to the astonishing functional movements of the wrist and hand. For order, the joints will be discussed primarily by row; however, in reality, movement may occur between carpal bones, in multiple axes, and through highly complicated mechanisms (17,18). The theoretical movement patterns of the wrist and hand are outlined in Table 9.7.
Table 9.7: Theoretical Resting Position, Close Pack, and Capsular Patterns of the Wrist and Hand.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal radioulnar joint</td>
<td>Resting position = 10° of supination</td>
</tr>
<tr>
<td></td>
<td>Close pack = 5° of supination</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = pain at extreme ends of motion</td>
</tr>
<tr>
<td>Radiocarpal joint</td>
<td>Resting position = neutral with slight ulnar deviation</td>
</tr>
<tr>
<td></td>
<td>Close pack = extension</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion and extension equally limited</td>
</tr>
<tr>
<td>Intercarpal joints</td>
<td>Resting position = neutral or slight flexion</td>
</tr>
<tr>
<td></td>
<td>Close pack = extension</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = none</td>
</tr>
<tr>
<td>Mid-carpal joints</td>
<td>Resting position = neutral or slight flexion with ulnar deviation</td>
</tr>
<tr>
<td></td>
<td>Close pack = extension with ulnar deviation</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion and extension equally limited</td>
</tr>
<tr>
<td>2nd to 5th carpometacarpal joints</td>
<td>Resting position = mid-way between flexion and extension</td>
</tr>
<tr>
<td></td>
<td>Close pack = full flexion</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = none</td>
</tr>
<tr>
<td>1st carpometacarpal joint</td>
<td>Resting position = mid-way between flexion, extension, abduction, and adduction</td>
</tr>
<tr>
<td></td>
<td>Close pack = full opposition</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = abduction and extension</td>
</tr>
<tr>
<td>Metacarpalphalangeal joints</td>
<td>Resting position = slight flexion</td>
</tr>
<tr>
<td></td>
<td>Close pack = Thumb-full opposition and fingers-full flexion</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion and extension</td>
</tr>
<tr>
<td>Interphalangeal joints</td>
<td>Resting position = Slight flexion</td>
</tr>
<tr>
<td></td>
<td>Close pack = full extension</td>
</tr>
<tr>
<td></td>
<td>Capsular pattern = flexion and extension</td>
</tr>
</tbody>
</table>

**Proximal Carpal Row**

The proximal carpal row consists of the lateral articulations of the lunate and scaphoid with the radius (radiolunate and radioscaphid) and the medial articulation of the ulna, TFCC, and the lunate (ulnolunate), TFCC, and triquetrum. The radiocarpal joints (radiolunate and radioscaphid)
include a biconvex carpal segment and the biconcave radial aspect. The ulnocarpal joint is further complicated by the presence of the TFCC that merges with the volar edge of the ulnocarpal ligaments and, at its dorsal edge, with the floors of the extensor carpi ulnaris and extensor digiti minimi, and separates the ulna and the proximal carpal row (19). The TFCC has numerous functions at the proximal carpal row. First, the disc provides a smooth and conformed gliding surface across the entire distal face of the ulna and proximal carpal row. Second, the disc allows flexion, extension, rotation, and translational movements. Third, the disc cushions forces that are transmitted through this region, thus reducing the risk of fracture (19). Lastly, the disc connects the two bony regions together in an otherwise poorly congruent region.

Figure 9.5: The Proximal and Mid-Carpal Row

Mid-Carpal Row

The mid-carpal row consists of the articulations of the triquetrum, lunate, and scaphoid (proximal row) with the hamate, capitate, trapezoid, and trapezium (distal row). The distal surfaces of the triquetrum, lunate, and scaphoid are biconcave, while the distal surfaces of most of the scaphoid is either convex or planar. The proximal surfaces of the capitate and hamate are convex, and the proximal surface of the trapezoid and trapezium are concave or planar.

Under normal situations, movements of the mid-carpal joint are disparate from the movements of the pisotriquetral, radiocarpal, and first carpometacarpal joints (2). This complex joint
provides numerous interosseous articulations, providing movement that is much more complex than simple extension and flexion, or radial and ulnar deviation. Because the large capitate crosses the axis of the mid-carpal row and encroaches into the proximal carpal joint, the mid-carpal joint will always demonstrate lower values of motion as compared to the proximal row.

**Intercarpal Joints**

Multiple intercarpal joints are present throughout the two rows of carpal bones. The joints are stabilized by ligamentous and capsular components but do allow movements such as shear, rotation, flexion, and extension relative to one another. Range-of-motion values differ among joints yet each intercarpal structure can be a pain generator. Instability may occur in many forms the most common are identified as a volar intercalated segmental instability (VISI) and a dorsal intercalated segmental instability (DISI). A VISI results from a disruption between the triquetrum and lunate, allowing volar drift of the lunate and problems during physiological flexion of the wrist (20). A VISI pattern is usually associated with triquetrolunate dissociation or triquetral-hamate instability. A DISI results from a disruption between the scaphoid and the lunate, allowing the scaphoid to float into volar tilt and the lunate to assume a dorsal tilt (20). A patient with a DISI (scapholigamentous disruption) exhibits problems with physiological dorsiflexion and is diagnosed by the presence of a scapholunate angle greater than 70 degrees.

**Carpometacarpal Joints**

The carpometacarpal joints are the articulations of the distal carpal row and the metacarpals of all five digits. The first carpometacarpal joint lies laterally to the rest of the palm, which promotes oppositional movements of the thumb. The joint is a sellar (saddle) joint with two main axes (a radiolunate axis for flexion and extension and a dorsopalmar axis for abduction and adduction). Some rotation is possible at this joint when the thumb is adducted or placed in slight flexion (21). The close-packed position of the thumb occurs during full abduction. Normally, the capsule of the carpometacarpal joint is lax, which allows opposition.
Joints of the Hand

There are numerous movements within the hand (Table 9.8). Structurally, the hand exhibits three primary arches to promote stable grasps and gripping functions (21). The proximal transverse arch forms at the posterior border of the carpal tunnel and is rigid and stable. The distal transverse arch is formed by the metacarpal heads and is maintained by the intrinsic muscles of the hand. The longitudinal arch allows the fourth and fifth metacarpals to oppose the palm longitudinally.

Table 9.8: Joints of the Wrist and Hand.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiocarpal</td>
<td>Condyloid joint</td>
<td>Convex scaphoid and lunate move on concave distal radius and adjacent articular disc. During flexion and extension, the joints roll and slide in opposite directions</td>
</tr>
<tr>
<td>Mid-carpal</td>
<td>Compound sellar joint</td>
<td>Complex coupled movement that spins around the capitate but involves combined movements of extension/radial deviation and flexion/ulnar deviation. For the most part, the joints roll and slide in opposite directions</td>
</tr>
<tr>
<td>2nd to 5th carpal-metacarpal</td>
<td>2 and 3 are considered sellar joints, 4 and 5 are considered plane joints</td>
<td>Joints 2 and 3 allow very little movement. Movements of 4 and 5 are gliding in nature during both extension and flexion</td>
</tr>
<tr>
<td>1st carpometacarpal joint</td>
<td>Complex sellar joint</td>
<td>Concave in the plane of CMC abduction/adduction. During CMC abduction or adduction (in a direction perpendicular to the palm), the metacarpal rolls and</td>
</tr>
</tbody>
</table>
glides in opposite directions. Convex in the plane of CMC flexion/extension. During abduction and adduction, the joints roll and slide in the opposite direction, whereas during flexion/extension, the joints move in the same direction.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Type</th>
<th>Movement Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacarpal-phalangeal joints</td>
<td>Condyloid</td>
<td>Base of proximal phalanx rolls and slides in the same direction as movement</td>
</tr>
<tr>
<td>Interphalangeal joints</td>
<td>Condyloid</td>
<td>Base of proximal phalanx rolls and slides in the same direction as movement</td>
</tr>
</tbody>
</table>

**Inter-metacarpal Joints**

The intermetacarpal joints allow movements within the distal transverse axis of the hand. The intermetacarpal joints help create an arch in the palm, an arch that is progressively more angular near the ulnar aspect of the hand. By far, the majority of transverse movement occurs at metacarpals 4 and 5, allowing further opponens movements toward the thumb of the hand (21). Overall, the amount of movement available at these joints is minimal but is necessary for appropriate fist making and hand manipulation.

**Metacarpophalangeal Joints**

The metacarpophalangeal joint is a condyloid classification that allows flexion, extension, abduction, rotation, and circumduction. The joint is well stabilized anteriorly and medially and laterally. The joints are most stable in flexion and allow the greatest amount of mobility in extension (21).

**Proximal and Distal Phalangeal Joints**

The phalangeal joints include the proximal interphalangeal joint (PIP) and the distal interphalangeal joints (DIP). Both joints have a fibrous capsule, collateral ligaments that stabilize lateral displacement, volar plates that stabilize against hyperextension forces, and additional soft
tissue stabilization from muscle and fascia. Both joints are considered hinge joints and are important in the manipulation of objects.

Numerous muscles in the hand are responsible for the complex and delicate movements required for the grasp and manipulation of objects. Table 9.9 outlines the muscles and movements associated with the fingers and the distal hand.

**Table 9.9: Finger Muscles and Function.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement and Function</th>
<th>Joint Motion</th>
<th>Spinal Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abductor digiti minimi</td>
<td>Abduction</td>
<td>Abduction of the 5(^{th}) digit</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Dorsal interossei</td>
<td>Abduction, flex proximal, extend middle and distal phalanges</td>
<td>Extension of the PIP and DIP and abduction of the MCP</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Extensor digiti minimi</td>
<td>Extension</td>
<td>Isolated extension of the 5(^{th}) digit</td>
<td>C6-C8</td>
</tr>
<tr>
<td>Extensor digitorum</td>
<td>Extension</td>
<td>Extension of digits 2 to 5</td>
<td>C6-C8</td>
</tr>
<tr>
<td>Extensor indicis</td>
<td>Extension</td>
<td>Extension of the 2(^{nd}) digit</td>
<td>C7-C8</td>
</tr>
<tr>
<td>Flexor digiti minimi</td>
<td>Flex metacarpophalangeal joint</td>
<td>Isolated flexion of the 5(^{th}) digit</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Flexor digiti profundus</td>
<td>Flex metacarpophalangeal, proximal, and distal interphalangeal joints</td>
<td>Flexion of the 2(^{nd}) through 5(^{th}) digits to the DIP</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Flexor digiti superficialis</td>
<td>Flex metacarpophalangeal and proximal interphalangeal joints</td>
<td>Flexion of the 2(^{nd}) through the 5(^{th}) digits to the PIP</td>
<td>C7-T1</td>
</tr>
<tr>
<td>Lumbricals</td>
<td>Flex metacarpophalangeal joints, extend middle and distal phalanges</td>
<td>Flexion of the 2(^{nd}) through 5(^{th}) MCP and extension (in concert with other muscles) of the PIP and DIP of the 2(^{nd}) through 5(^{th}) digit</td>
<td>C7-C8</td>
</tr>
<tr>
<td>Volar interossei</td>
<td>Adduction, flex proximal, and extend middle and distal phalanges</td>
<td>Extension of the PIP and DIP and adduction of the MCP</td>
<td>C8-T1</td>
</tr>
</tbody>
</table>

The extensor mechanism of the hand is a complex mechanism of passive and active tension. Prime movement occurs through the insertion of the extensor digitorum communis (and the
extensor indicis and extensor digiti minimi at the 2nd and 5th digits, respectively) in the dorsum of each phalanx just distal to the metacarpal-phalangeal (MCP) joint. This connection is responsible for extension of the MCP and contributes to the elaborate further extension of the proximal interphalangeal (PIP) and distal interphalangeal (DIP) (22). A central tendon proceeds from the extensor insertion to the base of the middle phalanx (just distal to the PIP) and contributes to extend the PIP. Structures called ‘lateral bands’ receive tendinous attachments from the lumbricals and the interossei and create tension (during contraction) of the DIP. The oblique retinacular ligament creates passive tension on the DIP during PIP extension and subsequently extends the DIP (23). Dysfunctions such as mallet finger (central insertion rupture at the DIP) and Boutonniere deformity (rupture of the central slip of the extensor tendon at the level of the proximal interphalangeal joint) can lead to the inability to straighten the finger at the middle joint or distal joint and subsequent contractures.

**The First Carpometacarpal Joint (The Thumb)**

The articular surface of the thumb involves the contact of the trapezium and the first metacarpal. The first metacarpal conforms to the biplanar articular surface of the trapezium creating a saddle joint with six degrees of freedom. This degree of freedom allows a great range of mobility in all directions so that the pad of the thumb can oppose any finger pad (Table 9.10). Individually, the metacarpalphalangeal joint of the thumb is capable of the movements of metacarpophalangeal flexion and extension, and interphalangeal flexion and extension. Conversely, the additional movements of abduction and adduction occur at the carpometacarpal joint through the interplay of numerous muscles such as the abductor pollicis brevis and longus, adductor and flexor pollicis, and extensor pollicis muscles.
Table 9.10: Thumb Muscles and Movements.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement and Function</th>
<th>Joint Motion</th>
<th>Spinal Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor pollicis brevis</td>
<td>Thumb flexion</td>
<td>1st digit Metacarpophalangeal flexion</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Flexor pollicis longus</td>
<td>Thumb flexion and some adduction</td>
<td>1st digit Interphalangeal flexion and slight adduction</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Extensor pollicis brevis</td>
<td>Thumb extension</td>
<td>1st digit Metacarpophalangeal extension</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Extensor pollicis longus</td>
<td>Thumb extension</td>
<td>1st digit Interphalangeal extension</td>
<td>C6-C7</td>
</tr>
<tr>
<td>Adductor pollicis</td>
<td>Thumb adduction</td>
<td>CMC and PIP adduction</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Abductor pollicis brevis, abductor pollicis longus</td>
<td>Thumb abduction</td>
<td>CMC and PIP abduction</td>
<td>C8-T1</td>
</tr>
<tr>
<td>Opponens pollicis, opponens digiti minimi</td>
<td>Thumb opposition</td>
<td>CMC and PIP opposition</td>
<td>C6-C7</td>
</tr>
</tbody>
</table>

Summary

- There are numerous joints of the wrist and hand, too numerous to note.
- Joints at the wrist are typically described by location and are generally divided into the proximal carpal row, the mid-carpal row and the distal carpal row.
- The joints of the hand are typically described by location and include the carpometacarpal, the metacarpal phalangeal, the proximal interphalangeal, and the distal interphalangeal joints.
- Movement at the wrist is coupled and depends on the complex interplay between the carpal bones.
- The carpometacarpal joint of the thumb has a biplanar articular surface of the trapezium creating a saddle joint with six degrees of freedom.

Online References