Anatomy and Biomechanics of the Elbow Joint

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- A sound understanding of elbow anatomy and biomechanics is necessary to treat common traumatic conditions of the elbow.

Elbow stability[1,2)]

➢ Primary static constraints
  Ulnohumeral articulation
  Anterior bundle of medial collateral ligament
  Lateral collateral ligament complex (esp, lateral ulnar collateral ligament)

➢ Sencondary constraints
  Radiocapitellar articulation
  Common flexor & extensor tendon
  Capsule

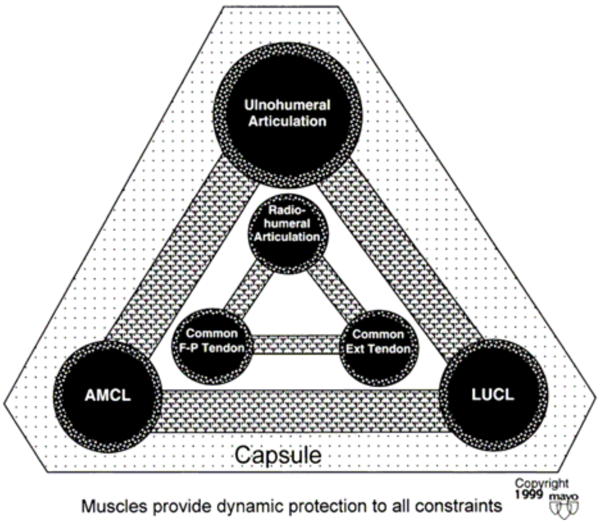

Fig. 1. The ''fortress'' of static and dynamic constraints to elbow instability. The three primary constraints are the ulnohumeral articulation, the anterior bundle of the medial collateral ligament (AMCL), and the lateral collateral ligament, especially the ulnar part known as the lateral ulnar collateral ligament (LUCL). The secondary constraints are the radiohumeral articulation, the common flexor-pronator (F-P) tendon, the common extensor tendon, and the capsule.The muscles that cross the elbow are the dynamic constraints.

Elbow Anatomy

Ⅰ. Osteoarticular anatomy

Trochleogingylomoid joint[2,3]

Ulnohumeral joint : hinged(gynglymoid) motion - flexion & extension

Radioulnar joint ; trochoid motion - supination & pronation

1. Distal humerus (trochlea, capitellum)4)

: anterior angulation about 30^{o} in lateral plane

: approximately 5^{o} internal rotation with respect to the epicondylar line

: approximately 6^{o} of valgus in AP plane

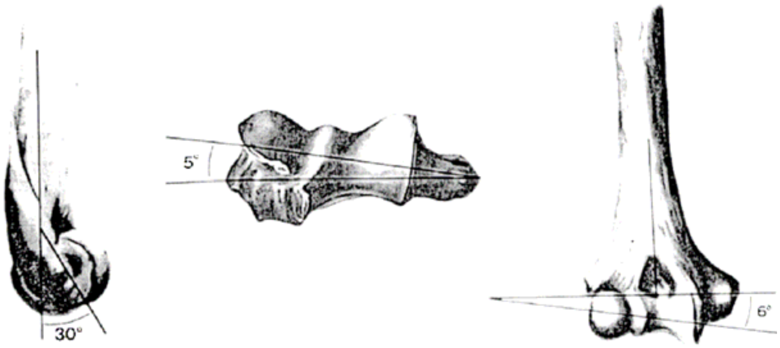

Fig. 2. A, Lateral view shows 30° anterior rotation of the distal humeral condyles. B, Axial view shows 5° to 7° internal rotation of the distal humerus articular surface. C, Anterior view shows 6° to 8° degrees of valgus tilt at the distal humerus.

2. Proximal ulna[3,4]

: 4^{o} valgus angulation with the shaft of the ulna

: rotated posteriorly approximately 30^{o} with respect to the long axis in lat. view.

3. Proximal radius[5]

: radial neck makes an angle of 15^{o} away from the radial tuberosity.

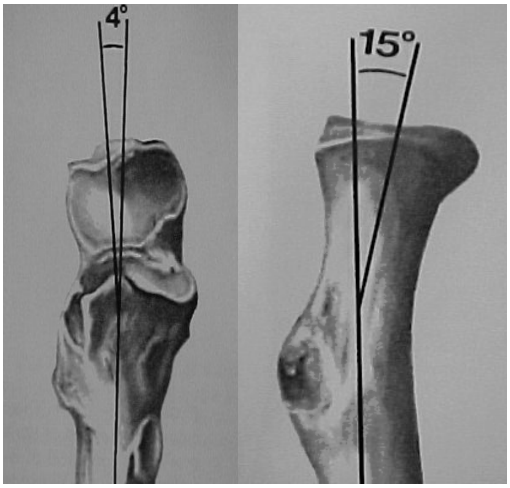

Fig. 3. A, Angular orientation of proximal ulna in anteroposterior projection. B, Angular orientation of the radial head and neck with respect to the shaft of the radius.

II. Capsuloligamentous anatomy

- anterior, posterior capsule, MCL, LCL complex

1. Capsule[6)]

intraarticular pressure - lowest at 70^{o} to 80^{o} of flexion
capacity - 25 to 30 mL at 80^{o} of flexion

2. Medial collateral ligament - valgus stability[7-9)]

ant. bundle : primary static constraints
: taut after about 20^{o} to 30^{o} of flexion
post. bundle : lax until about 60^{o} of flexion
transverse ligament

3. Lateral collateral ligament complex : varus stability[9-10)]

radial collateral ligament
lateral ulnar collateral ligament : posterolateral stability
annular ligament
accessory collateral ligament

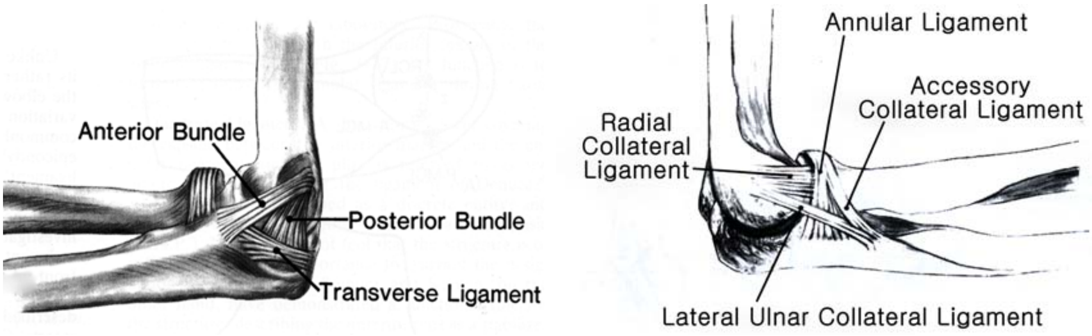

Fig. 4. Medial and lateral collateral ligament complex.

III. Muslces[2,3)]

- provide dynamic stabilization and protect static constraints
- 4 groups
  : elbow flexor, elbow extension, forearm flexor-pronators, forearm extensors
    1. Biceps : principal supinator of forearm
    2. Triceps : main elbow extensor
    3. Anconeus : minor role in elbow extension
       dynamic constraint to varus and posterolateral rotator instability

Elbow Biomechanics

➢ Elbow function
- link in the lever arm system
- fulcrum of the forearm lever
- loading-carrying joint

I. Kinematics

1. Flexion-Extension[11,12)] : hinge type
- normal ROM : 0^o - 140^o
- a range of 30^o to 130^o required for most activities of daily living
- axis of motion
  : in line with the anteroinferior aspect of the medial epicondyle, the center of the trochlea, and the center projection of the capitellum onto a parasagittal plane.
  : is oriented at approximately 3^o to 5^o of internal rotation in relation to the plane of the medial and lateral epicondyles and in 4^o to 8^o of valgus relative to the long axis of the humerus.

2. Pronation-Supination[13)]

- radiocapitellar joint & proximal radioulnar joint
- normal ROM : pronation 75°, supination 85°
- 50° of pronation and 50° supination required for most activities of daily living
- normal axis of forearm rotation
  : runs from the center of the radial head to the center of the distal ulna

3. Carrying angle

: formed by the long axis of the humerus and the long axis of the ulna and is most evident when the elbow is straight and the forearm is fully supinated.

- man (average : 10°), women (average : 13°)
- cubitus valgus : > 15°
- cubitus varus : < 5°

II. Osseous Stability

- congruent articulation of the ulnohumeral joint is responsible for as much as 50% of the stability of the elbow

1. Coronoid process[14-16)]

- key role in stabilization of the elbow

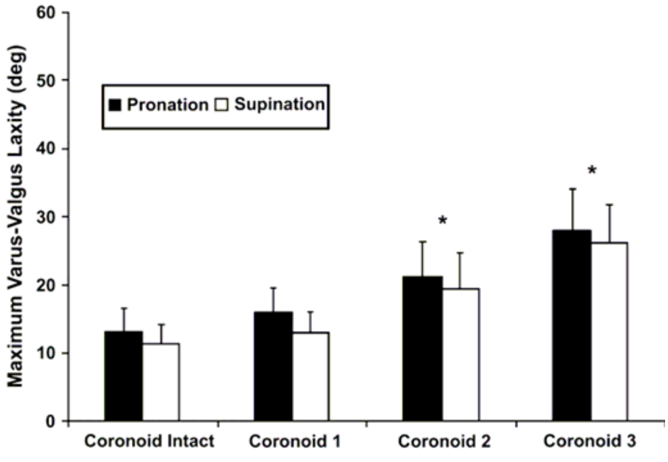

Fig. 5. Average maximum varus-valgus laxity after repair of collateral ligaments with intact coronoid, and simulated coronoid fractures. Coronoid 1 = 10% of bone removed from coronoid tip; coronoid 2 = 50% removed; coronoid 3 = 90% removed. There was significant laxity after 50% of the coronoid was removed.

- pathognomonic for an episode of elbow instability
- more than 50% involved fractures
  : significantly increase varus-valgus laxity, even in the setting of repaired collateral ligament.

2. Olecranon[17,18]

- 80% of the olecranon could be removed without compromising elbow stability.
- but significant increases in joint pressure with excision of 50% of the olecranon, which over time may contribute to elbow pain and arthritis.

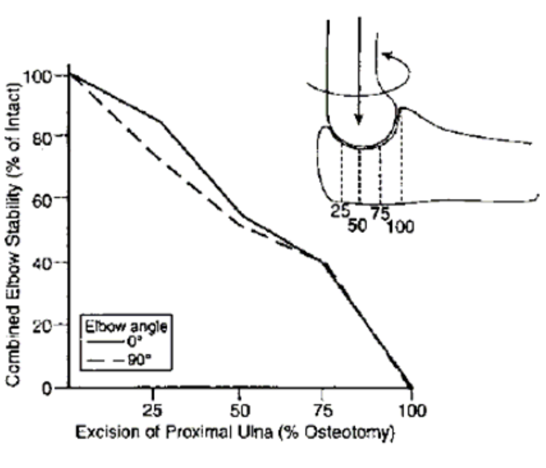

Fig. 6. Successive resection of the proximal ulna showed a linear decrease in elbow stability in both full extension and 90° flexion.

3. Proximal radius[2,19]

- important secondary valgus stabilizer of the elbow
- radial head is responsible for approximately 30% of valgus stability
- become more important for valgus stability in the presence of MCL deficiency
- radial head excision increases varus-valgus laxity, regardless of whether the collateral ligaments are intact.

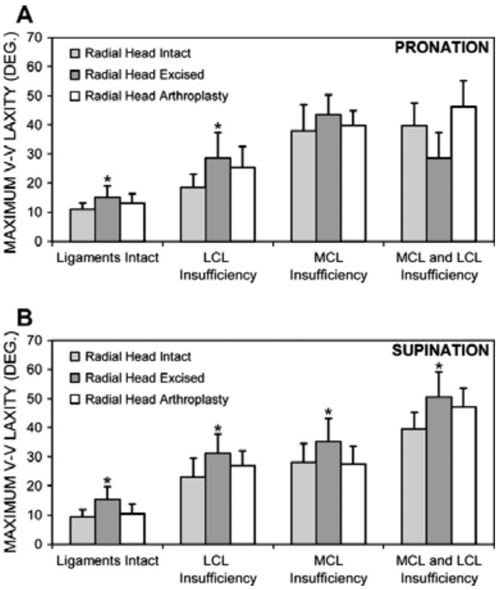

Fig. 7. Maximum varus-valgus laxity plotted for intact and insufficient collateral ligaments with radial head intact, excised, and replaced. Significant increases in laxity after radial head excision are denoted by asterisks.

III. Soft Tissue Stability

1. Medial collateral ligament complex[3,7-9]

- consists of two main components, neither of which originates on the axis of rotation of the elbow.
- anterior bundle has been further subdivided into an anterior band that is taut in extension and a posterior band that is taut in flexion.

2. Lateral collateral ligament complex[3,9,10]

- LCL lying on the axis of rotation will assume a rather uniform tension, regardless of elbow motion
- lateral ulnar collateral ligament
  : insert on the ulna and help to stabilize the lateral ulnohumeral joint
  : major component on the varus and posterolateral rotatory stability
  : essential to control the pivot shift maneuver

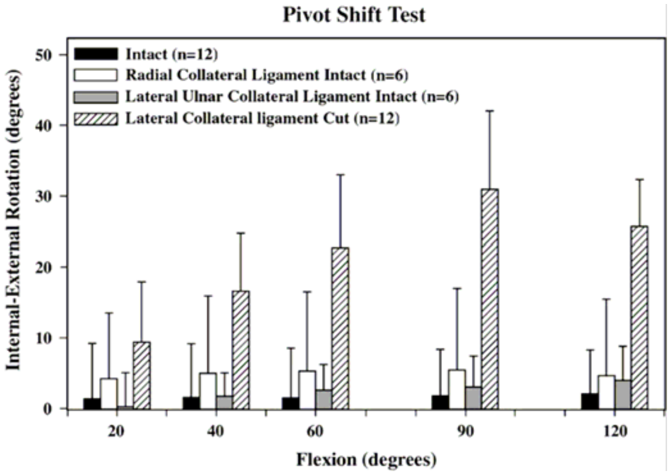

Fig. 8. Mean internal-external elbow rotation during the pivot shift test is plotted for the intact elbow and after sectioning components of lateral collateral ligament. The only significant difference occurred after sectioning of the complete LCL.

IV. Joint Forces[2,3,20]

- with extension and axial loading, the distribution of stress is 40% across the ulnohumeral joint and 60% across the radiohumeral joint.
- force transmission through the radial head
  : radial head forces were greatest from 0^{o} to 30^{o} flexion and always higher in pronation

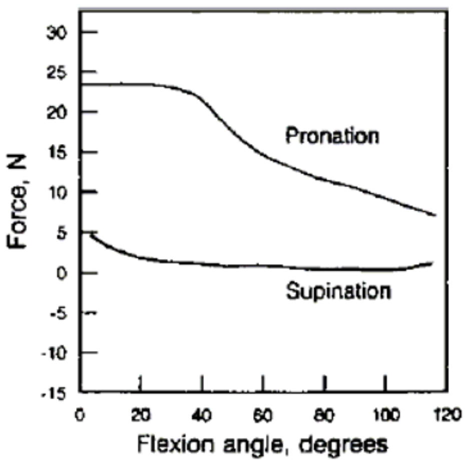

Fig. 9. Greater force transmission across the radial head with pronation, suggesting proximal migration of radial head with pronation.

- When the elbow is extended, the overall force on the ulnohumeral joint is more concentrated at the coronoid; as the elbow is flexed, the force moves toward the olecranon.

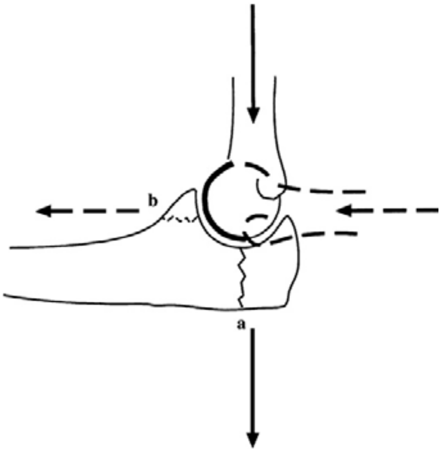

Fig. 10. Concentration of the force at the ulnohumeral joint varies with flexion and extension of the elbow. When the elbow is flexed at 90° (solid line), force is concentrated at the olecranon. When the elbow is extended (dashed line) the forced is concentrated at the coronoid. The olecranon fracture (a) and coronoid fracture (b) are shown.

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