

## Biomechanics of the elbow

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Elbow function,

- 1) link in the lever arm system
- 2) fulcrum of the forearm lever
- 3) load-carrying joint

### A. Kinematics

Trochoginglymoid joint

: 2 degrees of motion (flexion-extension, supination-pronation)

Articular component

- 1) trochlea, capitulum
- 2) upper end of the ulna
- 3) head of the radius

Three articulations: radiohumeral, ulnohumeral, radioulnar

#### (1) Flexion-Extension

Elbow joint motion : hinge type

Flexion axis

: helical motion of the flexion axis

: attributed to the obliquity of the trochlear groove along which the ulna moves

Amount of potential varus-valgus and axial laxity that occurs during elbow flexion

: 3-4 degrees

#### (2) Center of rotation

Locus of the instant center of rotation

: area 2 to 3 mm in diameter at the center of the trochlea

Axis of motion in flexion and extension

: Does not change during flexion-extension (Youm and associate)

: Variations of up to 8 degrees in the position of the screw axis (Morrey and associate)

- 1) axis of rotation: internally rotates 3-8 degrees relative to the plane of the epicondyles.
- 2) In the coronal plane: a line perpendicular to the axis of rotation forms a proximally and laterally opening angle of 4 to 8 degrees with the long axis of the humerus.  
→ inspired the development of semiconstrained elbow replacement design

Center of rotation identified from external landmarks.

- In the sagittal plane,
  - 1) axis lies anterior to the midline of the humerus
  - 2) axis lies on a line that is collinear with anterior cortex of the distal humerus
- In the coronal orientation
  - 1) defined by the plane of the posterior cortex of the distal humerus.  
: Axis emerges from the center of the projected center of the capitellum and from the anteroinferior aspect of the medial epicondyle.

### (3) Forearm rotation

Radiohumeral joint

- : Common transverse axis with the elbow joint
- : Coincides with the ulnohumeral axis during flexion-extension motion.

Radius rotates around the ulna

- : Allowing for forearm rotation or supination-pronation.

Longitudinal axis of the forearm

- : Convex head of radius at proximal radioulnar joint - convex articular surface of ulna at the dist radioulnar joint.

Axis is oblique, rotation is independent of elbow position.

Axis of forearm rotation (Mori)

- : Passing through the attachment of the interosseous membrane at the ulna in the distal fourth of the forearm

Less than 10% angulation of either the radius or the ulna

- : causes no functionally significant loss of forearm rotation.

Radius has been shown to migrate proximally with pronation.

### (4) Carrying angle

Defined as that formed by the long axis of the humerus and the long axis of the ulna.

Men: averages 10 to 15 degrees (Women, 15 to 20 degrees)

Definition 1: the carrying angle is the acute angle formed by the long axis of the humerus as the long axis of the ulna projects on the plane containing the humerus.

Definition 2: the carrying angle is described as the acute angle formed by the long axis of the ulna and the projection of the long axis of the humerus onto the plane of ulna.

Definition 3: the carrying angle is defined analytically as the abduction-adduction angle of the ulna with respect to the humerus when Eulerian angles are being used to describe arm motion.

### (5) Restriction of motion

Elbow flexion range

: from 0 degree or slightly hyperextended to about 150 degrees in flexion.

Forearm rotation

: from 75 degrees (pronation) to 85 degrees (supination).

Cartilage of the trochlea

: arc of about 320 degrees

Sigmoid notch

: arc of about 180 degrees

Arc of the radial head depression

: 40 degrees, which articulates with the capitulum, presenting an angle of 180 degrees.

The factors limiting joint extension (Kapandji)

: impact of the olecranon process on the olecranon fossa

: tension of the anterior ligament and the flexor muscles

: tautness of the anterior bundle of the medial collateral ligament as serving as a check to extension

The factors limiting passive flexion

: impaction of the radial head against the radial fossa

: impact of the coronoid process against coronoid fossa

: tension from the capsules and triceps

: Anterior muscle bulk of the arm and forearm, along with contraction of the triceps prevent active flexion beyond 145 degrees.

For pronation and supination (Braune and Flugel)

: passive resistance of the stretched antagonist muscle restricts the excursion range more than that of the ligamentous structures.

Quadratus ligament (Spinner and Kaplan)

: provide some static constraint to forearm rotation.

Impingement of tissue restrains pronation,

: especially by the flexor pollicis longus, which is forced against the deep finger flexor.

Entire range of active excursion in an intact arm is about 150 degrees.

### **(6) Capacity and Contact Area of the Elbow Joint**

Capacity: average about 25ml (maximum capacity at about 80 degrees of flexion)

The upper rim of the radial head made no contact at all

At the humeroulnar joint, the articular surfaces were always in contact during some phases of movement.

Radiocapitellar joint, contact during flexion under no externally applied load

Contact areas of the elbow occur at four "facets"

: two at the coronoid, two at the olecranon

## **B. Elbow Stability**

The Static soft tissue stabilizers

: include the collateral ligament complexes and the anterior capsule.

The lateral collateral ligament originates from the lateral condyle at a point through which the axis of rotation passes.

The medial collateral ligament has two discrete components,

neither of which originates at a site that lies on the axis of rotation

: Anterior portion of anterior bundle is taut in extension the converse is true for posterior fibers of anterior bundle.

: Different parts of the medial collateral ligament complex will be taut at different positions of elbow flexion.

The lateral collateral ligament lying on the axis of rotation will assume a rather uniform tension, regardless of elbow position.

Lateral ulnar collateral ligament

: inserts on the ulna and, as such, helps to stabilize the lateral ulnohumeral joint

: essential to control the pivot shift maneuver (O'Driscoll and associates)

Lateral ligament complex

: the major component in the varus and rotatory stability is the structure termed the lateral ulnar collateral ligament

: lateral complex is a major stabilizer of elbow joint and functions with or without the radial head

: lateral complex is also an important stabilizer in forced varus and external rotation.

### Articular and Ligamentous Interaction

In extension,

- : the anterior capsule provides about 70% of soft tissue restraint to distraction, whereas the medial collaeral ligament assumes this function at 90 degrees of flexion.

Varus stress

- : In extension, checked by the joint articulation (55 percent) and soft tissue, lat collateral ligament, capsule
- : In flexion, the articulation provides 75 percent of varus stability.

Valgus stress

- : In extension, equally divided between the medial collateral ligament, the capsule, and the joint surface.
- : In flexion, the capsular contribution is assumed by the medial collateral ligament, which is the primary stabilizer (54 percent) to valgus stress at this portion.

Anterior portion of medial collateral ligament provides virtually all of the structure's functional contribution.

- : The radial head is a secondary stabilizer for resisting valgus stress, whereas the medial collateral ligament is the primary stabilizer against valgus force.

Contribution of the articular geometry

- : Valgus stress, both in extension and at 90 degrees of flexion, was primarily (75~85%) resisted by the proximal half of the sigmoid notch, whereas varus stress was resisted primarily by the distal half, or the coronoid portion of the articulation, both in extension(67%) and in flexion(60%).
- : Serial portions of the coronoid are removed the elbow becomes progressively more unstable. This is especially true if the radial head has been resected. As little as 25% resection causes elbow subluxation at about 70 degrees of flexion.

### C. Force Across Elbow Joint

#### Distributive forces on the articular surfaces

With the elbow extended and axially loaded, distribution of stress across the joint

- : approximately 40% across the ulnohumeral joint and 60% across the radiohumeral joint

With the elbow in valgus realignment,

- : only 12% of the axial load is transmitted through the proximal end of the ulna,

With the elbow in varus alignment,

: 94% of the axial force is transmitted to proximal ulna

The greatest force was transmitted across the radiohumeral joint in full extension

When elbow flexion

: inward rotation of the forearm against resistance imposes large torque to the joint

: twice body weight tension into the medial collateral ligament and three times body weight at the radiohumeral joint

The greatest force on the radial head occurs with the forearm in pronation

Significant force with daily activities that not only occur at the radiohumeral and ulnohumeral joints but also are generated in the collateral ligaments (Nicol).

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