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

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 instanat center of rotation
  : area 2 to 3 mm in diameter at the center of the trochla
- Axis of motion in flexion and extension

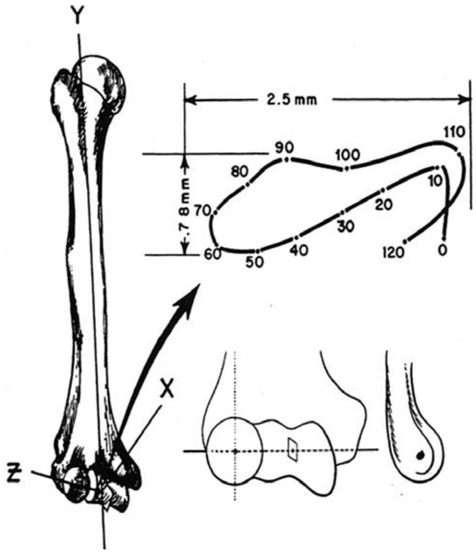

Fig. 1. configuration and dimensions of the locus of the instant center of rotation of the elbow.

: Does not change during flexion-extention (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, idefined 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 anterioinferior 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 whit 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 angleis described as the acute angle formed by the long axis of theulna 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 whit 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 capitullum, presenting an angle of 180 degree.
- 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.
- Quadrate 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 25 ml (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?

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

Table 1. Percent contribution of restraining varus-valgus displacement

Position	Component	Varus	Valgus
Extension	MCL*	—	30
	LCL†	15	—
	Capsule	30	40
	Articulation	55	30
Flexion	MCL*	—	55
	LCL†	10	—
	Articulation	75	35

*MCL = medial collateral ligament complex.
†LCL = lateral collateral ligament complex.

- 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 constribution is assumed by the medial collateral ligament, which is the primary stabilizer (54%) 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 radical head has been resected. As little as 25% resection causes elbow subluxation at about 70 dgrees of flexion.

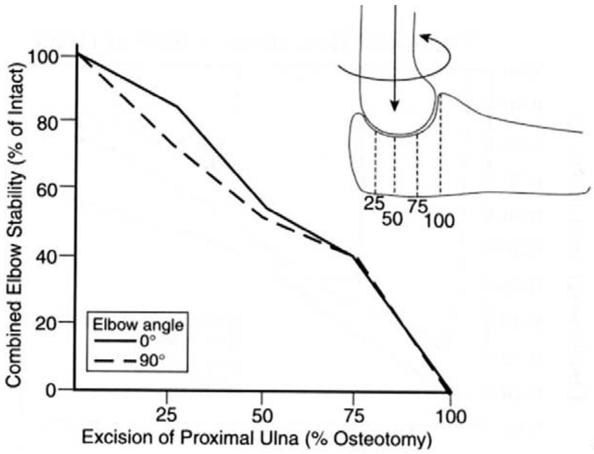

Fig. 2. Contribution of articular geometry

Force Across Elbow Joint

Distributive forces on the articular surfaces

- With the elbow extended and axaially loaded, distribution of stress across the joint
  : 40% across the ulnohumeral joint and 60% across th radiohumeral joint
- With the elbow in valgus realignment,
  : 12%t 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 & ulnohumeral joints but also are generated in the collateral ligaments (Nicol).

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