13 Biomechanics of the Elbow

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13.1 Kinematics

The normal elbow range of motion (ROM) goes from 0º to 140º for flexion/extension and 80º/90º for pronation/supination, but the functional ROM for most daily activities is 30º to 130º for flexion/extension and 50º/50º for pronation/supination. Daily activities considered are to bring the hand to the face, to drink, eat, dress, perform hygiene with elbow flexion/pronation and throw and push with elbow extension/supination [1]. There is a valgus alignment called carrying angle, which measures 10 to 15º in men and 15º to 20º in women [2].

Variation of flexion and extension axis throughout ROM is described as the screw displacement axis (SDA). The flexion axis is oriented at 3º to 5º of internal rotation to the medial and lateral epicondyles plane and 4º to 8º valgus to the humerus long axis. The axis of rotation planned on the surface of the condyles lean to be smaller on the medial side than on the lateral side, varying from 5.67° to 17.23° (mean, 11.02°) in the axial plane, 7.80° to 19.4° (mean, 11.95°) in the coronal plane. The center of rotation changes during the elbow's movement, recent literature has presented that the elbow joint does not function as a simple hinge joint since its axis translates and rotate. The lateral condyle demonstrated a counterclockwise circular pattern (Fig. 13.1), the axis of rotation changes lightly ulnar and volar in supination, radial and dorsal in pronation and the Radius, as well, moves proximally with pronation and distally with supination [3, 4].

While the congruency of the elbow articular surfaces is perfect, the compression and weight-bearing loads are not equally distributed. Elbow is stilted by the position of the forearm,: in elbow

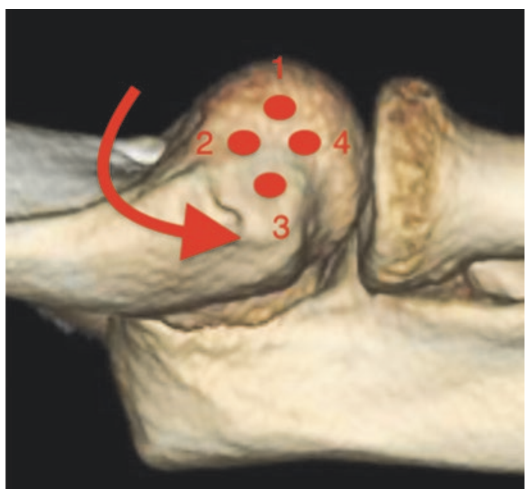

Fig. 13.1 Axis of rotation on the lateral condyle with counterclockwise pattern. (1) 30°, (2) 60°, (3) 90°, (4) 135°

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extension the Radial Head has no pressure against Humeral Capitulum, supination decreases the contact, for as much as pronation increases [2]. The contact area of the ulna against the trochlea is on the medial facet of the trochlear notch for any elbow motion [3].

13.2 Elbow Stability

Elbow stability is provided by static stabilizers and muscle dynamic stabilizers. The constraints are the ulnohumeral articulation, anterior and posterior bundle of Medial Collateral Ligament (MCL), Lateral Collateral Ligament LCL complex, radiocapitellar articulation, common flexor tendons, common extensor tendons, and the joint capsule [5]. The elbow becomes progressively unstable when each of the bony structures are removed, especially the radial head and coronoid process [6]. Coronoid Fractures Type III with more than 50% of the coronoid compromised increase results in varus-valgus laxity, even with normal collateral ligaments [7]. The coronoid is extremely important in posterolateral stability in association with the radial head. With 30% of the coronoid height loss and without radial head, the ulnohumeral joint dislocates, and the stability can just be restored with replacement of the radial head [4]. On the other hand, fractures of less than 80% of the olecranon can be removed without compromising elbow stability [8].

The anterior capsule supplies 70% of the soft tissue restraint to distraction, while the medial collateral ligament has this function at 90° of flexion. Varus stress is tested in extension equally by the articulation, lateral collateral ligament, and capsule (Fig. 13.2), while valgus is equally divided among the medial collateral ligament, articulation, and capsule (Fig. 13.3). In flexion, the articulation supplies 75% of the varus stability and in valgus the medial collateral ligament supplies 54% of stability [9].

Forearm rotation is important for elbow stability. With passive flexion, the MCL tear is more stable in supination, while the LCL absence is more stable in pronation. Literature has also

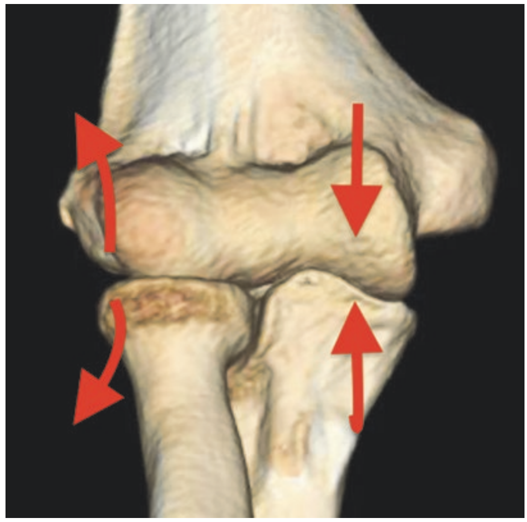

Fig. 13.2 Varus stress (The osseous stability provides the majority of joint stability; while the LCL complex holds out 10% of varus stress)

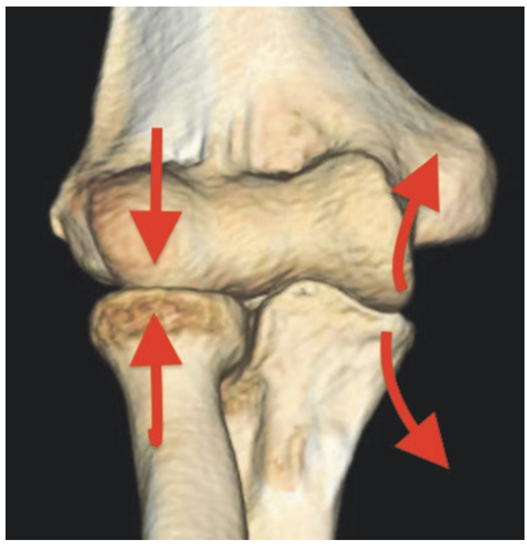

Fig. 13.3 Valgus stress (The MCL is a restraint to valgus stress and the radial head provides a secondary restraint)

shown that the elbow is more stable in supination in coronoid fractures with more than 50% of the coronoid [7].

The anterior bundle of the medial collateral ligament (A-MCL) is the main static stabilizer of the elbow in valgus stress, and this bundle is taut in 0 to 85°, while the posterior band is taut from 55° to 140°. Morrey et al. studied the muscle contributions to dynamic valgus stability of the elbow simulating, in a cadaver model, the contraction of the biceps, brachialis, and triceps. They suggest that the elbow joint forces created by muscles subscribe to valgus stability in a deficient MCL. The flexor carpi ulnaris (FCU) is proposed as a contributor to dynamic valgus stability because the FCU position is in line with the medial ulnar collateral ligament and fine wire electromyographic studies demonstrate that pitchers' players with symptomatic valgus instability have reduced flexor–pronator muscle action [1].

13.3 Joint Forces

The compressive forces at the elbow are significant that some doctors have affirmed that it is "wrong to think of the elbow as non-weightbearing" [10]. Loads are distributed about 43% across at the ulnohumeral joint and 57% at radiocapitellar joint. Force transfer at the radiocapitellar joint is greatest between 0 and 30° of flexion and in pronation position. When the elbow is extended, the higher part of force across the ulnohumeral joint is intent at the coronoid; while when the elbow is flexed, is on the Olecranon (Fig. 13.4) [4, 11].

The compression forces on the elbow have been determined when maximal isometric elbow flexion and extension happens. The largest forces occur during isometric elbow flexion in near full extension, but compressive forces from isometric extension contraction are reduced in more extended positions and largest in flexed positions.

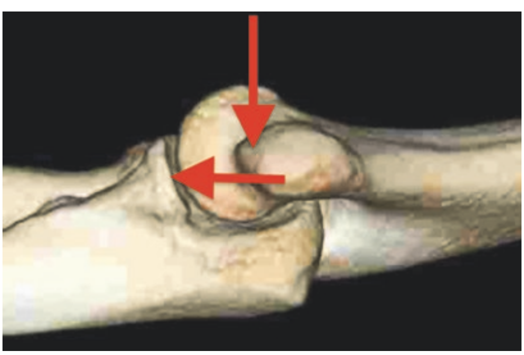

Fig. 13.4 In an extended joint position, forces are driven more anteriorly

The applied muscle action force is assumed to be perpendicular to the forearm. The muscle and joint reaction forces change lightly with the shift of the muscle action. Nonetheless, the orientation of the resultant joint force is responsive to changes in the muscle force line. The guidance of the joint force goes from the central part of the trochlea toward to the rim with the direction of muscle action. This is particularly for joint forces in the trochlea where the forearm axis changes with the elbow joint flexion angle [12]. Considerations about forearm rotation or elbow pronation and supination equilibrium, demonstrate that pronator teres had rotation moment counter the biceps tension. The pronator teres force must be relaxed to maintain the equilibrium, rather than sum to the humeroradial joint tension [10, 13].

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