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The load on the radius and ulna in different positions of the wrist and forearm

A cadaver study

Nine cadaver specimens were tested with load cells attached to both sides of an osteotomy of the distal radius and ulna. The load along the radius relative to the ulna could be measured in different positions of the wrist and forearm. There was less load along the radius in a position of wrist flexion, ulnar deviation and full forearm pronation.

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Flexion and ulnar deviation of the wrist in Colles' fracture is a commonly accepted posture to minimize dislocation forces. The position of forearm rotation during fixation is still in question (Cotton 1900, Lambrinudi 1938, Pool 1973, Sarmiento 1965, Sarmiento et al. 1980, Wahlström 1982), and the best position of forearm rotation during reduction has been discussed (Böhler 1953, Charnley 1963, Milch 1964).

The longitudinal load along the radius relative to the ulna must be of importance both for reduction and for the subsequent stability of the radius fracture. We have constructed a model to measure the load along the radius and ulna in different wrist and forearm rotation positions in order to find a forearm and wrist posture where the load along the radius is minimal.

Material and methods

Nine arm specimens including the elbow were used. The specimens were frozen 4–8 days after death. The mean age was 68 (49–80) years.

There were four left and five right arms in eight females and one male. Each specimen was radiographed with AP and lateral views according to Epner et al. (1982) and Palmer et al. (1982) to exclude any abnormality.

Method

The specimens were amputated at the mid-upper-arm level and all of them were prepared in exactly the same way (Figure 1). Five cm of the distal humeral end, including the bone marrow, was cleaned of soft tissue. A screw-bolt was inserted into the marrow cavity of the humerus and fixed with bone-cement (methylmethacrylate). This end of the arm was finally attached to a table. The elbow joint, including the surrounding soft tissues, was kept intact and was locked in 90° of flexion, using two Steinman pins between the ulna and the humerus. The forearm was then denuded of soft tissue, except for around the interosseous membrane, where some tissue was left to prevent dryness. The distal 8 cm of the five wrist tendons, including the bony insertion, were kept intact to be used for weight attachment. The extensor carpi radialis longus and brevis tendons (ECRL, ECRB) were used as one tendon, and the flexor carpi radialis tendon (FCR), flexor carpi ulnaris tendon (FCU) and extensor carpi ulnaris tendon (ECU) as separate tendons. To measure the load on the distal ulna and radius, a precision scale (load cells model 3168) (Elbow Associates Inc.), weighing 0.5 kg, was attached to each bone. Two strain gauge transducers (indicator model 7530) were connected to each of the load cells. The load cells were then mounted onto the bones, one on the ulna and one on the radius, as far distally as possible. Four screws were used for each load cell, and to get full stabilization these screws were secured with

Table 1. Mean relative load on the ulna and radius in different wrist and forearm positions, including basic statistics on the radius figures. The percentage radius load figures have been tested statistically according to Student's t-test as paired samples. SD = Standard deviation. SE = Standard error of the mean. Values for each wrist and forearm position were calculated from nine specimens (n = 9)

Forearm position	Wrist position	Mean relative ulna load (%)	Mean relative radius load (%)	SD	SE	Significance*
Neutral	Neutral	15	85	13	9	–
Neutral	15° radial dev.	9	91	12	8	Yes
Neutral	15° uln.dev.	20	80	12	8	No
Neutral	25° uln.dev.	24	76	16	11	Yes
Neutral	25° flexion	8	92	9	6	Yes
Neutral	50° flexion	14	86	11	7	No
Neutral	25° extension	15	85	15	10	No
Neutral	50° extension	13	87	13	9	No
50° sup	Neutral	15	85	13	9	No
75° sup	Neutral	14	86	12	8	No
50° pron	Neutral	19	81	13	8	No
75° pron	Neutral	37	63	16	11	Yes

* Significance = Significant difference ($p < 0.05$) where the measurements of each forearm and wrist position have been tested against the measurements of both the wrist and forearm in a neutral position.

bone cement. The bones were osteotomized 2–3 cm proximal to the radio-carpal joint between the two pairs of screws so that the load cells were attached to each side of the osteotomy. The specimen was then mounted on the table and one pin was inserted longitudinally into the third metacarpal, leaving a good distance of the pin outside the hand attached to the motion frame. This pin was an important part of the motion frame, so that every motion was reproducible. The specimen could now be moved in ulnar and radial deviation, flexion and extension, supination and pronation. Wrist motion was controlled by the metacarpal pin which could be locked in the desired position in the motion frame. Forearm motion was controlled and guided by the load cells which could be held in the desired forearm position with a stopper.

The transducers were calibrated to zero with the load cells attached to the forearm bones and with the wrist and forearm in a neutral position. Calibrated weights of 0.5 kg were attached to each of the four tendons throughout the experiment and the load was measured in different wrist and forearm positions (left column Table 1). In each position two measurements were made and the mean value was calculated. The results were expressed as mean relative load to the radius and ulna in per cent. Between each change of position the transducers were calibrated. Five specimens were also tested with up to 9 kg loads and two specimens were tested in a combined position of 75° pronation – 25° volar flexion – 25° ulnar deviation, and also in 75° supination – 25° dorsal extension – 15° radial deviation.

The percentage figures showing the relative load of the radius have been tested statistically as paired samples, using Student's *t*-test.

Results

Wrist flexion compared to wrist extension resulted in no significant load difference. In 15° and 25° ulnar deviation, there was less load along the radius compared to radial deviation. Moderate forearm rotation did not cause any load difference. Maximal pronation, however, gave a marked decrease of the load along the radius compared to maximal supination. More weights attached to the tendons did not change the relative loads. In the two specimens measured with the wrist in the 75° pronation, 25° wrist flexion and 25° ulnar deviation position, the load transmission was 25 per cent resp. 34 per cent along the radius and 75 per cent resp. 66 per cent along the ulna. When the same two specimens were tested in 75° supination, 25° wrist extension and 15° radial deviation position, all the load was transmitted along the radius. One specimen had an ulna plus of 2 mm and two specimens had an ulna minus of 2 mm. These specimens were responsible for the high range. To exclude the possible effect of this anatomical variation, the results were tested statistically as paired samples.

Discussion

In 1982, both Palmer et al. and Epner et al. reported that the length of the radius relative to the ulna changes with forearm rotation, and

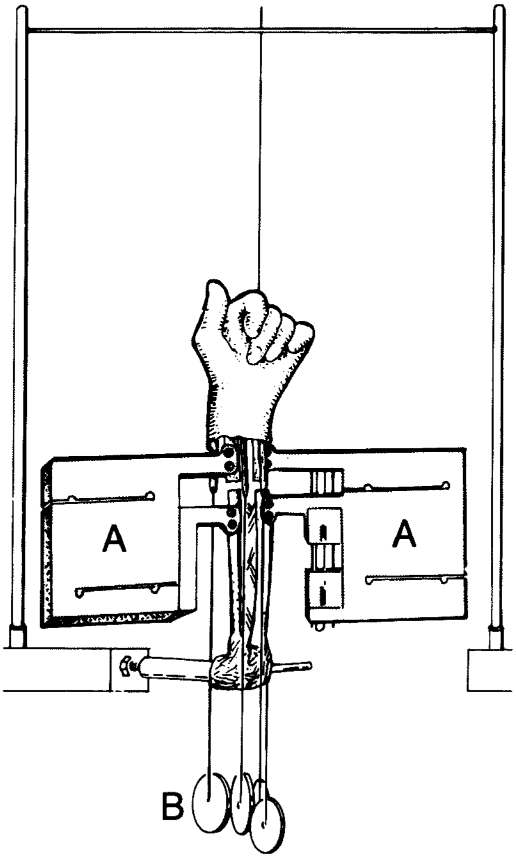

Figure 1. One-arm cadaver specimen mounted on a table including a motion frame. Two load cells (A) are attached to both sides of an osteotomy of the ulna and radius, respectively, and four 0.5 kg weights (B) are attached to the wrist tendons (ECRL + ECRB, ECU, FCR and FCU). Each load cell is connected to a strain gauge transducer. The wrist could be moved in ulnar and radial deviation, flexion and extension, and the forearm in supination and pronation.

also to some extent with wrist motion. According to these authors, pronation gives a relative lengthening of the ulna and supination a relative shortening. The change of the relative length of the ulna in forearm rotation might be the explanation for the variation in the load along the radius observed in our experiments. Our results correspond well with Palmer and Epner's observations with less load along the radius in pronation.

The load we have measured is the result of different forces acting in different directions. In a Colles' fracture the direction of these forces might also be of great importance but could not be measured with this equipment.

According to our results, reduction of the dislocated radius fragment ought to be easier in ulnar deviation and full pronation when there is less load along the radius. This also favours immobilization of the fracture with the wrist in ulnar deviation and the forearm in full pronation. The dynamic muscle and tendon forces which may influence the distal radius fragment must, however, also be taken into consideration (Milch 1964, Sarmiento 1965, Sarmiento et al. 1980, Wahlström 1982), but these forces could not be simulated in this experimental model.

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