THE MECHANISM OF ROTATION AT THE FIRST CARPO-METACARPAL JOINT

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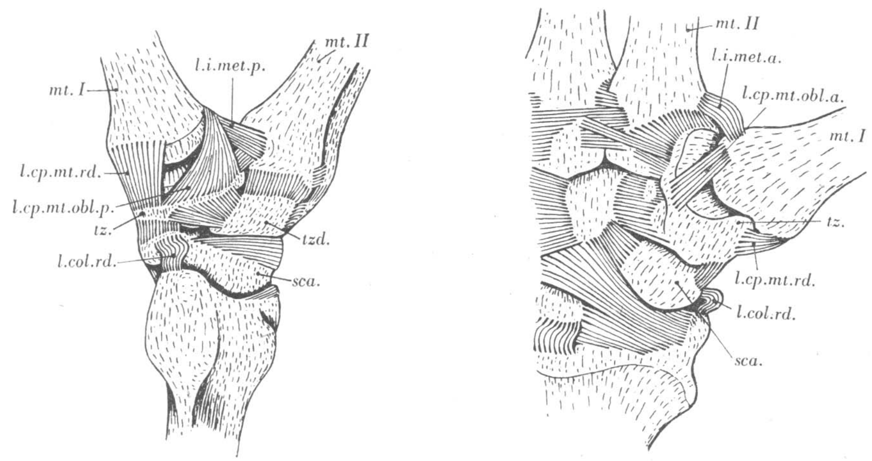
The various movements involved in opposition and reposition of the thumb have been carefully studied by several anatomists, and in particular by du Bois-Reymond (1895, 1896 *a*, *b*), who has given a detailed account of the joints involved and a full mathematical analysis of the mechanism of the saddle-joint. We shall follow this author in describing opposition as a combination of movements of the carpo-metacarpal, metacarpo-phalangeal and interphalangeal joints, but particular attention will be paid to the mechanism of rotation of the metacarpal bone about its own long axis.



(*a*) (*b*)

Fig. 1. Carpo-metacarpal joint of the thumb (*a*) in dorsal and radial view, and (*b*) in volar view.

Key to lettering: *l.col.rd.* radial collateral ligament of wrist-joint. *l.cp.mt.obl.a.* anterior oblique ligament of carpo-metacarpal joint. *l.cp.mt.obl.p.* posterior oblique ligament of carpo-metacarpal joint. *l.cp.mt.rd.* radial ligament of carpo-metacarpal joint. *l.i.met.a.* anterior inter-metacarpal ligament. *l.i.met.p.* posterior inter-metacarpal ligament. *mt.* metacarpal. *sca.* scaphoid. *tz.* trapezium. *tzd.* trapezoid.

If the thumb is circumducted the distal end of the metacarpal is found to move through a path which approximates to a circle, and a central position of the metacarpal can then be taken as a starting point for the description of the movements. The use of the central position as a starting point, rather than the anatomical position, greatly simplifies the account of the movements. These movements are, following the ordinary English usage, extension in the radial direction, flexion in the ulnar direction, abduction in the volar direction and adduction in the dorsal direction. At the starting point the central parts of the joint surfaces on the trapezium and metacarpal are in contact with each other, while the more peripheral parts are separated from each other by a slight gap occupied partly by synovial fluid and partly by fibro-fatty synovial folds which are well developed in this joint. As each of the four movements is carried out one surface rolls on the other so that the area of contact passes nearer the periphery of the joint, while with the rolling there is combined a very limited gliding movement (du Bois-Reymond, 1895). The movements of flexion and extension occur approximately in the plane passing through the greatest concavity of the metacarpal and the corresponding convexity of the trapezium; the movements of abduction and adduction in the plane of the greatest concavity of the trapezium.

Following his mathematical analysis of the saddle-joint du Bois-Reymond likened the articular surfaces of the joint to the region of contact of two links of a chain, so that the area of contact must necessarily be restricted, and some degree of rotation must be present. This rotation can be demonstrated, following the method of Fick (1911) and others, by using the basal phalanx as an indicator of the movement of the metacarpal bone, but care must be exercised in this use of the phalanx, for abduction, adduction and rotation, as well as flexion and extension, may occur at the metacarpo-phalangeal joint and give a false impression of movement of the metacarpal bone. These phalangeal movements have been described in detail by du Bois-Reymond (1896*b*), and I am able to confirm his findings, though their existence was denied later by Fick. When the phalanx is fully flexed the angle it makes with the metacarpal varies greatly in different individuals, but the phalanx always faces the ulnar direction so that the plane of flexion corresponds closely to the plane of greatest concavity of the metacarpal bone at the carpo-metacarpal joint.

If, with the muscles relaxed, the phalanx is used as a lever to rotate the metacarpal bone about its own long axis, or alternatively, if the metacarpal is held rigidly while the trapezium is moved by pronating and supinating the forearm (an action which most individuals find rather easier to carry out), it can be demonstrated that passive rotation of about 45° is permitted at the carpo-metacarpal joint without the use of undue force. If the carpo-metacarpal joint is but slightly flexed and extended the whole movement is a simple one through the plane of greatest concavity of the metacarpal. But towards the end of flexion there is a sudden swinging of the phalanx towards the palm, indicating an axial rotation (in the sense of pronation) of the metacarpal bone through about 30°, and at the same time the capability of passive rotation disappears, so that when the metacarpal is forced into the fully flexed position it is at the same time fully rotated. Any attempt to undo the rotation leads immediately to some degree of extension. Similarly, towards the end of extension there is usually an axial rotation of the metacarpal in the opposite direction, but of about 15° only. So we find that the metacarpal can be rotated passively while it is near the centre of its range of movement, but that towards either limit in the plane discussed it undergoes a forced axial rotation in one direction or the other. Du Bois-Reymond (1896*b*) has worked out the amounts of this rotation associated with the whole perimeter of circumduction, but these movements are more difficult to understand than the simple flexion and extension considered above, since they require for their description a use of spherical trigonometry.

It has been seen that axial rotation occurs during passive movement with the muscles relaxed, which suggests that the causation is not directly muscular. A ligamentous preparation confirms this. When the metacarpal is near its central position in such a preparation all ligaments are slack and the joint allows a wide range of axial rotation, but towards the extremes of flexion and extension the metacarpal rotates just as in the living hand. On removing the rather dense connective tissue surrounding the joint three strong ligaments are seen, for which I propose the names radial, anterior oblique and posterior oblique carpo-metacarpal ligaments. The first is a broad band from the radial side of the trapezium to the base of the metacarpal, the other two arise from the anterior and posterior surfaces of the trapezium, and converge to be inserted near each other on a bony elevation of the ulnar side of the base of the metacarpal. A weak anterior and a strong posterior inter-metacarpal ligament unite the first and second metacarpal bones. Besides these there may be some accessory bands, but I have found them inconstant.

When the joint is near its mid-position all the ligaments are slack, so that circumduction and axial rotation in either direction are allowed, but when the joint is flexed the posterior oblique ligament, assisted by the posterior intermetacarpal ligament, becomes taut, and pulling on the ulnar side of the base of the metacarpal bone forces it to rotate. Similarly, when the joint is extended the anterior oblique ligament causes axial rotation in the opposite direction. Cutting the ligaments destroys the mechanism. Abduction also leads to a tightening of the posterior oblique ligament and to an enforced rotation. In the living hand the muscles are of course responsible for the movements, but the axial rotation is determined by the ligamentous arrangement.

That these important ligaments have remained so long unknown, in spite of the interest of clinicians and anatomists in the movements of opposition, is, I believe, primarily due to the lack of a clear understanding of the nature of ligamentous tissue. The quadrate radio-ulnar ligament and the capsules of most joints are composed of dense connective tissue, while, on the other hand, the cruciate or collateral ligaments of the knee or the oblique ligaments of the carpo-metacarpal joint of the thumb are built essentially of straight fibre bundles giving a much less extensible tissue. It may well be that these two kinds of tissue, the one similar to fascia or adventitial coats, and the other to tendons or aponeuroses, may be found to grade into one another, but for practical purposes they are quite distinct: the one is teased away by dissection while the other adopts a polished appearance as the fibrous tissue surrounding it is removed and the direction of the fibre bundles becomes clear. In the carpo-metacarpal joint of the thumb Fick's classical drawing is of the dense connective tissue surrounding the joint, not of the straight-fibred ligaments, but it is drawn and coloured as if it were of the same nature as the inter-metacarpal ligaments.

Moreover, our conception of the function of ligaments may need revision. It is usual to describe many ligaments as preventing excessive movement, and to think of them as slack throughout the greater part of the range of movement, but as tightening suddenly as the end of the range is approached and so limiting the movement. The anterior and posterior cruciate ligaments of the knee joint, for instance, have been said to limit extension and flexion respectively, and the anterior and posterior radio-carpal ligaments have been assigned similar functions. On the other hand some ligaments, notably the annular ligament of the elbow and the transverse ligament of the atlas, have always been considered as guiding rather than as limiting movements and as remaining taut over a long range of movement rather than as suddenly becoming taut as the limits of movement are reached. At the same time the former conception has often been questioned, notably by Partridge (1924), who believed the ligaments to be incapable of taking the sudden strains which would be involved in checking movements, so that she supposed them to be rather of the nature of sensory organs for the reflex activity of the muscles. Even the importance of ligaments in the mechanism of the body has increasingly been questioned. For instance, in the support of the arches of the foot most authors have followed Keith (1929) in ascribing the greater part of the work to muscles.

Yet Jones (1941) has shown recently that even when the arches of the foot are subjected to great loads the muscles may be quite relaxed. The truth seems to be that many ligaments have the dual function of restraining and of guiding movements; for example, the anterior and posterior cruciate ligaments of the knee are now known to act throughout the movement of the joint, so as to regulate the relative position of the femur and tibia, though they also help to limit extension (Haines, 1941). Similarly, the ligaments of the carpo-metacarpal joint of the thumb seem to be arranged so as to determine an axial rotation of the metacarpal bone at the end of the movements of flexion and extension, though they act as limiting agents also.

It seems probable that a careful examination of the ligaments of other joints will show that they have guiding actions which modify the direction of the forces exerted by the muscles.

SUMMARY

1. Certain hitherto unrecognized ligaments associated with the first carpo-metacarpal articulation are described.

2. It is suggested that their function is mainly a guiding one, and that they are responsible for the axial rotation of the first metacarpal bone which takes place at the end of the movements of flexion and extension at the first carpo-metacarpal joint.

3. It is suggested that the ligaments of some other joints also have a regulating action on the bones concerned.

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