THE ANATOMY OF THE METACARPO-PHALANGEAL JOINTS, WITH OBSERVATIONS OF THE AETIOLOGY OF ULNAR DRIFT

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One hundred normal fingers were dissected and arthrographs obtained by injection of a chromopaque-gelatin mixture, allowing comparison between the radiographic and macroscopic configuration of the synovial capsule. Synovial recesses protruding from each side of every metacarpo-phalangeal joint were found in relation to the collateral ligaments and corresponding exactly with the site of radiological erosions. A group of bursae lying on the superficial aspect of collateral ligaments were also demonstrated. A rudimentary intra-articular meniscus was found. The results of examination of the insertions of the interossei showed differences from traditional descriptions.

The cause of rheumatoid deformity was suggested to be the rheumatoid process arising in the lateral recesses and lateral bursae, weakening the collateral ligaments, which give way in the directions of the deforming forces. These are derived from the long flexor tendons, which were shown to exert an ulnar and volar strain on the metacarpo-phalangeal joint of every finger during grip.

Textbook descriptions of the structure of the metacarpo-phalangeal joints seem to be inadequate when applied to certain surgical problems. The present study describes in some detail several features which have previously received only passing mention, and also adds new structural observations. The bearing of these findings on the aetiology of rheumatoid deformities and associated radiographic observations is discussed. Brewerton (1957) pointed out that the incidence of ulnar drift increases with increased duration of the disease; in the first five years 9 per cent of patients exhibit it, but in longer standing cases the incidence rises to 43 per cent. The ring and little fingers are affected more frequently and more severely than the index and middle fingers. In Brewerton’s series ulnar deviation was bilateral in forty-two patients; it affected the right hand only in twenty-four and the left only in sixteen. Ulnar drift is often combined with volar subluxation of the metacarpo-phalangeal joints and then the deformity becomes disabling.

EXISTING THEORIES EXPLAINING ULNAR DRIFT

Shape of the metacarpal heads—Hakstian and Tubiana (1967) noted that some degree of ulnar deviation was normal in the anatomical position; they calculated the average ulnar deviation of a finger relative to its metacarpal as follows: index 14 degrees; middle 12-9 degrees; ring 4 degrees; little finger 7-9 degrees. They pointed out that the metacarpal heads sloped towards the ulnar side, thus allowing greater ulnar than radial deviation, and that the dorsum of the ulnar side of the metacarpal head (“ulnar shoulder”) was more pronounced than the radial side, restricting movement of the ulnar collateral ligament, whereas the radial collateral ligament was free to glide over its side of the head. Smith and Kaplan (1967) further drew attention to Landsmeer’s observation (1955) that the ulnar collateral ligament was nearly parallel to the axis of the finger while the radial collateral ligament was more oblique, thus allowing greater ulnar deviation by “unwinding” (supination).

Gravity—The influence of gravity is often quoted as playing a part in the production of ulnar drift, but neither joint shape nor gravity can be a major cause since they do not act consistently in the direction of the deformity. Thumb pressure—The fingers may be pushed by the thumb into ulnar deviation during the power grip.

Interosseous spasm—Bunnell (1964) favoured interosseous spasm as a cause of ulnar deviation. Brewerton (1957), although finding intrinsic spasm commoner in the first three years of the disease, came to the conclusion that contractures might supervene and play a part. Some apparent confirmation of the view that spasm and contracture play a part is provided by the observation (Backhouse 1968) that ulnar deviation and rotation are stronger than radial deviation. Fearnley (1951) stated, however, that radial deviation of the index, middle and ring fingers was the stronger. Backhouse (1968) measured electromyographic activity of the interossei and found greater activity in the ulnar-sided interossei during normal movements, while equal stimuli produced ulnar deviation. However, he found a general decrease in activity in rheumatoid arthritis, and drew a comparison with the observation of deAndrade, Grant and Dixon (1965) that the quadriceps reflexly relaxes when the knee joint is distended.

Variations in the extensor apparatus—Backhouse (1968) believed that the detailed anatomy of the interossei was irrelevant in consideration of the natural history of the
deformity. He proposed the generalisation that the ulnar-sided interosseous had a strong connection through the transverse fibres to the extensor tendon, while the radial-sided interosseous sent most of its fibres in the line of the finger and had a smaller number of transverse fibres, producing a weak triangular area proximally in the hood. He suggested that a mass of synovium was prone to herniate itself through this area, thus impairing the abductor pull of the radial interosseous and deviating the extensor tendon to the ulnar side of the joint. Snorrason (1951) similarly suggested that ulnar dislocation of the extensor digitorum communis tendon was the cause of ulnar deviation. Fearnley (1951), however, thought the dislocation of the tendon was the result rather than the cause of the deformity. Brewerton (1957) concluded that tendon dislocation was rarely a primary cause of ulnar deviation but found it occurring as a complication in fifty out of eighty-two patients with ulnar drift, and a third of these patients suffered from ineffective finger extension. However, three of his patients clearly underwent spontaneous ulnar dislocation of the extensor digitorum communis tendon, resulting in immediate ulnar drift. This phenomenon has also been reported by Elson (1967) and may be a rare primary cause.

The pull of the flexor tendons—The flexor tendons are said to exert a volar and ulnar force on the flexor sheath, which acts in effect as a pulley. Smith, Juvinall, Bender and Pearson (1964) calculated the volar component of the force of the flexor tendon at the flexor sheath to be 3F and the ulnar component to be 2F, where F equals the force exerted at the finger tip: thus a pinch of 0.5 kilogram will produce a volar strain on the flexor sheath of 1.5 kilograms. The flexor sheath is attached to the palmar plate and proximal phalanx, and hence the force is transmitted to the collateral ligaments of the metacarpophalangeal joint (Fig. 7). The radial collateral ligament may be already stretched by the rheumatoid process (Smith and Kaplan 1967) or this force may stretch the ligament (Smith et al. 1964), resulting in volar subluxation and ulnar deviation. Stretching or rupture of the collateral ligaments has been widely reported (Fearnley 1951; Brewerton 1957; Brooks 1963). In the case of the ring finger, the flexor tendons do not take an ulnar bend at the flexor sheath, and in the case of the little finger they actually take a radially directed bend, so that in order to account for ulnar deviation in the medial two fingers, the ones most commonly and severely affected, these workers were forced to incriminate abductor digitii minimi in producing the ulnar component. This muscle was again implicated by Clayton (1964) and by Hakstian and Tubiana (1967). Going one stage further, Straub (1962) suggested that abductor digitii minimi pulled the little finger into ulnar drift, and indirectly through the palmar plates and deep metacarpal ligaments pulled all the other fingers into ulnar deviation. It is salutary to recall that some workers consider the small muscles of the hand to be less active in this disease.

MATERIALS AND METHODS

One hundred normal fingers of thirteen right and twelve left hands of cadaveric, fresh post-mortem and amputation specimens were dissected. Arthrographs were obtained by the following method: a warmed mixture of Chromopaque and gelatin was injected by a warmed syringe into the dorsolateral aspects of the metacarpophalangeal joints of cooled, separated but undissected fingers. The coloured radio-opaque mixture set hard in a few minutes. A volume of 1 to 2 millilitres was necessary to distend the joint, which then adopted a position of about 15 degrees of flexion. After radiographs had been taken the fingers were dissected so that macroscopic and radiological appearances could be compared.

OBSERVATIONS

The capsule

The fibrous capsule of the metacarpophalangeal joint is attached to the whole circumference of the base of the proximal phalanx, slightly distal to the articular surface, but its metacarpal attachment is much less extensive. In fact, the latter is almost confined to the tubercles on either side of the dorsum of the metacarpal head. Between these two points the weak dorsal part of the capsule takes origin, but elsewhere the metacarpal head is virtually free of capsular attachment. The volar portion of the capsule consists of the thick fibrous palmar plate, which moves with the phalanx and is independent of the metacarpal. Important thickenings on either side form the collateral ligaments, which run from the metacarpal tubercles in two parts to insert into the volar two-thirds of the lateral margin of the phalangeal base and the lateral margin of the palmar plate. Other than to the tubercles these ligaments have no metacarpal attachment, but present an extensive free proximal margin extending from the tubercles to the palmar plate; the fibrous capsule thus effectively has no substantial attachment to the sides of the metacarpal head (Fig. 1). Similarly, the palmar plate has a free proximal margin, with only a loose membranous attachment to the metacarpal.
The meniscus
A rudimentary meniscus, easily overlooked, projects into the interior of the joint. This thin marginal meniscus separating the periphery of the phalangeal articular surface from direct contact with the metacarpal head has been briefly noted by Gad (1967). These structures are constant and well shown by the arthographs in Figures 3 to 6.

The lateral synovial recesses
The synovial membrane lines the capsule and is reflected on to the non-articular intracapsular parts of the bones of the joint. However, it is to be emphasised that in all 100 fingers dissected, the synovial membrane protruded from each side of the joint between the free proximal margin of the fibrous capsule, represented by the border of the collateral ligaments, and the side of the metacarpal head, here forming a distinct pouch or lateral synovial recess. This synovial outpouching facilitates movement of the capsule relative to the metacarpal head in all movements of the joint, and here the volar portion of the head projects considerably on either side. Moreover, where a phalangeal tendon of a dorsal interosseous muscle is present, the synovial recess intervenes between that tendon and the projecting head (Fig. 2). The arrangement is reminiscent of the obturator externus bursa of the hip joint. The recess projects up to 7 millimetres proximal to the capsular margin in extension, and is almost covered by it in flexion.

Although always found if specifically sought on ordinary dissection, after injection of the chromopaque-gelatin mixture the recesses are at once seen to protrude out of the joint like crimson balloons, and correspond well to the recesses seen on arthographs (Fig. 3).

The lateral bursae
The tendon of extensor digitorum communis is connected on each side to the palmar plate by a tendinous band known as the transverse lamina, which forms the proximal margin of the extensor hood. It is entirely separate from the capsule, and deep to it may run the phalangeal tendon of a dorsal interosseous, while superficially to it runs the tendon of a palmar interosseous or the palmar portion of a dorsal interosseous, continuing as the wing tendon of the hood, reinforced on the radial side by a lumbral. The function of the transverse lamina is to stabilise the extensor digitorum communis tendon, preventing it from slipping to one side of the joint.

A group of bursae exists which facilitates movement between the transverse lamina and the capsule. They were noted by Lewis (1965) but not described in detail. A phalangeal tendon, if present, runs between the transverse lamina and the capsule, most commonly partly fusing with the collateral ligament. A bursa may lie between the tendon and the capsule, or between the tendon and the transverse lamina, or on both sides of the tendon. When no phalangeal tendon occurs a bursa may simply separate the transverse lamina from the capsule (Figs 1 and 2). These bursae may measure up to 18 millimetres proximo-distally and 12 millimetres antero-
The overall incidence is as follows: index finger, radial side 40 per cent, ulnar side 48 per cent; middle finger, radial side 84 per cent, ulnar side 56 per cent; ring finger, radial side 48 per cent, ulnar side 64 per cent; little finger, radial side 48 per cent, ulnar side 40 per cent. A dorsal bursa lying between the extensor apparatus and the dorsal capsule of the metacarpophalangeal joint was found to be present in 87 per cent of the fingers, and of these 20 per cent communicated with the cavity of the joint. In all the specimens the dorsal capsule was very thin, and if no dorsal bursa was present this part of the capsule was thrown into folds. A communicating dorsal bursa is well shown in the arthrograph illustrated in Figure 5.

Lewis (1965). The present results are as follows: first dorsal interosseous, both tendons 94 per cent, wing tendon only 16 per cent; second dorsal interosseous, both tendons 100 per cent, wing tendon only 0 per cent; third dorsal interosseous, both tendons 8 per cent, wing tendon only 92 per cent; fourth dorsal interosseous, both tendons 84 per cent, wing tendon only 16 per cent; abductor digitii minimi, both tendons 68 per cent, wing tendon only 32 per cent. The precise arrangement at the radial side of the index and ulnar side of the minimus may be difficult to establish because the transverse lamina fuses early (more dorsally) with the capsule, and therefore obscures the separation of wing from phalangeal tendon. This may explain Salsbury's (1937) conclusion that the first dorsal interosseous muscle possesses no wing tendon.

**DISCUSSION**

The typical rheumatoid deformity of a metacarpophalangeal joint consists of ulnar deviation and subluxation combined with volar subluxation, and a satisfactory explanation of the mechanism must fulfil the following requirements: it must include a force possessing an ulnar and a volar component; the force must act consistently in those directions; it must affect all the fingers, especially the medial two; it must provide an explanation of the failure of the appropriate structures resisting this force. The force—The powerful force that fulfils all the requirements is that exerted by the long flexor tendons on their pulley, the fibrous flexor sheath (Fig. 7). Its volar component is plain, but in the case of the little finger its radial component has clouded the issue. However, the radial bend of the flexor tendons of this finger exists only in extension, and in this position any force exerted is negligible. It is only during grip that forces become considerable. During the power grip (Napier 1956) the index and middle fingers are obviously deviated ulnwards, while ulnar deviation of the ring and little fingers is less obvious when considered in relation to the long axes of their metacarpals. However, in this position the transverse metacarpal arch is exaggerated by flexion of the fourth and fifth metacarpals, and the volar aspects of their heads face in a radial as well as a palmar direction (supination). The volar directed force of their flexor tendons will, therefore, tend to pull the flexor sheaths, and with them the palmar plates and proximal phalanges, down towards the ulnar side of the metacarpal heads, this tendency being resisted by the radial collateral ligaments (Figs. 8 and 9). Thus the metacarpophalangeal joint of every finger is required to withstand both an ulnar (2F) and volar (3F) strain, which explains Hakstian and Tubiana's (1967) observation that the radial collateral ligaments are stronger than the ulnar in all four fingers.

It is suggested that because the medial two fingers are most active in this damaging power grip, they show the classical deformity most frequently and most severely. The flexor sheath is anchored to the palmar plate and

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**FIGS. 5 AND 6**

Figure 5—Arthrograph of middle finger metacarpo-phalangeal joint. The lateral recess is less well shown but a good example of a communicating dorsal bursa is demonstrated. (× 14.) Figure 6—Diagram of arthrographic features. P.P. proximal phalanx. M. filling defect due to meniscus. D.B. dorsal bursa confluent with joint cavity. T. tubercle. M.C. metacarpal. L.R. lateral recess.

**Insertions of the dorsal interossei**

Lewis (1965) showed that the human dorsal interossei were composite muscles derived from the merging of one of each of four bipennate dorsal abductor muscles with one of the original ten flexores breves (numbers 3, 5, 6, 8) leaving the four palmar interossei (numbers 2, 4, 7, 9) as separate entities. Thus a typical dorsal interosseous muscle possesses a phalangeal tendon running deep to the transverse lamina, and derived from its bipennate dorsal abductor portion, while it also possesses a wing tendon derived from its flexor brevis portion and running superficially to the transverse lamina, just as does the wing tendon of a palmar interosseous. However, this basic pattern is subject to variation in the several fingers, for example, the third dorsal interosseous commonly loses its phalangeal attachment, although a relic of the phalangeal tendon may persist. The figures given by Salisbury (1937) and by Eyler and Markee (1954) for the insertions of the interossei contrast with the findings in this series, which are in general agreement with those of
proximal phalanx and hence the force is transmitted to the collateral ligaments. It is to be emphasised that the collateral ligaments are already taut in the flexion that accompanies grip, and that the radial collateral ligament is subjected to greater strain in resisting ulnar deviation. The ulnar component of the force acting on the flexor sheaths may be magnified if a zigzag deformity is present. This consists of ulnar deviation of the fingers combined with radial deviation of the wrist, and results in an alteration of the direction of approach of the flexor tendons (Shapiro 1968; Pahle and Raunio 1969).

**Effect of the lateral synovial recesses and the lateral bursae on the collateral ligaments**—Radiographs of hands in the early stages of rheumatoid disease frequently show characteristic erosions at the sides of the metacarpal heads (Fletcher and Rowley 1952; Bywaters 1960; Martel, Hayes and Duff 1965). These erosions exactly correspond in position to the lateral synovial recesses (compare Figure 10 with Figure 3). It can be assumed that the rheumatoid process occurring in these synovial culs-de-sac produces a mass of pannus which erodes the bone locally. More importantly, however, it must weaken the deep aspects of the collateral ligaments. McMaster (1972) in a study of the operative findings in 126 rheumatoid metacarpophalangeal joints, noted bony erosions deep to the radial collateral ligaments in 76 per cent of the fingers and deep to the ulnar collateral ligaments in 73 per cent. The earliest erosions occurred next to the articular cartilage margins and those under the collateral ligaments were the deepest.

At operation, masses of rheumatoid synovial tissue are sometimes seen over the sides of the joint, and these presumably arise from the lateral bursae. Thus a collateral ligament is attacked both from its superficial aspect
Diagram explaining the mechanism of the rheumatoid deformity.

by the pannus derived from the synovium of the lateral bursa, and from its deep aspect by that from the lateral recess, with the result that the ligament stretches or ruptures. The deforming forces due to the pull of the long flexor tendons are now no longer resisted, so that volar subluxation and ulnar deviation and subluxation result. The dorsal rim of the proximal phalanx then comes to abut against the metacarpal head, explaining the wear found in these areas.

Moreover, the rheumatoid tissue arising from the lateral bursa is in a position to attack the transverse lamina, but this is subject to much less ulnar strain than the collateral ligaments. Nevertheless, a mechanism is now furnished for ulnar dislocation of the extensor digitorum communis tendon by rupture of its anchor, the transverse lamina, either as a complication or rarely as the primary cause of the deformity. Figure 11 shows the conception of the mechanisms causing deformity.

REFERENCES


