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Histological studies on the triangular fibrocartilage complex of the wrist

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INTRODUCTION

The triangular articular disc of the wrist joint and its associated structures (the radio-ulnar ligaments, the homologue of the ulnocarpal meniscus, the sheath of extensor carpi ulnaris and the ulnar collateral ligament) extend from the lower end of the radius and ulna to the base of the fifth metacarpal. The whole collection is viewed as an homogeneous structure and called the 'triangular fibrocartilage complex' (TFCC) by Palmer & Werner (1981). This name is now widely adopted in the clinical literature.

The TFCC is of interest to clinicians because it is frequently involved in wrist injuries. Recent studies include those of Zinberg, Palmer, Coren & Levinsohn (1988), Green & Greenspan (1988), Watson & Brown (1989), Hanel & Scheid (1988), Palmer (1989) and Bottke, Louis & Braunstein (1989). However, studies on its anatomy are fewer. The most notable are those of Lewis, Hamshere & Bucknill (1970), Kauer (1975), Mikić (1978), Palmer & Werner (1981), Mohiuddin & Janjua (1982), Thiru-Pathi, Ferlic, Clayton & McClure (1986) and Garcia-Elias & Domènech-Mateu (1987).

The general histology of the TFCC and particularly the structure of its radial and ulnar attachment zones is unclear. According to the illustration of Lewis *et al.* (1970) and the modified version of their drawing adopted by Williams, Warwick, Dyson & Bannister (1989), the base of the triangular disc replaces articular cartilage between the ulnar notch and carpal surface of the radius. In contrast to this, Mohiuddin & Janjua (1982) show that the disc arises from articular cartilage covering the edge of the radius and not from the bone itself. Although the photographic evidence of Mohiuddin & Janjua (1982) is convincing, an attachment to cartilage alone would increase the risk of the TFCC tearing away from the radius. As the TFCC is considered by Palmer & Werner (1984) to have a major role in stabilising the inferior radio-ulnar joint, it is important to clarify the structure of its radial attachment and to establish the basis for the motility at its ulnar attachment zone.

MATERIALS AND METHODS

The parts of the TFCC related to the radius and ulna were removed from eight dissecting room cadavers (ages 54–85 years) by severing the extensor tendons and opening the wrist joint dorsally. Perforated articular discs or discs with severe degenerative changes on their carpal surface were frequent and were not used in this study. The radius and ulna were sawn transversely 1 cm proximal to the TFCC. The

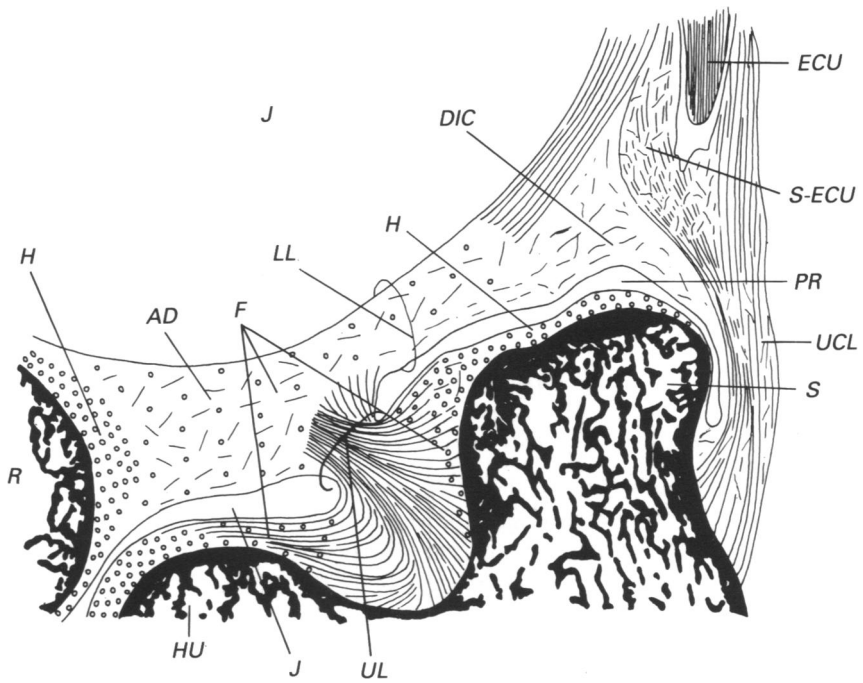


Fig. 1. A diagrammatic interpretation of the structure of the TFCC as seen in a coronal section through the lower end of the radius (*R*) and ulna. The section passes through the middle of the complex and thus misses the radio-ulnar ligaments. *AD*, articular disc; *DIC*, dense irregular connective tissue corresponding in position to the meniscus homologue; *ECU*, tendon of extensor carpi ulnaris; *H*, hyaline cartilage; *HU*, head of the ulna; *J*, joint cavity; *LL*, lower lamina; *PR*, prestyloid recess; *S*, styloid process of the ulna; *S-ECU*, sheath of extensor carpi ulnaris; *UCL*, ulnar collateral ligament; *UL*, upper lamina. ×4.

tissue, initially fixed for student dissections in unbuffered formalin, was further treated for one week with 10% neutral buffered formal saline, decalcified with 2% nitric acid (the end point being determined radiographically), dehydrated with graded alcohols and embedded in Paramat. The discs were cut on a rotary microtome at 8 μm in the coronal plane and four sections were collected at 250 μm intervals throughout the block. Alternate sections were stained with haematoxylin and eosin, Masson's trichrome, Azan, van Gieson's connective tissue stain/Weigert's elastic stain, and Alcian blue/Direct red.

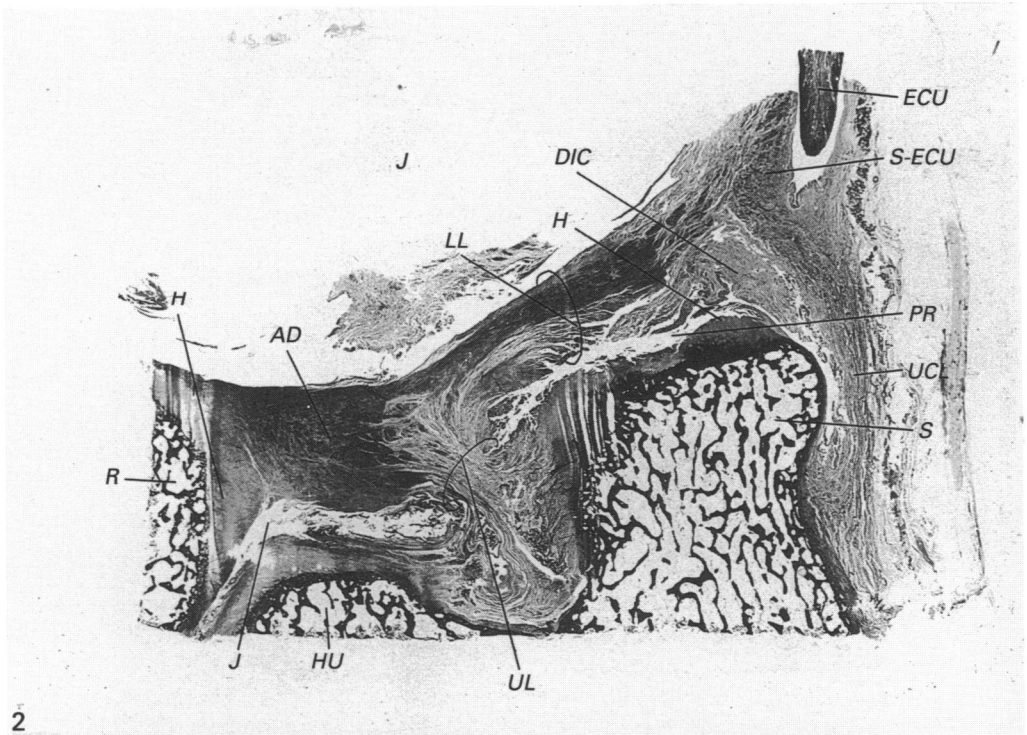
OBSERVATIONS

The components of the TFCC are illustrated in Figures 1 and 2. In all specimens, the articular disc arises from the radius as a fibrocartilaginous extension of the superficial zone of hyaline articular cartilage (Figs. 1–3). This cartilage is continuous

Fig. 2. A coronal section through the TFCC similar to that featured in Fig. 1. For abbreviations, see Fig. 1. Masson's trichrome. ×4.

Fig. 3. Continuity between the fibrocartilaginous articular disc (*AD*) and hyaline cartilage (*HC*) at the lower end of the radius (*R*). Masson's trichrome. ×48.

Fig. 4. The volar radio-ulnar ligament is well defined histologically and attached directly to the radius (compare with Fig. 3). *B*, bone; *CF*, calcified fibrocartilage; *UF*, uncalcified fibrocartilage. Masson's trichrome. ×37.



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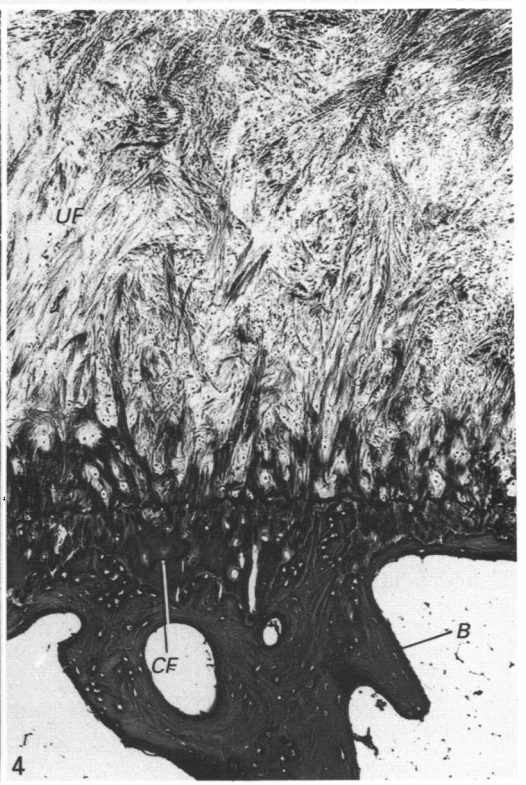

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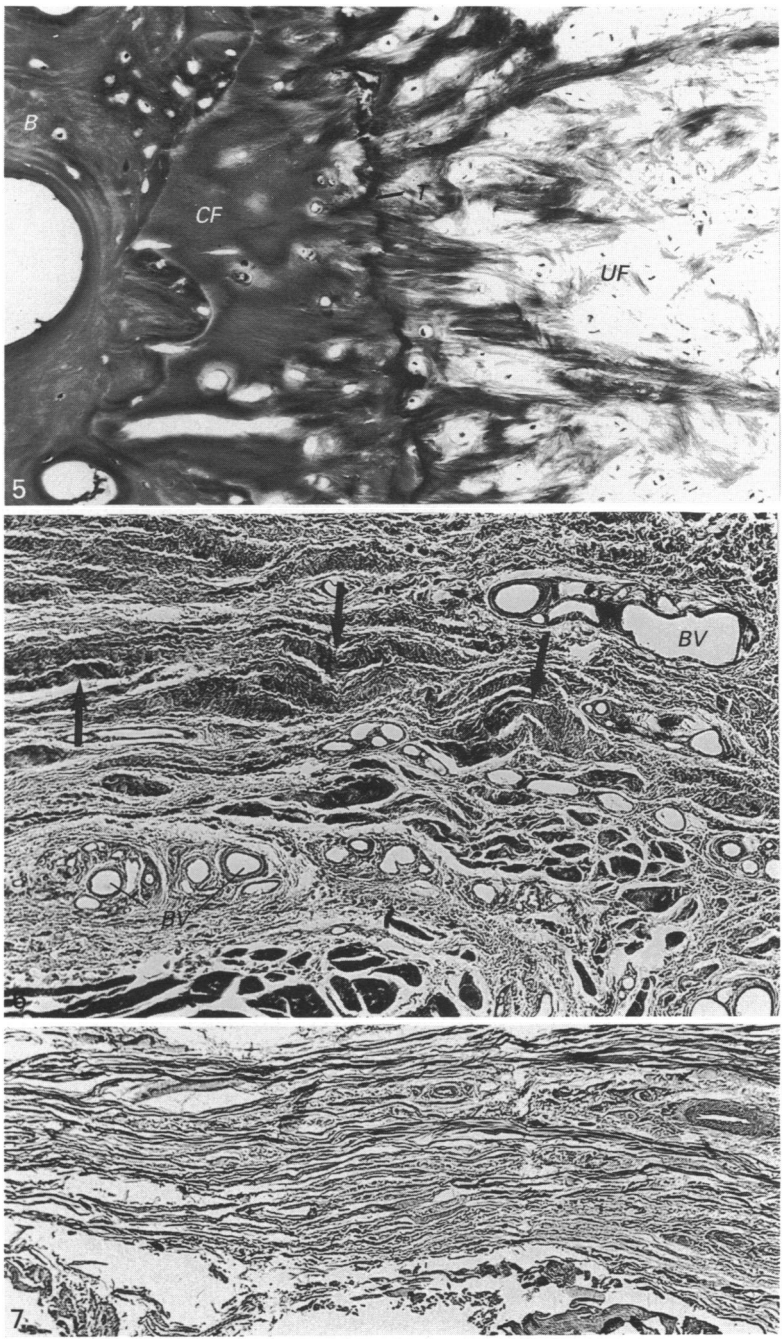

Fig. 5. Calcified (*CF*) and uncalcified (*UF*) fibrocartilage at the attachment zone of the dorsal radio-ulnar ligament. *B*, bone. *T*, tidemark. Masson's trichrome. × 120.

Fig. 6. A region of highly vascular loose connective tissue through which bundles of collagen fibres (arrows) pass *en route* to their ulnar attachment. *BV*, blood vessels. Masson's trichrome. × 48.

Fig. 7. The ulnar collateral ligament is poorly defined and of a loose texture. However, it is possible to recognise a predominant longitudinal orientation of the fibres in this specimen. Masson's trichrome. × 37.

from the ulnar notch to the carpal surface of the radius. The disc arises from the sharp border between the two articular surfaces and is thus not directly attached to bone. However, the radio-ulnar ligaments (which are not seen in a coronal section through the middle of the disc) are attached to the radius via zones of calcified and uncalcified fibrocartilage (Figs 4, 5).

Medially, the disc splits into two laminae (Fig. 2). Strands of collagen fibres from the upper lamina arch through a region of vascular connective tissue (Fig. 6) towards the styloid process and the head of the ulna. The lower lamina extends beyond the ulna, and blends with the dense fibrous connective tissue of the prominent sheath of extensor carpi ulnaris and with the ulnar collateral ligament (Fig. 2). The dorsal radio-ulnar ligament also blends with the tendon sheath. The ulnar collateral ligament is poorly defined, and of a far looser texture than that of the tendon or even the tendon sheath (Figs. 7, 8). Occasionally, however, it is possible to recognise a distinct longitudinal orientation of the collagen fibres (Fig. 7) and thus to see that the ligament is attached to the medial side of the base of the ulnar styloid process, above the prestyloid recess. The meniscus homologue of Lewis *et al.* (1970) is an ill-defined region of irregular, dense fibrous connective tissue that forms an integral part of the lower lamina (Figs. 2, 9), but has no independent histological identity.

A few fibres from the upper lamina attach directly to bone in the roughened area at the base of the styloid process. However, the majority of fibres attach to the ulna via regions of fibrocartilage (Fig. 10). The fibres come from both the disc and the radio-ulnar ligaments and are intermingled at their attachments. The bone–cartilage junction in the attachment zones is exceedingly irregular, so that islands of bone appear isolated (in section at least) among regions of calcified fibrocartilage (Fig. 10). The fibrocartilaginous attachments of the TFCC occur both on the lateral side and at the base of the styloid process. At the base, many fibres arch upon themselves and pass towards the head of the ulna where they blend with its articular cartilage (Fig. 11). Thus, this cartilage is often fibrous in its medial half (Fig. 12).

The tip of the styloid process is generally covered by cartilage (hyaline or fibrous) and related to a prestyloid recess (Fig. 9). This cartilage merges imperceptibly with fibrocartilaginous attachments of the TFCC. In one specimen, there were signs of osteoarthritic degeneration (deep fissures and clustering of chondrocytes) on the hyaline cartilage at the tip of the styloid process and considerable vascularisation and thickening of the synovial membrane.

DISCUSSION

The results show that the TFCC arises both from articular cartilage on the radius (as described by Mohiuddin & Janjua, 1982) and directly from bone, as illustrated by Lewis *et al.* (1970). It is the disc itself that arises from hyaline cartilage but the radio-ulnar ligaments that attach to bone. The ligaments do so via zones of calcified and uncalcified fibrocartilage in a manner that is typical of epiphyseal tendons and ligaments (Benjamin, Evans & Copp, 1986; Donthineni Rao, 1989). It is suggested therefore that Palmer & Werner's (1981) radio-ulnar ligaments, although poorly defined by gross anatomy, are easily recognisable histologically at their distinctive radial attachment zones. Garcia-Elias & Domènech-Mateu (1987) have denied the existence of the volar radio-ulnar ligament in fetal material. According to these authors, the dorsal radio-ulnar ligament is the only ligament attaching the radius to the ulna at the wrist. However, their Figure 3 shows a less well-defined volar ligament

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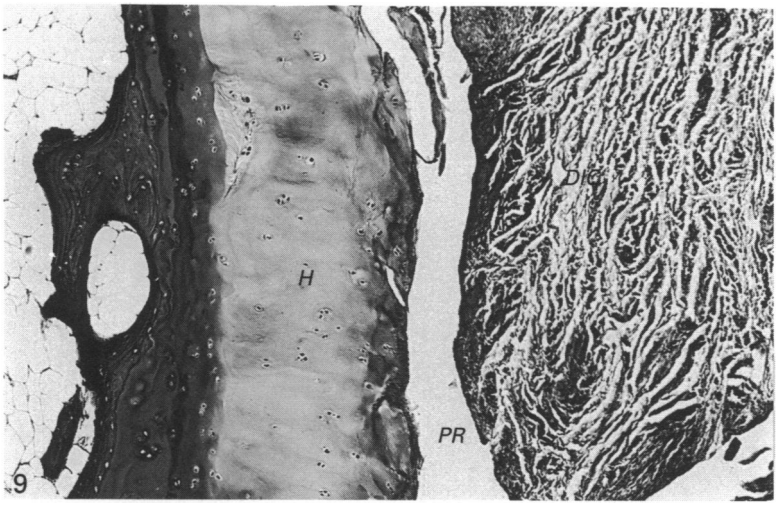

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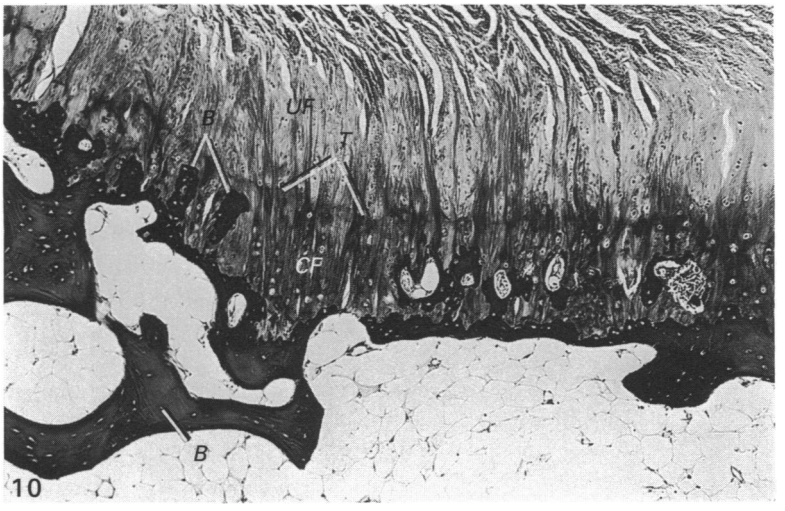

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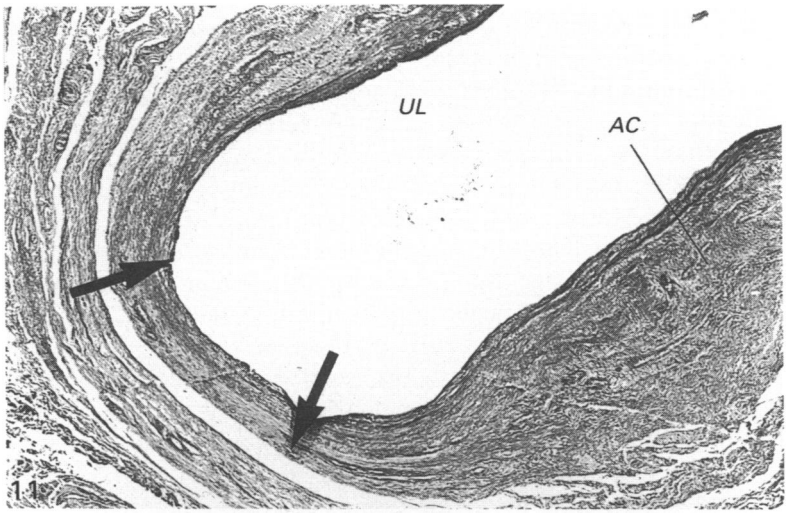

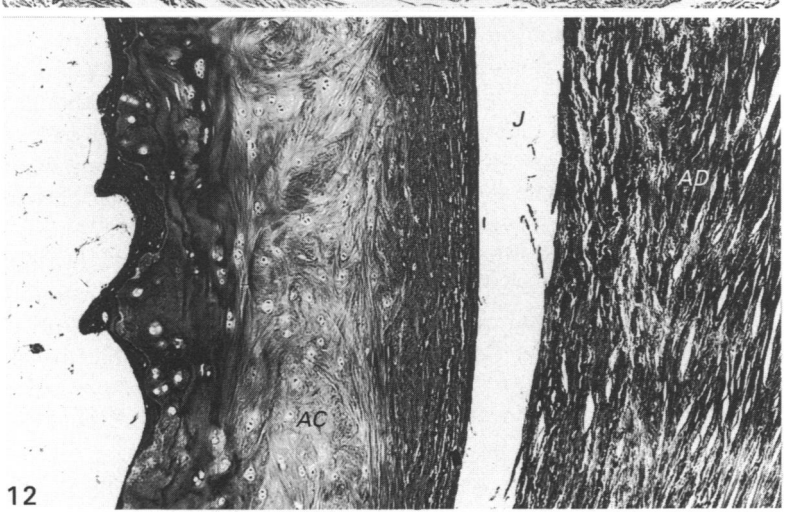

Fig. 11. Arching fibres (arrows) from the upper lamina (*UL*) blending with articular cartilage (*AC*) on the head of the ulna. Masson's trichrome. ×48.

Fig. 12. The fibrocartilaginous, medial part of the articular cartilage (*AC*) covering the head of the ulna. *AD*, articular disc; *J*, joint cavity. Masson's trichrome. ×48.

running from the radius to the disc. We found fibres that ran from the radius to the ulna, in *both* radio-ulnar ligaments.

According to the vascular injection studies of Thiru-Pathi *et al.* (1986), the radial attachment of the articular disc is avascular, although blood vessels enter other parts of the periphery. This is explained by our finding that all attachments of the TFCC to

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Fig. 8. The prominent sheath of extensor carpi ulnaris. Masson's trichrome. ×48.

Fig. 9. The meniscus homologue is a region of dense irregular connective tissue (*DIC*) that is separated from articular hyaline cartilage (*H*) that covers the tip of the ulnar styloid process, by the prestyloid recess (*PR*). Masson's trichrome. ×48.

Fig. 10. The attachment of part of the upper lamina of the TFCC to the radial side of the styloid process of the ulna. *B*, bone; *CF*, calcified fibrocartilage; *UF*, uncalcified fibrocartilage. *T*, tidemark. Masson's trichrome. ×48.

the radius are cartilaginous. Tendon and ligament attachments to bone that have fibrocartilage at the insertion site do not generally have vascular connections with the underlying bone (Benjamin *et al.* 1986; Woo *et al.* 1988).

In view of the continuity of the disc with articular cartilage, one can view the former as a labrum that extends the carpal articular surface of the radius. However, it develops later than the cartilage model that foreshadows the radius (Kauer, 1975). Furthermore, it differs from the glenoidal labrum in being primarily fibrocartilaginous, rather than fibrous (Johnson, 1987). The different means of radial attachment of the disc and the radio-ulnar ligaments suggest some division of labour between these components of the TFCC. The disc provides an articular surface for the ulna and for the carpal bones, while the ligaments strengthen the vulnerable radial attachment of the disc. As the disc blends with articular cartilage on the ulna, one can also view it as a fibrocartilaginous link between articular cartilages at the lower end of the radius and ulna. It is attached to all areas of the ulna between the cartilage on the head and that on the styloid process.

The arching ligamentous bands that connect the TFCC to the ulna permit the necessary degree of play that allows the disc to keep close company with the radius during pronation and supination (Mohiuddin & Janjua, 1982). However, there is considerable movement of the disc relative to the bone at the ulnar attachment (Kapandji, 1982). Mohiuddin & Janjua (1982) did not consider how the increased risk of wear and tear is reduced at that site. The presence of a cartilage matrix near the hard tissue interface of the TFCC prevents the collagen fibres from splaying where they are most likely to be damaged. The region of vascular connective tissue between the two laminae provides for motility.

In contrast to Mohiuddin & Janjua (1982), we provide histological evidence that the styloid process of the ulna is covered by articular cartilage and is associated with a prestyloid recess (a diverticulum of the radiocarpal joint). Lewis *et al.* (1970) and Taleisnik (1976) have described these features in earlier gross anatomy studies. We further report that the articular cartilage on the styloid process is subject to the osteoarthritic degeneration that commonly affects other regions of the TFCC and the wrist joint.

We agree with Garcia-Elias & Domènech-Mateu (1987) that the ulnar collateral ligament is generally poorly defined histologically and has a loose texture that would allow the ligament to stretch considerably. Nevertheless, a distinct longitudinal arrangement of bundles of collagen fibres separated by areas of looser connective tissue was sometimes seen.

SUMMARY

The triangular fibrocartilage complex of the wrist was serially sectioned for routine histology. Results from eight dissecting room cadavers show that the complex is attached to hyaline cartilage on the radius via its articular disc. In contrast, the dorsal and volar radio-ulnar ligaments attach to the radius via zones of calcified and uncalcified fibrocartilage. The articular disc is thus a wide labrum that provides an articular surface for the ulna and for the carpal bones, and the radio-ulnar ligaments strengthen the attachment of the disc to the radius.

Medially, the complex divides into upper and lower laminae. Arching strands of collagen fibres emerge from the upper lamina and pass through a region of highly vascular connective tissue to be attached to the ulna between the articular cartilage on the head and that at the tip of the styloid process. Much of the ulnar attachment is via zones of calcified and uncalcified fibrocartilage which blend with the adjacent articular

cartilages. Such an arrangement of tissues prevents undue wear and tear at the ulnar attachment zone during pronation and supination of the forearm.

The lower lamina blends with the sheath of extensor carpi ulnaris and the ulnar collateral ligament and allows the whole complex to attach to the carpal and metacarpal bones. The meniscus homologue is a region of dense irregular connective tissue with no independent histological identity.

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REFERENCES

BENJAMIN, M., EVANS, E. J. & COPP, L. (1986). The histology of tendon attachments to bone in man. *Journal of Anatomy* **149**, 89–100.

BOTTKE, C. A., LOUIS, D. S. & BRAUNSTEIN, E. M. (1989). Diagnosis and treatment of obscure ulnar-sided wrist pain. *Orthopedics* **12**, 1075–1079.

DONTHINENI RAO, R. (1989). Fibrocartilage in the epiphysial attachments of ligaments in man. *Journal of Anatomy* **164**, 254.

GARCIA-ELIAS, M. & DOMÈNECH-MATEU, J. M. (1987). The articular disc of the wrist. Limits and relations. *Acta anatomica* **128**, 51–54.

GREEN, S. M. & GREENSPAN, A. (1988). An expanded imaging approach for diagnosing tears of the triangular fibrocartilage complex. *Bulletin of the Hospital for Joint Diseases* **48**, 187–190.

HANEL, D. P. & SCHEID, D. K. (1988). Irreducible fracture-dislocation of the distal radioulnar joint secondary to entrapment of the extensor carpi ulnaris tendon. *Clinical Orthopaedics and Related Research* **234**, 56–60.

JOHNSON, L. L. (1987). The shoulder joint. An arthroscopist's perspective of anatomy and pathology. *Clinical Orthopaedics and Related Research* **223**, 113–125.

KAPANDJI, I. A. (1982). *The Physiology of the Joints*, vol. 1, 2nd ed. Edinburgh: Churchill Livingstone.

KAUER, J. M. G. (1975). The articular disc of the hand. *Acta anatomica* **93**, 590–605.

LEWIS, O. J., HAMSHERE, R. J. & BUCKNILL, T. M. (1970). The anatomy of the wrist joint. *Journal of Anatomy* **106**, 539–552.

MIKIĆ, Z. DJ. (1978). Age changes in the triangular fibrocartilage of the wrist joint. *Journal of Anatomy* **126**, 367–384.

MOHIUDDIN, A. & JANJUA, M. Z. (1982). Form and function of radioulnar articular disc. *Hand* **14**, 61–66.

PALMER, A. K. (1989). Triangular fibrocartilage complex lesions: a classification. *Journal of Hand Surgery* **14A**, 594–606.

PALMER, A. K. & WERNER, F. W. (1981). The triangular fibrocartilage complex of the wrist – anatomy and function. *Journal of Hand Surgery* **6A**, 153–162.

PALMER, A. K. & WERNER, F. W. (1984). Biomechanics of the distal radioulnar joint. *Clinical Orthopaedics and Related Research* **187**, 26–35.

TALEISNIK, J. (1976). The ligaments of the wrist. *Journal of Hand Surgery* **1**, 110–118.

THIRU-PATHI, R. G., FERLIC, D. C., CLAYTON, M. L. & MCCLURE, D. C. (1986). Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. *Journal of Hand Surgery* **11A**, 258–263.

WATSON, H. K. & BROWN, R. E. (1989). Ulnar impingement syndrome after Darrach procedure: treatment by advancement lengthening osteotomy of the ulna. *Journal of Hand Surgery* **14A**, 302–306.

WILLIAMS, P. L., WARWICK, R., DYSON, M. & BANNISTER, L. H. (1989). *Gray's Anatomy*, 37th ed. Edinburgh: Churchill Livingstone.

WOO, S., MAYNARD, J., BUTLER, D., LYON, R., TORZILLI, P., AKESON, W., COOPER, R. & OAKES, B. (1988). Ligament, tendon, and joint capsule insertions to bone. In *Injury and Repair of the Musculoskeletal Soft Tissues* (ed. S. L-Y Woo & J. A. Buckwalter), pp. 133–166. Park Ridge, Illinois: American Academy of Orthopaedic Surgeons.

ZINBERG, E. M., PALMER, A. K., COREN, A. B. & LEVINSOHN, E. M. (1988). The triple-injection wrist arthrogram. *Journal of Hand Surgery* **13A**, 803–809.