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Age changes in the triangular fibrocartilage of the wrist joint

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INTRODUCTION

It is well known that degenerative changes occur with ageing in all components of synovial joints, including intra-articular fibrocartilaginous structures (Barnett, Davies & MacConaill, 1961).

Age changes in the menisci of the knee joint have been studied by Burman & Sutro (1933), Tobler (1929), Niessen (1934), Bennett, Waine & Bauer (1942), Zippel (1964), Pfeil (1966), Refior & Fischer (1974) and Noble & Hamblen (1975), while DePalma (1957) has investigated ageing in the discs of the sternoclavicular and acromioclavicular joints.

Some attention has been given to the triangular fibrocartilage of the wrist joint by Lang (1942), Hoegen & Reske (1956) and Maraval-Bonnet (1969), but, despite its clinical importance, it has not been studied systematically, so that, for example, information about the nature and frequence of perforations of this disc is not available.

The aim of this paper is to report the findings of an extensive study of the regressive alterations in the triangular fibrocartilage of the human wrist joint in successive decades of life.

MATERIALS AND METHODS

One hundred and eighty wrist joints were studied in 81 fresh cadavers (ranging from premature infants to persons 94 years old) and 19 fetuses (6–8 months old) (Table 1).

In all cases death was due to causes unassociated with primary joint disease, and no subject presented evidence of any abnormality, injury or operative interference in or about the wrist joint studied.

The joints were opened in such a manner that the intra-articular structures, particularly the triangular fibrocartilage, were clearly visualized. After gross examination of the radiocarpal and distal radioulnar joints the intra-articular disc was removed, measured, thoroughly inspected and preserved in 4 % formol solution. All discs were studied in serial macroscopic sections; in addition 37 were sectioned and examined with the light microscope, using haematoxylin and eosin, and orcein stains.

RESULTS

In the first three age groups (fetuses, first and second decades) the discs were all normal, that is to say, they showed no evidence of degeneration (Table 2). They were glistening, white, and smooth on both their upper (ulnar) and lower (carpal) surfaces. Some of the discs were rather thin and slightly translucent in their central parts, but none were perforated.

Table 1. *Sex and age distribution of cadaveric material*

Age of subjects	Number of subjects	Sex F	Sex M	Number of wrist joints
Fetuses	19	7	12	38
First decade	11	4	7	21
Second decade	6	2	4	12
Third decade	8	3	5	13
Fourth decade	7	3	4	11
Fifth decade	9	5	4	15
Sixth decade	11	1	10	21
Over 60 years	29	8	21	49
Total	100	33	67	180

Table 2. *Incidence of degenerative lesions*

Age of subjects	Number of discs	Normal appearance	Degenerative appearance: More on carpal side	More on ulnar side	Equal on both sides
Fetuses	38	38	—	—	—
First decade	21	21	—	—	—
Second decade	12	12	—	—	—
Third decade	13	8 (61·5 %)	—	5 (38·4 %)	—
Fourth decade	11	6 (54·5 %)	—	5 (45·4 %)	—
Fifth decade	15	—	—	15 (100 %)	—
Sixth decade	21	—	—	20 (95·2 %)	1 (4·7 %)
Over 60 years	49	—	—	41 (83·6 %)	8 (16·3 %)

In the third decade of life degenerative changes began to appear. The earliest changes were noted in the cells; with advancing age the discs became much less cellular, and the cells themselves changed their character (Fig. 1). In children the majority of the cells had the appearance of young fibroblasts; in later years almost all of them were chondrocytes. Mucoid degeneration of the ground substance, with chondrocyte proliferation, could be seen in some areas (Fig. 2). Proliferated cells were sometimes in clusters, and sometimes arranged in rows along the clefts (Fig. 3). There was fibrillation, i.e. a loss of intercellular substance and exposure of collagenous fibres (Fig. 4). The number of elastic fibres also decreased and in older subjects these became irregular and fragmented (Fig. 5).

Grossly the older discs became more yellow and felt less elastic. Their surfaces became less smooth, appearing matted and irregular; there was some fibrillation, pitting and shredding. In more advanced cases the discs exhibited deep erosions, ulcerations, and abnormal thinning, until finally they became perforated (Figs. 6, 7). These changes were present in varying degrees in 38·4 % of cases in the third decade (Table 2). During subsequent decades the regressive changes became more marked and more frequent, and from the fifth decade onward no completely normal discs were found.

Calcification of the ground substance was observed in 2 of the 29 individuals over 60 years old (Fig. 8).

The degenerative lesions first occurred, and they were always much more severe,

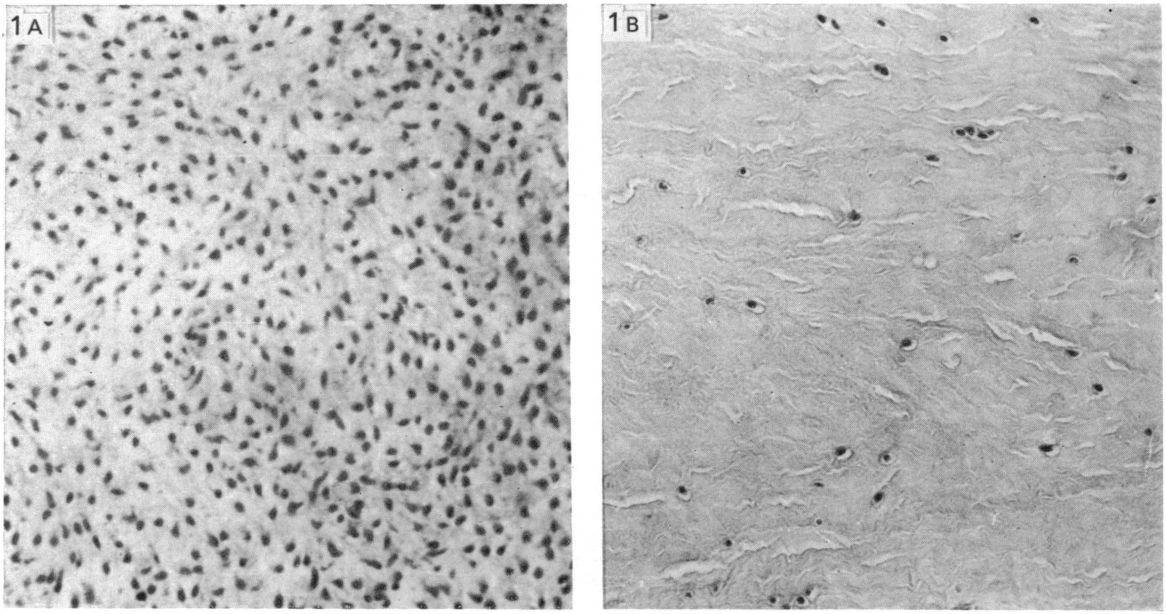


Fig. 1. Section of the central part of the triangular fibrocartilage from the wrist joint of an infant (A), and of a 50 years old subject (B). Note much less cellularity of the adult specimen, and the differences in the character of the cells: namely, cartilage cells are not present in the infant, but all cells in the adult are of chondrocyte type. Haematoxylin and eosin. ×100.

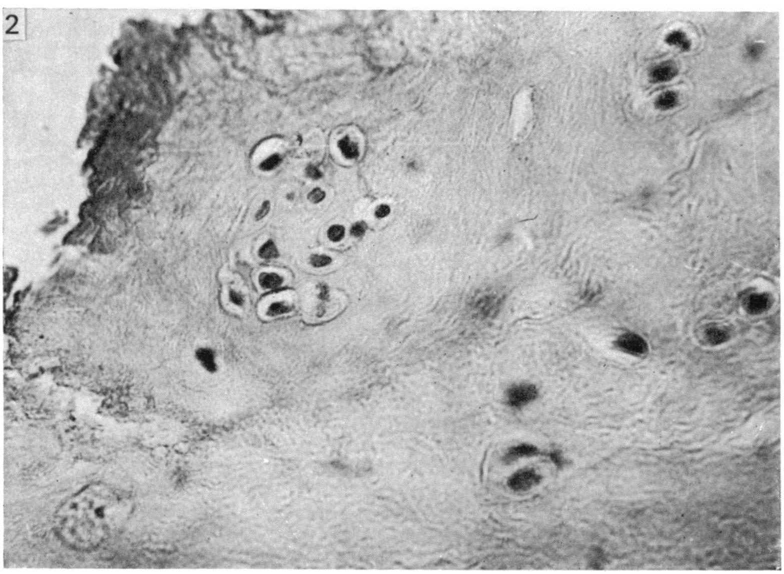


Fig. 2. Mucoid degeneration, and a globular group of proliferated cells, in a disc from a 50 years old subject. Haematoxylin and eosin. ×252.

Fig. 3. Proliferated cells arranged along the fissure in a disc obtained from a 75 years old subject. Haematoxylin and eosin. ×252.

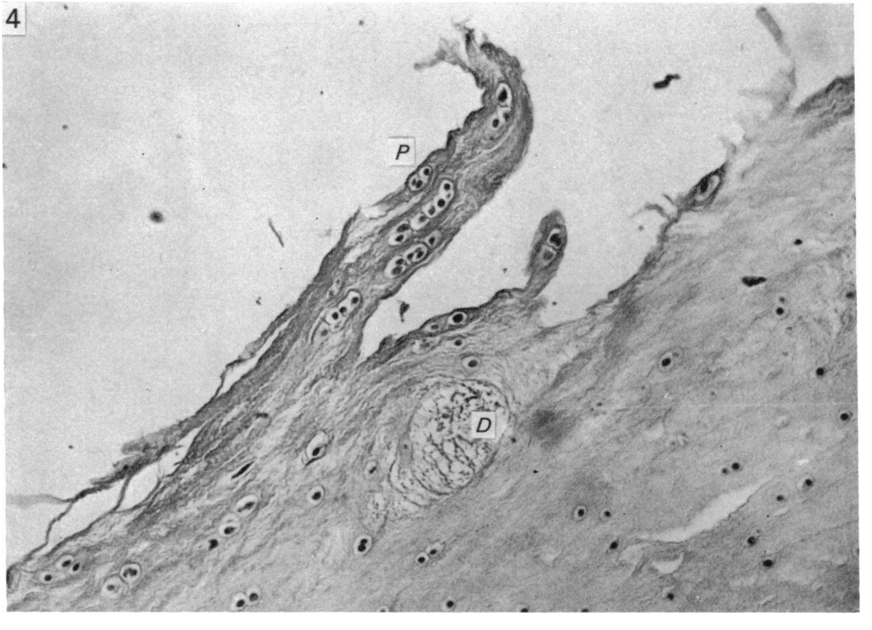


Fig. 4. Fibrillation and shredding on the ulnar surface of a disc taken from a 53 years old person. Note the cell proliferation in the shredded parts (*P*), and a focus of disintegration (*D*). Haematoxylin and eosin. ×90.

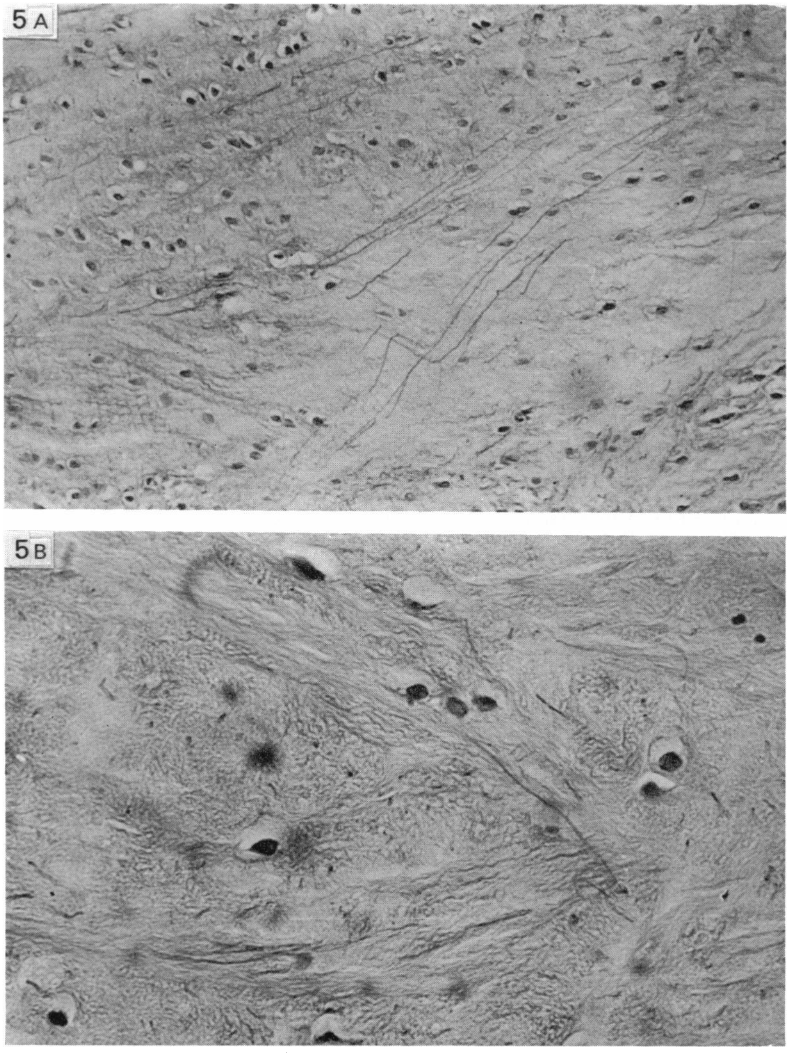


Fig. 5. Transverse section of the triangular fibrocartilage from the wrist joint of a child aged 2 years (A) and of an old man aged 75 years (B), showing elastic tissue. Note the decreased amount of elastic fibres, and their fragmentation, in the adult specimen. Orcein. ×252.

on the ulnar side of the disc (Table 2). The carpal side seemed quite well preserved for a long time (Figs. 6, 7), so the two surfaces were often of very different appearance (Fig. 9). The changes were invariably situated in the thinner, central parts of the disc; the thick periphery was almost always well preserved (Fig. 6). In only one case (Fig. 10) had the anterior edge of the disc disintegrated.

No perforations of the disc were seen in fetuses, or during the first two decades. In the third decade two perforations were encountered (Table 3): in one of these, from a 23 years old male who died from uraemia, the disc appeared grossly normal but rather thin; however, in the central part of the disc a fissure was found. In older age groups the incidence of perforations increased progressively from decade to decade (Table 3).

All perforated discs except one exhibited severe degenerative changes. The edge

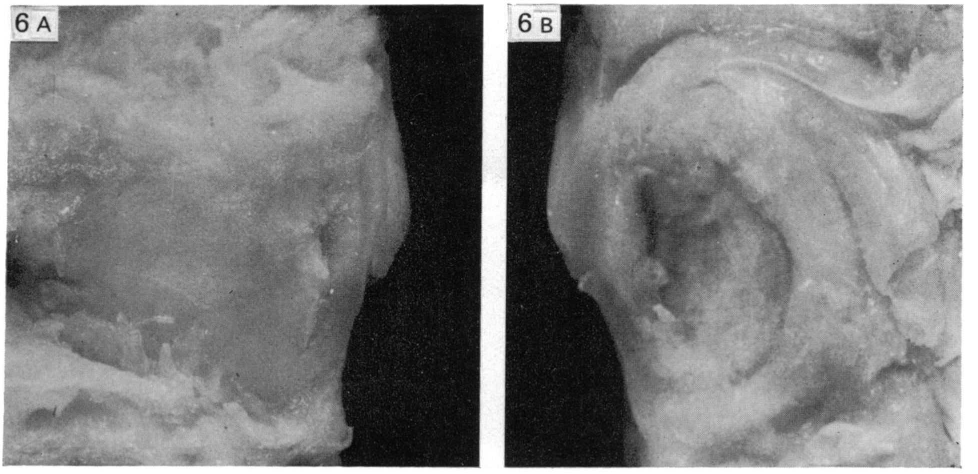


Fig. 6. Progressive degenerative changes in a disc obtained from a subject 50 years old; view from the carpal side (A) and from the ulnar side (B). There is a fissure along the radial border of the disc, and deep ulceration and shredding on the ulnar surface. The changes occur in the central part of the disc; the edges are preserved. Note the difference between the carpal and ulnar surfaces.

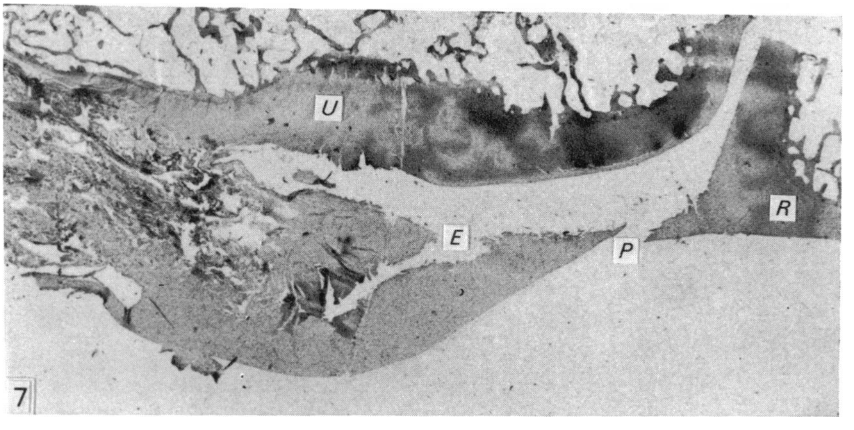


Fig. 7. Cross section of the distal radioulnar joint of the same subject as in Fig. 6. The disc attached to the ulna (*U*) and radius (*R*) is perforated (*P*). The ulnar surface is fibrillated and there is a deep erosion (*E*). Haematoxylin and eosin. × 5.

of the perforation was always thin, irregular, and shredded (Fig. 11). Surrounding the perforation, particularly on the ulnar side of the disc, there were profound alterations (Figs. 6, 7, 8).

There were altogether 45 perforated discs. In 18 cases (40 %) the perforations took the form of a fissure located periradially (Fig. 6). In 23 cases (51·1 %) the defect was located in the central part of the disc, and was more obvious, being round, oval, triangular or irregular in form (Figs. 8, 10, 12, 15). In 3 cases (6·6 %) the perforation was in the form of a long fissure running sagittally from the anterior to the posterior border (Fig. 13) through the centre of the disc. In 1 case (2·2 %) the perforation was completely irregular, involving almost the whole disc (Fig. 10). The perforations varied considerably in size; sometimes there was a mere fissure (Fig. 6),

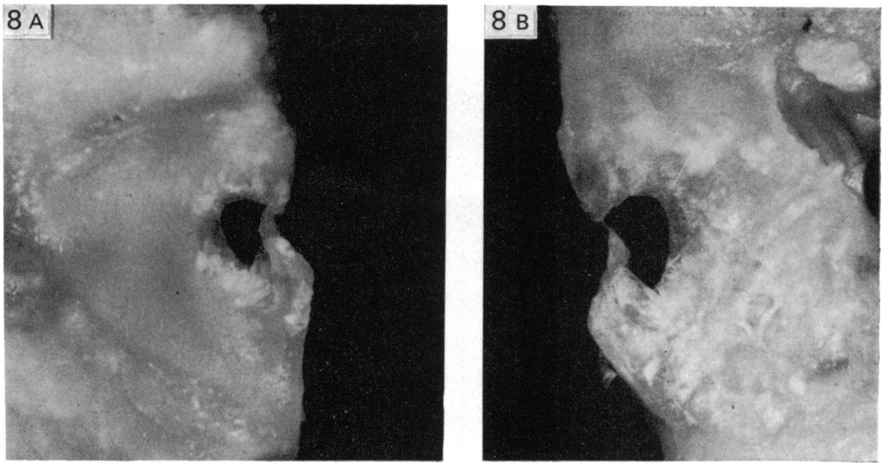


Fig. 8. Triangular fibrocartilage obtained from a subject 82 years old. Note the calcification around the perforation on the carpal surface (A) and the speckled calcification over the entire ulnar surface (B).

Fig. 9. Transverse section through the disc of a subject 50 years old contrasting the altered ulnar surface (*U*) with the normal carpal surface (*C*). Haematoxylin and eosin. ×36.

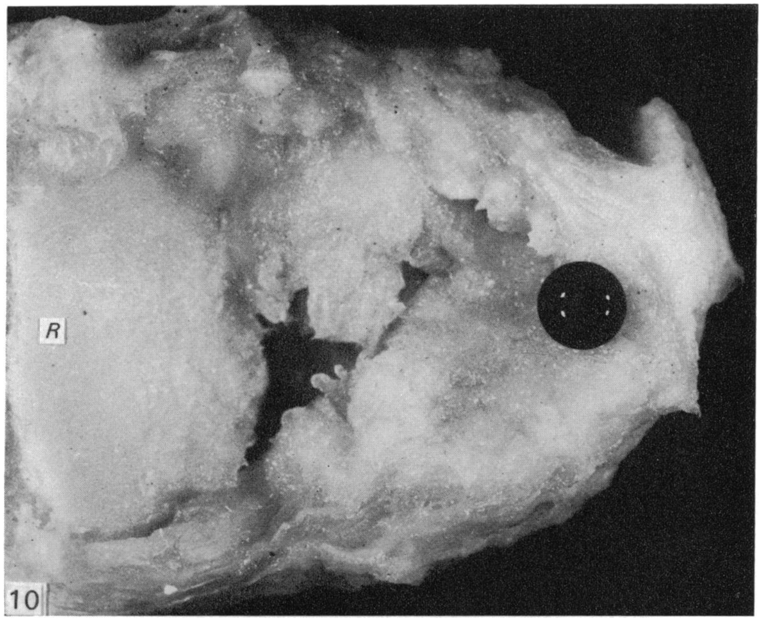


Fig. 10. A profoundly degenerated disc taken from the left wrist joint of a 77 years old subject. The anterior border of the disc is also disintegrated. Viewed from the carpal side. *R*, radius. The head of a pin at the apex of the disc gives an indication of size.

Table 3. *Incidence of disc perforations*

Age of subjects	Number of discs	Grossly normal discs with perforations	Degenerative discs without perforations	Degenerative discs with perforations
Fetuses	38	—	—	—
First decade	21	—	—	—
Second decade	12	—	—	—
Third decade	13	1 (7·6 %)	4 (30·7 %)	1 (7·6 %)
Fourth decade	11	—	3 (27·2 %)	2 (18·1 %)
Fifth decade	15	—	9 (60·0 %)	6 (40·0 %)
Sixth decade	21	—	12 (57·1 %)	9 (42·8 %)
Over 60 years	49	—	23 (46·9 %)	26 (53·1 %)

sometimes a substantial defect (Fig. 12B). The largest perforation measured 9 × 6 mm, and the disc was meniscoid.

Besides the disc changes, severe changes in other joint structures were found (Table 4). The interosseous ligaments between scaphoid and lunate, and between lunate and triquetrum, were often partially disintegrated and perforated. Apertures through which the radiocarpal and mediocarpal joints could communicate were discernible as early as the third decade. Their frequency increased progressively from decade to decade. Starting with the third decade, gross alterations in the articular cartilage of the ulna, radius and carpal bones were encountered; these included fibrillation, erosion and irregular ulceration (Fig. 14). Such lesions were much more frequent on the ulna and lunate than on the other bones (Table 4). More precisely, the changes of the greatest intensity were always located in the structures adjacent to the articular disc. As a rule, the cartilage of the lunate bone was ulcerated in its

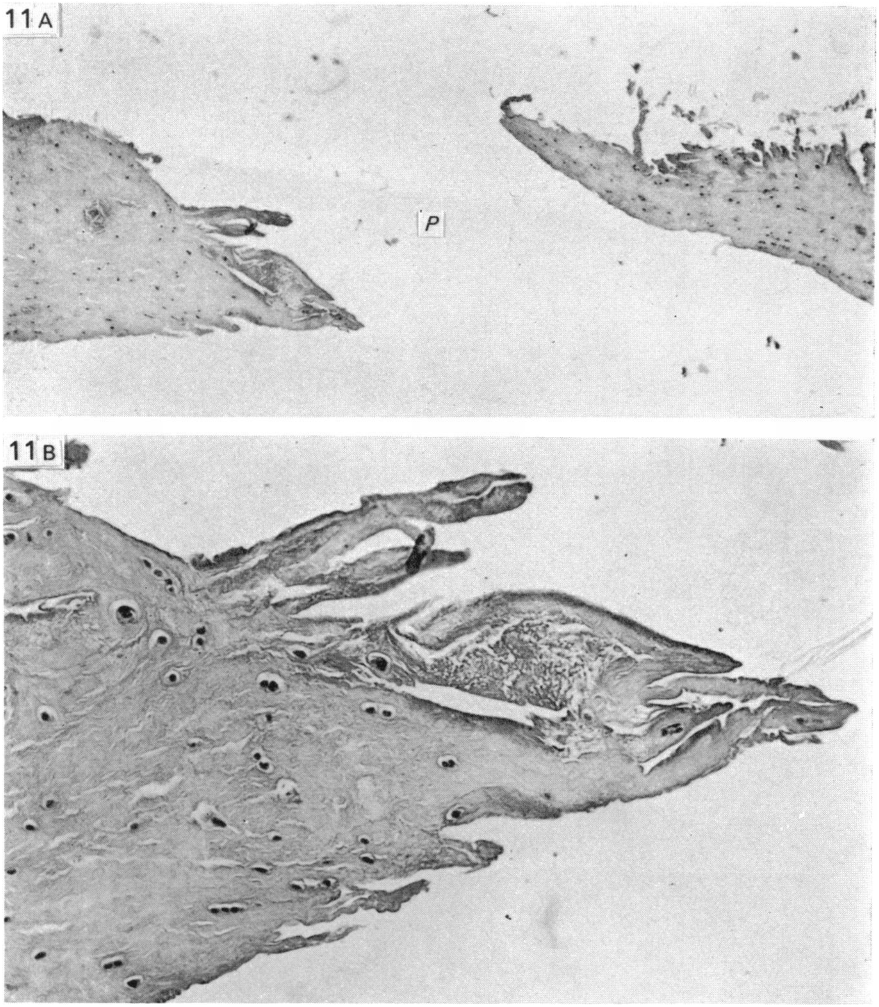
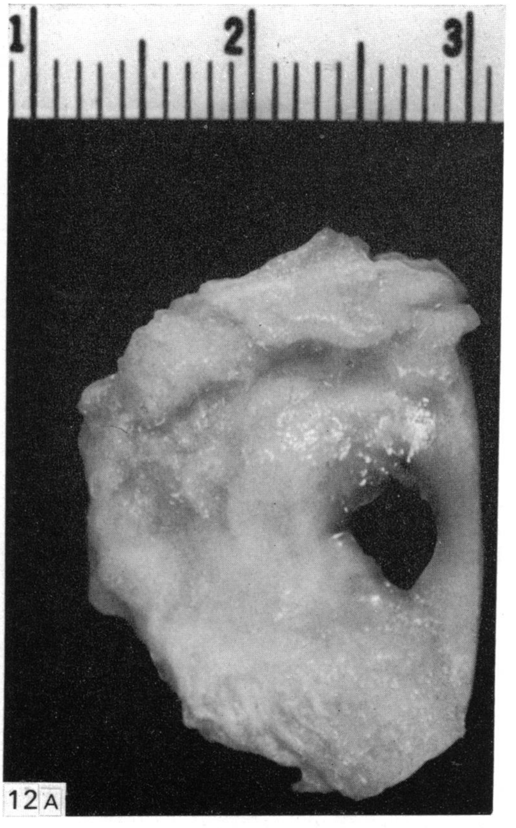


Fig. 11 (A). Transverse section of the perforation site in a disc obtained from a 50 years old subject. The edges of the perforation (*P*) are profoundly degenerated. Haematoxylin and eosin. × 25. (B) The same specimen. × 100.

discal half, while the radial half was normal (Figs. 15, 16). A similar difference in the incidence of degenerative changes on the ulnar head was also noted; the radial surface was never ulcerated, all changes being located on the discal surface (Fig. 16).

Lesions of the ulnar cartilage were most often found in cases where the disc, although altered, had not actually perforated. Advanced alterations on the lunate bone, however, were only found in cases where the disc had perforated, and they were always situated opposite the perforation (Fig. 15). The subchondral osseous tissue of the lunate bone also appeared to be involved in several cases, and this was confirmed radiographically (Fig. 17).

The wrist joints were examined bilaterally in 80 cases. Apart from the 35 subjects younger than 20 years and 5 from the third decade, in whom the joints were normal, there were 40 cases where degenerative changes on the two sides could be compared.



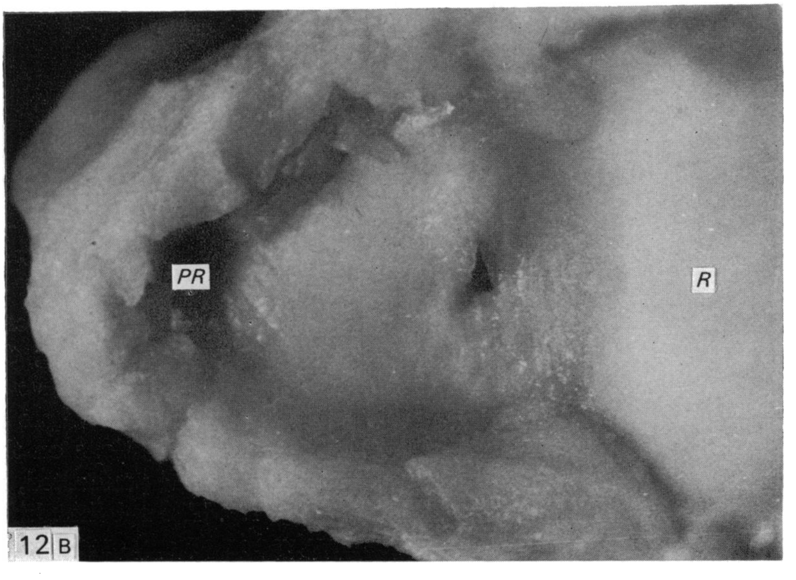
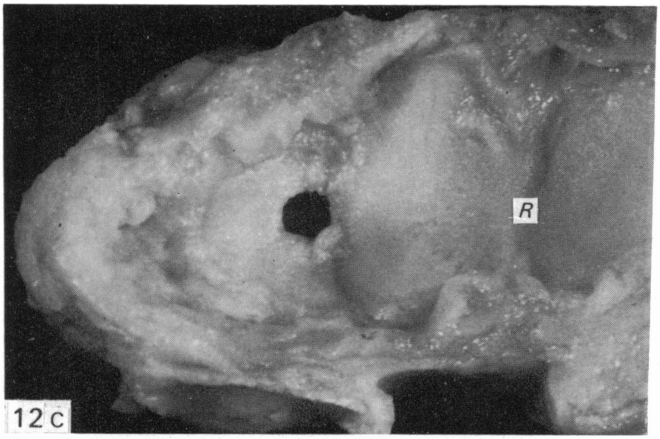
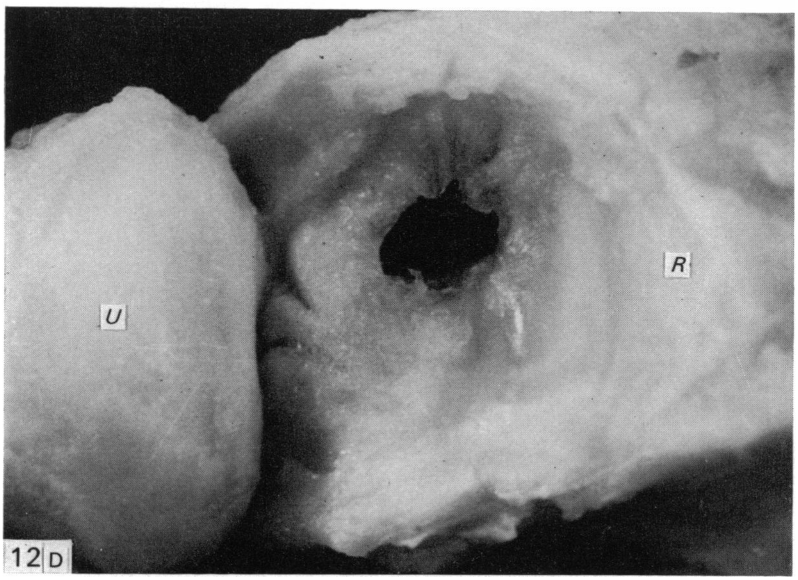


Fig. 12. Various forms of the disc perforations; view from the carpal side (A, B, C), and from the ulnar side (D). *R*, radius; *U*, ulna; *PR*, prestyloid recess.





Figs. 12C and D. For legend see opposite.

Equal changes were noted in 14 subjects, more intensive on the left in 14 and more on the right in 12 cases. Disc perforation was found 16 times on the left and 13 times on the right side.

A comparison was also made of the incidence of disc perforation in the two sexes. There were 36 joints examined in females older than 20 years; the disc was perforated in 14 cases (38·8 %). In males older than 20 years 73 joints were examined and disc perforation was found in 31 cases (42·4 %).

DISCUSSION

This study of the triangular fibrocartilage of the wrist joint has demonstrated clearly that this structure is very liable to regressive alterations which are basically the same as those found in similar intra-articular fibrocartilages in other joints

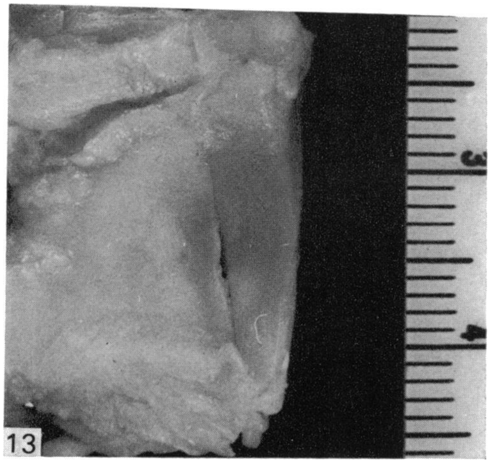


Fig. 13. A long fissure in the central part of the disc. Viewed from the carpal side.

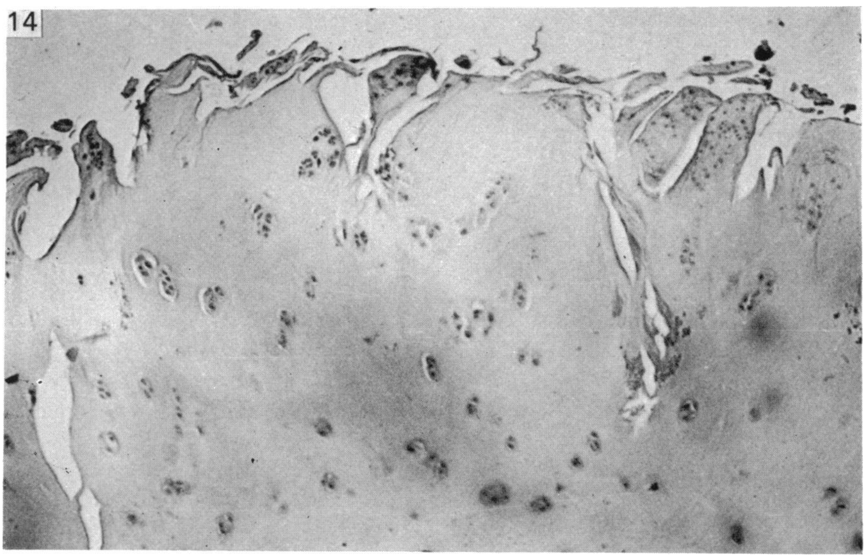


Fig. 14. Transverse section through the articular cartilage of the ulna adjacent to the triangular fibrocartilage showing fibrillation, shredding and fissuration. There is also cell proliferation in some areas. Haematoxylin and eosin. ×36.

(Tobler, 1929; Burman & Sutro, 1933; Niessen, 1934; DePalma, 1957; Barnett *et al.* 1961). There are, however, several features which are specific to the intra-articular disc in the wrist.

It was noticed by Lang (1942), and is confirmed by this study, that degenerative lesions are much more frequent and more advanced on the ulnar surface of the disc. This is consistent with the idea that biomechanical forces are more intensive on the ulnar side. The rotational movements during pronation and supination, producing a kind of drilling effect of the ulna on the disc, would appear to be much more stressful than the sample gliding movements of the carpal condyle which occur on the carpal side of the disc.

Table 4. *Incidence of gross degenerative changes of various wrist joint structures*

Age of subjects	Number of joints	Perforated interosseous ligaments between: Lunate and triquetral	Scaphoid and lunate	Gross alterations of articular bone surfaces of: Triquetral	Lunate	Scaphoid	Ulna	Radius
Fetuses	38	—	—	—	—	—	—	—
First decade	21	—	—	—	—	—	—	—
Second decade	12	—	—	—	—	—	—	—
Third decade	13	2	—	—	1	—	—	—
Fourth decade	11	3	3	—	2	—	—	—
Fifth decade	15	6	5	—	4	—	6	—
Sixth decade	21	14	7	—	4	—	7	—
Over 60 years	49	35	32	6	24	—	34	2
Total (over the third decade)	109	60	47	6 (5·5 %)	35 (32·1 %)	—	47 (43·1 %)	2 (1·8 %)

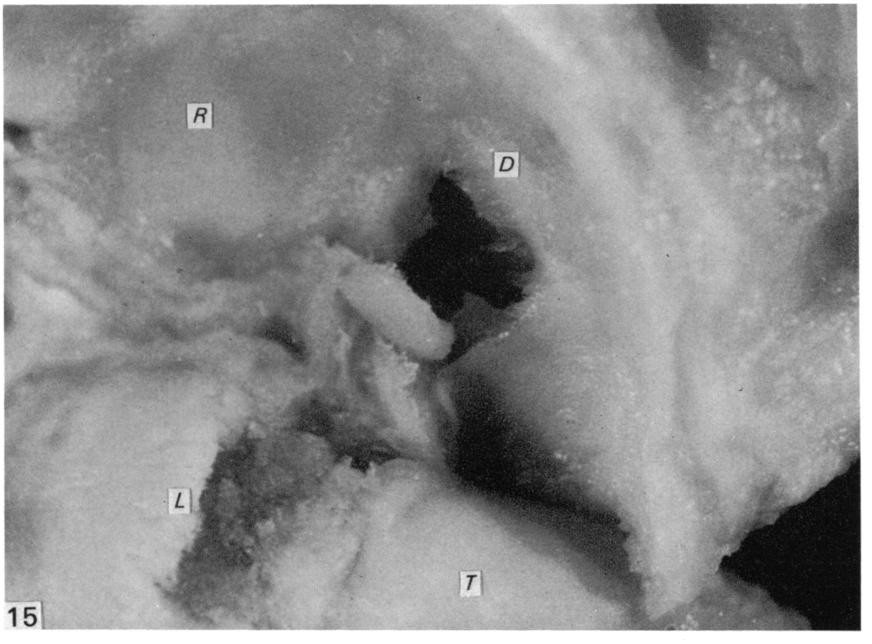


Fig. 15. Wrist joint of a subject aged 67 years opened from the dorsal side. *R*, radius; *D*, disc; *L*, lunate; *T*, triquetral bone. There is a large perforation of the disc and just opposite this there is profound ulceration on the lunate. The radial half of the lunate, the radius and triquetral are normal.

It is significant that degeneration occurs mostly in the thinner, central part of the disc, the thicker edges almost always escaping. This is probably due to the way the blood vessels in the triangular fibrocartilage are arranged. My investigations have shown that the major central portion of the disc is avascular, and only its peripheral parts are vascularized. Accordingly, one would imagine the central area of the disc to be particularly vulnerable, and predisposed to the early appearance of degenerative processes. Owing to the fact that its ligamentous borders remain intact for a

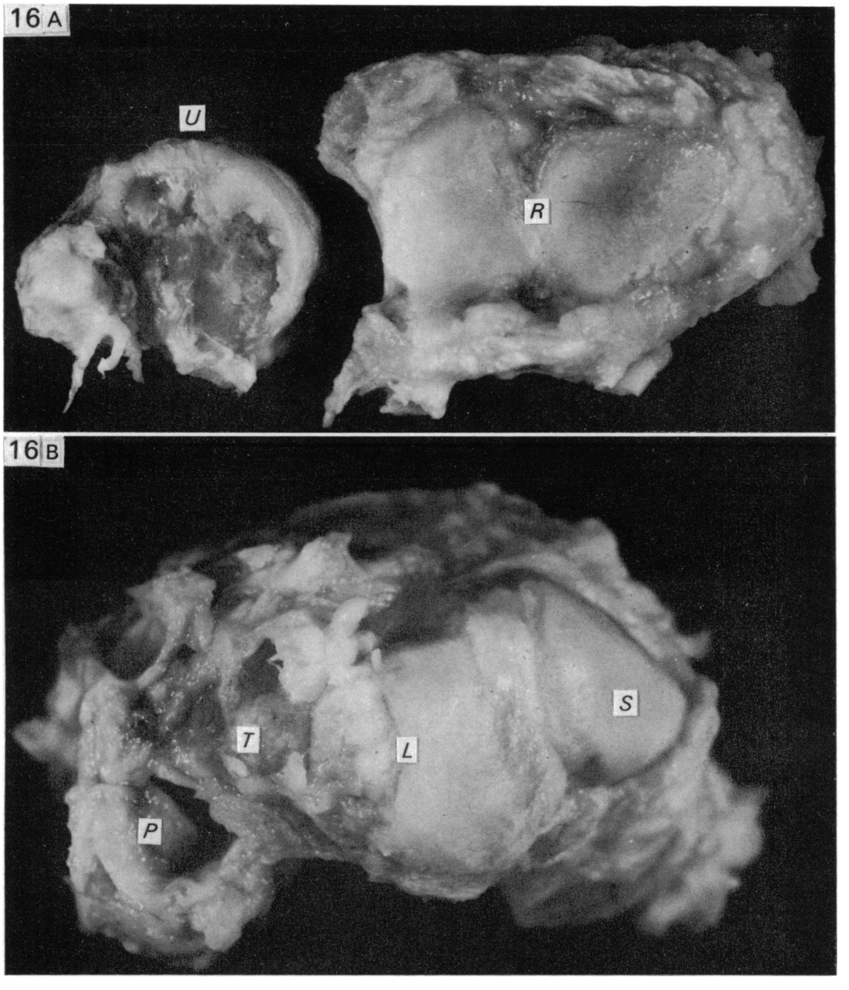


Fig. 16. The bone elements of the distal radioulnar and radiocarpal joints obtained from a subject 63 years old contrasting the discal with non-disease joint compartments. Whereas the discal surface of the ulnar head (*U*), the triquetral (*T*) and the discal half of the lunate (*L*) are grossly ulcerated, the radial surface of the ulnar head, radius (*R*), the pisiform (*P*), the radial half of the lunate (*L*), and the scaphoid (*S*) are in good condition.

long time, the disc remains capable of meeting functional demands; it continues to act as a powerful intra-articular ligament, providing for stability in the distal radioulnar joint (Lippmann, 1937; Rose-Innes, 1960; Heiple, Preehafer & Van't Hof, 1962).

It has been known for a long time that the triangular fibrocartilage of the wrist joint is sometimes perforated, but published accounts concerning the nature and incidence of the perforation vary considerably. Poirier & Charpy (1911) indicated the incidence of perforation as 40·3 %, Lanz & Wachsmuth (1935) as 25 %, and Grant (1944) as 30 %. Lang (1942) examined 19 wrist joints and found massive degenerative changes and perforations in 7 discs (36·6 %). He considered that the degenerative changes were the main cause of perforation, but he also suggested that trauma could produce defects. Liebolt (1950) found perforation in 30·6 % of cases

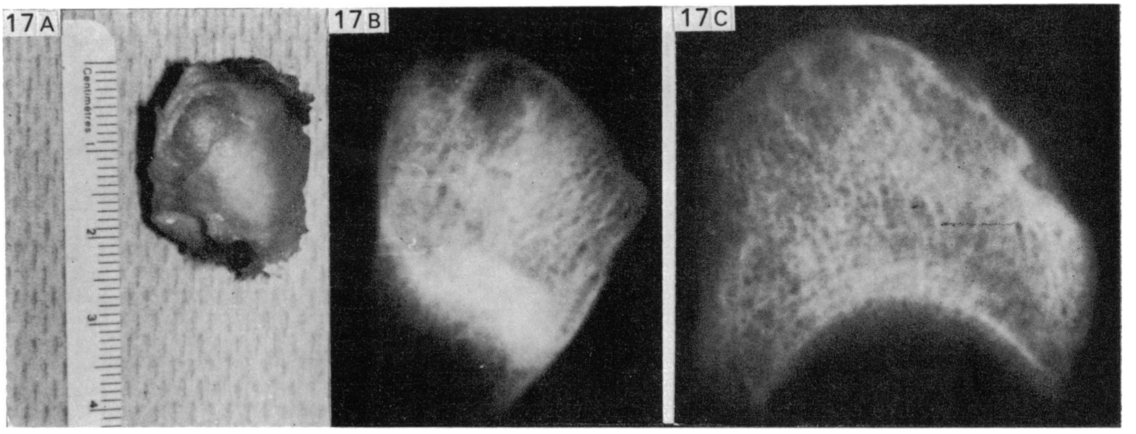


Fig. 17 (A). Lunate bone obtained from a subject aged 63 years; there is profound ulceration on the discal half of the bone. (B) Antero-posterior and (C) lateral radiographs of the same bone showing the radiographic appearance of the ulceration.

Fig. 18. A routine radiograph from a patient aged 60 years who sustained an injury to his right hand. Apart from the fracture, note the changes in the lunate, which are indicative of ulceration adjacent to a disc perforation.

and considered it congenital. Kessler & Silberman (1961) studied 60 wrist joints in anatomical specimens from individuals ranging in age from 14 to 76 years and found disc perforation in only 4 cases. They also expressed the opinion that trauma could cause perforation. Ranawat *et al.* (1969) found a perforation in 16 % of discs obtained from 50 cadavers whose ages ranged from 18 to 72 years. They suggested that unilateral perforations result from traumatic tears in the joint capsule of the wrist. Maraval-Bonnet (1969) studied 49 wrist joints in 35 cadavers. In 22 joints obtained from persons under 50 years of age she found 3 perforations (13·6 %), and in 27 joints obtained from persons over 50 years old there were 22 perforations (81·4 %). She concluded that disc perforation was degenerative in origin. Lewis, Hamshere & Bucknill (1970) found perforation in 60 % of discs, but mostly very old subjects were studied.

From the present study it is obvious that the incidence of perforation increases with age. There were no perforations in children and young people, but later they became more frequent, and in the later decades of life their incidence was rather high. Therefore, it is valueless to express the incidence of disc perforation without reference to age. Since all perforated discs show severe degenerative changes, both macroscopically and microscopically, and the incidence in perforation increases with age, one must conclude that perforation of the triangular fibrocartilage of the wrist joint occurs spontaneously as the last stage in a progressive degenerative condition.

Degenerative changes in other joint tissues occur almost exclusively in the disc joint compartment, there being a striking disparity between the articular surfaces adjacent to the triangular fibrocartilage and the other joint surfaces. This does not seem to have been noted previously. Lang (1942) and Maraval-Bonnet (1969) mention that they have seen ulcerations of the ulna and lunate in a few cases, but they do not pursue the matter.

It is obvious that there is close correlation between the changes in the disc and on the ulna and lunate which suggests that they are causally related, and possibly provoked by strong rotational forces in the disc joint segment, these forces presumably being of greater intensity than the gliding forces in the other joint compartments.

Changes on the surface of the lunate bone are only seen in cases where the disc has perforated, allowing rotational contact between lunate and ulna. Radiographic changes in the subchondral zone of the lunate bone, mentioned earlier (Fig. 17), can, therefore, be used in clinical practice as evidence of disc perforation (Fig. 18).

As the degenerative changes begin in the third decade and become progressively more frequent and more severe with advancing age, there is no doubt that fundamentally they are part of the ageing processes. However, the effects of the ageing process are modified by various factors. First of all, there are clearly constitutional differences: severely degenerated and perforated discs can be found in quite young individuals, the youngest in the present series being only 27 years old. On the other hand, moderate degeneration without perforation can be found in the very old, the oldest in this series being 92 years.

It has been argued that biomechanical factors are important. However, it is interesting that there are no significant differences in the incidence and severity of degenerative changes as between the two sexes and as between left and right sides.

Lang (1942), Kessler & Silberman (1961), and Ranawat *et al.* (1969) suggested that trauma was the principal factor in disc degeneration but the findings in the present study make it clear that disc degeneration is basically a spontaneous, natural process. Of course, it is highly probable that trauma, including occupational trauma, is an added factor and will accelerate changes in a disc which has started to degenerate.

Hoegen & Reske (1956) suggested that metabolic factors may be involved. In this connexion one recalls the solitary example of a perforated disc without macroscopic degenerative changes which came from a uraemic subject.

SUMMARY

On the basis of a study of 180 wrist joints from 100 fresh cadavers of individuals ranging in age from fetuses to 94 years, it is concluded that the triangular fibrocartilage is very liable to degenerative alterations associated with ageing. Degeneration begins in the third decade and progressively increases in frequency and severity in subsequent decades. The changes comprise reduced cellularity, loss of elastic fibres, mucoid degeneration of the ground substance, exposure of collagen fibres, fibrillation, erosion, ulceration, abnormal thinning, and, ultimately, disc perforation. The changes are more frequent and more intense on the ulnar surface, and they are always situated in the central part of the disc. It appears that disc perforation is degenerative and age-related: thus there were no perforations in the first two decades of life; in the third there were 7·6 %, in the fourth 18·1 %, in the fifth 40·0 %, in the sixth 42·8 %, and in the over sixties 53·1 %.

There was an associated pattern of degenerative changes in the wrist joint as a whole. The structures adjacent to the articular disc (discal surface of the ulnar head, discal part of the lunate) were much more often involved, and the changes were much more advanced, than on non-discal surfaces. It is argued that this is because of more intensive biomechanical forces, particularly rotational forces, in the disc compartment of the joint.

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