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Cartilage fibrillation on the lateral tibial plateau in Liverpool necropsies

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INTRODUCTION

Studies of the state of the articular surface of various synovial joints have recently been made at necropsies from the Liverpool population (Emery & Meachim, 1973; Meachim & Emery, 1973). In the case of the knee, the patello-femoral and tibio-femoral articulations have initially been treated separately, since these two regions of the joint may alter independently of one another in disease as well as in normal ageing (Meachim, unpublished observations). Results for the patello-femoral articulation have been described previously (Emery & Meachim, 1973; Meachim & Emery, 1974). The present findings concern the state at necropsy of the hyaline articular cartilage of the adult tibial plateaux, with particular reference to the lateral plateau. The state at necropsy of the fibrocartilaginous menisci of the knee is the subject of a separate study (Meachim, unpublished).

The surface morphology, topographical distribution and natural history of upper tibial articular cartilage lesions are described for the bare area of the lateral plateau and its meniscus-covered segments, and quantitative, age-related, point-counting data is presented for the amount of overt fibrillation on the bare area.

MATERIAL AND METHODS

The upper end of the left tibia was obtained from the knee joint at necropsies in the city of Liverpool on a random series of 47 white Europeans (24 men; 23 women) aged between 21 and 88 years. Joints with evidence of inflammatory disease, disuse atrophy, old or recent injury, previous surgery such as meniscectomy, chondrocalcinosis, or congenital discoid meniscus, were excluded.

The specimens were collected into physiological saline. In the laboratory the surface of the hyaline articular cartilage of the left lateral tibial plateau was painted with India ink, after reflecting the lateral meniscus. The technique used has been described previously (Meachim, 1972). The articular surface, moist and unfixed, was examined *en face* by stereomicroscopy at a magnification of $\times 10$. When necessary, tangential surface slices were also examined, by transmission light microscopy at $\times 150$ (Meachim, 1972). The part of the surface not covered by meniscus was photographed with a Polaroid Land camera set at a magnification of $\times 3$. For point-counting of this bare area of the cartilage, a grid, with points arrayed at the corners of squares, 5 mm^2 in size, was superimposed over the photographic prints.

In ten of the subjects the left medial tibial plateau was also painted and its bare area point-counted.

RESULTS

The articular surface of the hyaline cartilage of the lateral tibial plateau shows a bare area, not covered by meniscus, and a meniscus-covered part (Fig. 11). For descriptive purposes, the meniscus-covered part was arbitrarily subdivided into a posterior, a lateral and an anterior segment (Fig. 11).

The *en face* appearance of the hyaline articular surface of the lateral tibial plateau differed according to the age of the subject and the region of the surface examined. The following account lists the main types of surface appearance encountered. Their usual, although not invariable, topographical distribution on the lateral plateau is shown according to age in Table 1; lesions with bone exposure are not included in this Table.

Intact sites

At intact sites the cartilage surface showed no distinct ink markings when examined *en face* (Fig. 1); vertically cut histological sections from such sites have confirmed that their surface presents a line free from sharply angled irregularities when examined at a magnification of × 150 (Meachim, 1972). In the case of the bare area and of the meniscus-covered posterior segment of the lateral plateau, intact sites on parts of the cartilage were much more common in younger than in older adults (Table 1). In the case of the anterior and, especially, the lateral meniscus-covered segments, the

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Fig. 1. Part of an upper tibial articular surface. Man aged 56 years. The periphery of the cartilage sheet is near the right of the field. Overt fibrillation, stained black, is shown at the upper left. In contrast, the intact cartilage is unstained. In this and in some of the subsequent illustrations, pieces of para-articular fibrofatty tissue are included in the photographic field, and it should be noted that the para-articular tissue normally stains black. This and all subsequent photographs are of India ink preparations from the left lateral tibial plateau, as seen after removing or reflecting its meniscus. × 2.

Fig. 2. Photomicrograph of a tangential surface slice, showing ink markings in one of a variety of *en face* patterns of minimal fibrillation. Transmitted light. × 150.

Fig. 3. Photomicrograph of minimal fibrillation with an *en face* pattern showing a major component of approximately straight, fine lines. A segment of a partly loosened elongated strand of tissue is seen across the lower part of the field (arrow). Tangential surface slice. Transmitted light. × 150.

Fig. 4. 'Ravines' (*R*) and artificial splits (*S*). Woman aged 28 years. × 2.

Fig. 5. Another example of 'ravines' (*R*). Note also the overt fibrillation, stained black, at the left and centre of the field. Artificial splits (*S*). Woman aged 40 years. × 2.

Fig. 6. Photomicrograph of overt fibrillation viewed *en face*. Frank disintegration of the surface with numerous flaps of partly loosened tissue. Tangential surface slice. Transmitted light. × 150.

Fig. 7. Bone exposure (*B*) on part of the lateral tibial plateau of a woman aged 85 years. Parallel grooving of the bone surface, due to abrasive wear, is indicated by the linear highlights, just visible on the left of the field. Overtly fibrillated cartilage, stained black, occupies the rest of the original articular surface. Osteophytic lipping (*L*) is also seen. × 1.

Fig. 8. The same specimen as that shown *en face* in Fig. 7, but here tilted and rotated to give another view of the osteophytic lipping (*L*). × 1.


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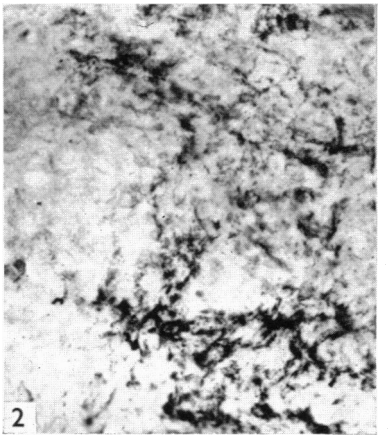
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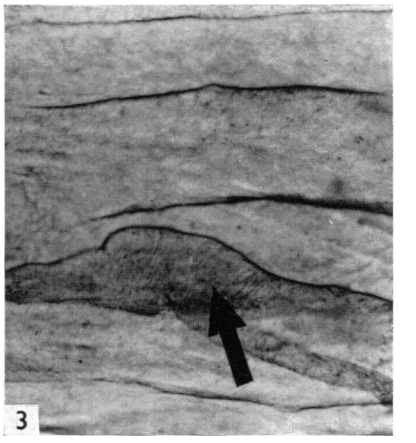
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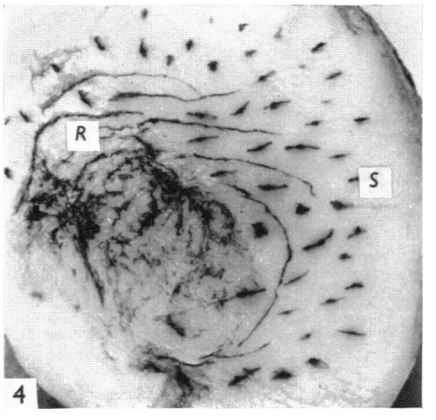

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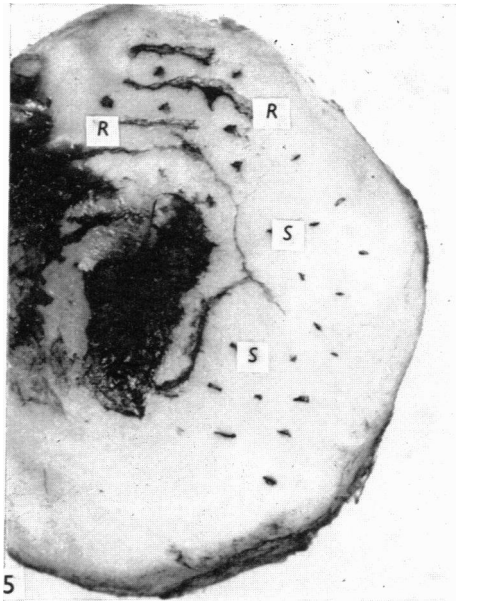

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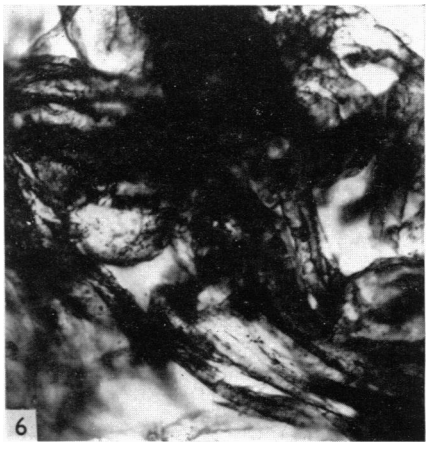
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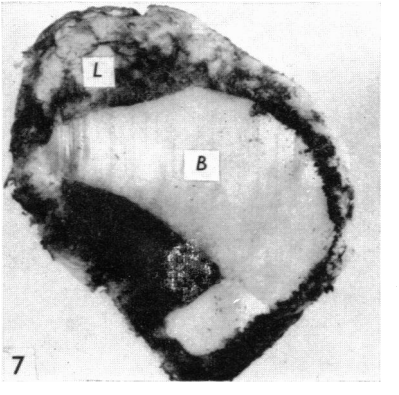

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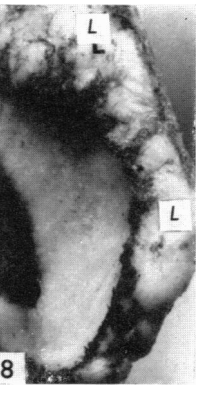

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Table 1. *Articular cartilage fibrillation on the left lateral tibial plateau: usual, but no invariable, topographical distribution according to age. The distribution of bone exposure is not shown*

	Age range (years)		
	21–40	41–60	61–88
Bare area	Intact and minimal with 0–35 % overt; ravines in some	Conversion to extensive overt	72–100 % overt
Meniscus-covered posterior segment	Mainly intact or, less often, variable amount overt and minimal; ravines in some	Conversion to extensive overt	Extensive overt ± localized incomplete defect
Meniscus-covered lateral segment	Mainly intact ± peripheral minimal; ravines in some	Mainly intact ± peripheral minimal; ravines in some	Mainly intact ± peripheral minimal or peripheral overt; or, less often, variable amount overt and minimal
Meniscus-covered anterior segment	Mainly intact ± small patches overt	Mainly intact ± small patches overt	Mainly intact ± small patches overt; or variable amount overt and minimal

surface was mainly intact in most of the younger adults (Figs. 10, 11), and continued to be mainly intact even in some, although not all, of the subjects aged 61–88 years (Table 1).

Minimal fibrillation

At sites of minimal fibrillation the cartilage surface showed dark ink markings against a pale grey background when examined *en face* by light microscopy (Fig. 2). Histological sections cut vertically through such sites have shown a very superficial splitting when examined at a magnification of × 150 (Meachim, 1972). 'Under-cut' ridges and other irregularities of the surface contour are seen as a feature of this phenomenon, as can be demonstrated by study of the surface profile in photomicrographs of vertical sections (Meachim, 1972, Figs. 14–19). This feature may be related to the 'quaternary surface irregularities' observed by Longmore & Gardner (1975) on cartilage surfaces deteriorating with age. They noted 'small irregular ridges' on such surfaces examined *en face* by interference microscopy.

On the lateral tibial plateau, sites of minimal fibrillation were encountered, for example, on the bare area of the upper tibial cartilage in younger adults, and at the periphery of the meniscus-covered lateral segment in some of the subjects from all age groups (Table 1). The markings of minimal fibrillation presented a variety of patterns when examined *en face* at a magnification of × 150 (Figs. 2, 3). One such pattern is shown in Fig. 2. Some of the other patterns showed a major component of approximately straight, fine lines, and the specific form of this pattern illustrated in Fig. 3 was sometimes sufficiently well developed to be macroscopically apparent; it could be accompanied by partly loosened, elongated strands of tissue (Fig. 3)

Table 2. *Percentage of the surface of the bare area of the tibial cartilage occupied by overt fibrillation and percentage of the surface exhibiting bone exposure*

Comparison between the left lateral and left medial tibial plateaux of the same subject. Note that the meniscus-covered cartilage (Table 1) was not included in this comparison.

Age (years)	Sex	Left lateral		Left medial	
		Overt fibrillation (%)	Bone exposure (%)	Overt fibrillation (%)	Bone exposure (%)
28	Woman	31	0	13	0
28	Man	0	0	0	0
40	Woman	35	0	15	0
49	Woman	90	0	28	0
62	Woman	76	0	31	0
80	Man	72	0	13	0
81	Woman	87	0	96	0
85	Woman	88	0	94	0
85	Woman	57	43	91	4
88	Woman	96	4	96	0

visible at × 10. This macroscopically apparent 'parallel linear' pattern had a moderate incidence on the tibial plateau. Its markings were orientated in a similar direction to that taken by elongated artificial splits made by pricking the cartilage surface with the round point of a pin (Meachim & Fergie, 1975).

'Ravines'

'Ravines', as illustrated in Figures 4 and 5, were encountered on some of the lateral plateaux, particularly in younger adults. They can occur on the bare area and on the meniscus-covered posterior and lateral segments (Table 1). When fully developed, 'ravines' showed a deeper splitting than that of minimal fibrillation. They had a tortuous, or curvilinear, or approximately straight contour when viewed *en face*. Their orientation in relation to that of nearby artificial splits varied, being parallel, or acutely angled, or at right angles (Figs. 4, 5).

Overt fibrillation

Sites of overt fibrillation gave a confluent or semi-confluent blackening in India ink preparations (Fig. 1). When examined *en face* at a magnification of × 150, they showed frank disintegration of the surface, with numerous flaps of partly loosened tissue (Fig. 6). Vertically cut histological sections from such sites have indicated that this frank splitting often affects only the superficial layer (zone 1) of the articular cartilage (Meachim, 1972), although in other instances it can be accompanied by a major element of destructive thinning of the tissue, which tends eventually to expose bone (Fig. 7).

The bare area of the tibial hyaline cartilage and the meniscus-covered posterior segment (Fig. 12) of the lateral plateau were more susceptible to overt fibrillation than were the anterior and, especially, the lateral meniscus-covered segments

(Table 1). In the case of the bare area, the percentage of its surface affected by overt fibrillation was measured by point-counting a photographic print of each specimen of lateral plateau. The individual results are shown in Figure 9 and summarized in Table 1. In two of the specimens there was also full-thickness cartilage destruction with bone exposure on part of the bare area (Fig. 7). In Figure 9 and Table 1 the results for these two specimens are shown as the sum of the percentage of exposed bone added to the percentage of overtly fibrillated cartilage. The percentages shown separately for these two specimens are given at the bottom of Table 2.

In the age group 21–40 years, 0–35 % of the bare area of the lateral plateau was affected by overt fibrillation. In contrast, 72–100 % was affected in the subjects aged 61–88 years. Thus during the age period 41–60 years the bare area shows, subject to variation between individuals, a relatively rapid development of extensive overt fibrillation (Fig. 9). A similar phenomenon was noted on the meniscus-covered posterior segment (Table 1).

Localized incomplete defect of the cartilage

In some of the older subjects, overt fibrillation of the lateral plateau was accompanied by a macroscopically apparent incomplete defect of the cartilage, localized to part of the meniscus-covered posterior segment. In the defect there was a localized thinning of the articular cartilage to a variable depth below the original plane of its surface, but no bone exposure. This incomplete defect had a rounded or elongated shape *en face*.

Bone exposure and osteophytic lipping

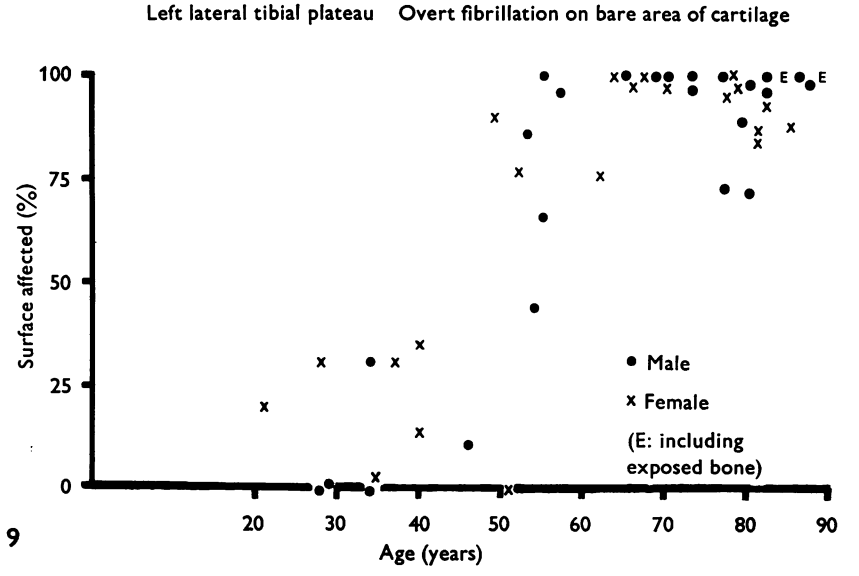
The incidence of bone exposure (Fig. 7) and of peripheral osteophytic lipping (Fig. 8) on the left upper tibia, taking both the medial and the lateral plateaux, was as follows:

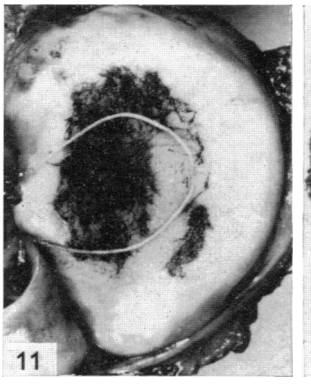
(1) Of the 16 subjects aged 21–54 years, none showed upper tibial osteophytosis nor bone exposure.

(2) Of the 19 subjects aged 55–79 years, 4 showed upper tibial osteophytic lipping, but none showed bone exposure.

(3) Of the 12 subjects aged 80–88 years, 2, both women, showed upper tibial bone exposure and osteophytosis. None showed osteophytosis without bone exposure.

In the two elderly women with upper tibial bone exposure and osteophytic lipping, the bone exposure was of osteoarthritic type (Fig. 7), with evidence of abrasive wear of the exposed bone surface. The opposing femoral surface also showed bone exposure and abrasive wear. On the lateral plateau the exposed bone formed a confluent lesion *en face*. In one of the women this lesion occupied (Fig. 7) all of the lateral segment originally covered by meniscus, as well as adjacent regions on the meniscus-covered posterior and anterior segments, and an adjacent region on the original non-covered area. In the other, exposed bone occupied most of the lateral segment originally covered by meniscus, also an adjacent region on the meniscus-covered posterior segment, and an adjacent small region on the original non-covered area. In both of these subjects the lateral meniscus overlying the exposed bone showed disintegration on naked eye examination, but the site of the original boundary between the meniscus-covered segments and the bare area could still be estimated





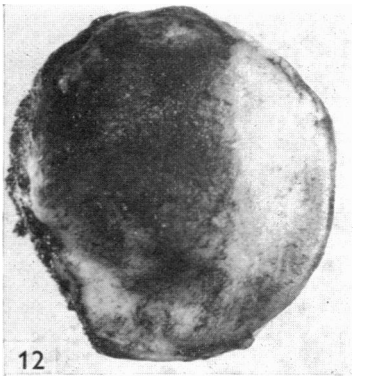


Fig. 9. The individual results for the percentage of the surface of the bare area of the left lateral tibial plateau involved by overt fibrillation of the hyaline articular cartilage. Note that meniscus-covered cartilage is not included in these results. In two of the subjects, both women, there was upper tibial bone exposure, and the percentage shown for these subjects (*E*), is the sum obtained by adding the percentage of fibrillated cartilage to the percentage of exposed bone.

Fig. 10. Left lateral tibial plateau from a woman aged 28 years. Overt fibrillation (stained confluent black) and minimal fibrillation (stippled appearance) on part of the bare area (left centre). 'Ravines', seen mainly on the meniscus-covered posterior (above centre) and lateral (right of centre) segments. The rest of the cartilage surface is intact and unstained. Parameniscal fibrofat is stained black. Part of this surface is also shown in Fig. 4. × 1.

Fig. 11. Left lateral tibial plateau from a man aged 55 years. The meniscus has been reflected to the left. The curved marker shows the boundary between the bare area (centre) and the meniscus-covered posterior (top), lateral (right) and anterior (bottom) segments. Overt fibrillation stained black. The rest of the hyaline cartilage was mainly intact, although it also had some sites of minimal fibrillation. × 1.

Fig. 12. Left lateral tibial plateau from a woman aged 86 years. Overt fibrillation (stained black) and minimal fibrillation (stippled appearance). Extensive overt fibrillation on the bare area (centre) and on the meniscus-covered posterior segment (top). The meniscus-covered anterior segment (bottom) is partly occupied by overt fibrillation. The meniscus-covered lateral segment (right) is partly intact and partly shows minimal fibrillation. × 1.

by reference to plateaux in subjects not showing bone exposure. It is of interest that neither of the two women with left tibio-femoral bone exposure showed bone exposure on the left patellar surface, although both had patellar osteophytic lipping. Conversely, four other subjects, aged 69, 78, 85 and 86 years, showed left patello-femoral bone exposure without left upper tibial bone exposure.

Comparison between the lateral and the medial tibial plateau

On the medial plateau, the bare area of the tibial hyaline cartilage was more susceptible to overt fibrillation than were the meniscus-covered segments. In contrast to the findings on the lateral plateau, there was no evidence that susceptibility to overt fibrillation was greater on the meniscus-covered posterior segment than on the meniscus-covered anterior and lateral segments.

The percentage of the surface of the medial bare area affected by overt fibrillation was compared with that of the lateral bare area of the same knee in ten subjects. The results are shown in Table 2. It will be seen that the surface percentage of overt fibrillation, or of overt fibrillation plus bone exposure, was usually higher on the lateral bare area. This result may be related to the smaller total size of the lateral, as compared with the medial, bare area. In the women the lateral bare area showed an average of 64 total points (range 44–95) in $\times 3$ photographic prints, while the medial bare area gave an average of 114 total points (range 87–141).

In the two specimens showing osteoarthritic bone exposure on the upper tibial articular surface, the total amount of exposed bone was much greater on the lateral than on the medial plateau.

DISCUSSION

Bennett, Waine & Bauer (1942) have previously described the state of the tibial plateaux at necropsy. Their observations relied mainly on naked-eye examination of unstained surfaces. The present study was made instead on cartilage surfaces painted with India ink. For this reason detailed comparison with the results of previous studies cannot be made, although in fact no obvious inconsistencies have been noted. India ink methods render minor alterations of the surface more apparent, they allow microscopical examination *en face* of minor and major alterations, and they facilitate mapping and quantitation of the changes seen.

The present results indicate that sites of superficial fraying and splitting of the articular cartilage are a normal finding on the adult human tibial plateaux, as is the case with the cartilage of other adult synovial joints (Meachim & Emery, 1973). Especially in younger adults, such sites are often accompanied by large areas of cartilage surface which is still intact.

The cartilage lesions observed on the lateral tibial plateau show a variety of morphological patterns *en face*: macroscopically apparent 'parallel linear' minimal fibrillation; other patterns of minimal fibrillation; 'ravines'; overt fibrillation; localized incomplete defects; and full-thickness cartilage loss with bone exposure. This morphological spectrum, also observed at other anatomical sites, but differing in detail according to site, has suggested that more than one mechanism may be concerned in the local pathogenesis of cartilage damage (Meachim & Fergie, 1975). Some of the patterns found on the lateral tibial plateau and elsewhere show alignment

in one main direction. It is then possible to study the relationship, if any, of this direction to that taken by elongated artificial splits made by pricking adjacent cartilage with a round pin, and the relationship to joint movement at sites where this is uni-directional. Such studies are relevant to discussions of the pathogenesis of the lesions, and have been described elsewhere (Meachim & Fergie, 1975).

The present findings show that susceptibility to overt fibrillation varies between different regions of the lateral tibial plateau, as is the case with the cartilaginous cover on the patello-femoral and other synovial joints (Emery & Meachim, 1973; Meachim & Emery, 1973). Study of the upper tibial articular surface thus confirms that fibrillation is influenced by the local biomechanical environment and local character of the cartilage (Emery & Meachim, 1973).

On most articular surfaces, such as those of the patella, the distal femur, the hip and the shoulder, overt fibrillation initially affects the periphery of the cartilage sheets and certain other characteristic sites (Emery & Meachim, 1973; Meachim & Emery, 1973). The present study has shown that the peripheral rim of the upper tibial cartilage sheet was often free from overt fibrillation, although there was some susceptibility to minimal change at the periphery of the meniscus-covered lateral segment. This exception to the general state of affairs on other surfaces might be due to protection afforded by the overlying meniscus. Similarly, the susceptibility of the bare area of the tibial cartilage has been attributed to the absence of such protection (Bullough, Munuera, Murphy & Weinstein, 1970). However, meniscal protection cannot provide a full explanation for the topographical distribution of the articular cartilage lesions, since the present study has demonstrated that the meniscus-covered posterior segment of the lateral plateau is also susceptible to overt fibrillation.

Once initiated in the young adult it would appear that overt fibrillation has, with increasing age, a tendency to involve an increasing area of the cartilage surface. This potential for tangential enlargement varies between different joints. In the case of the lateral tibial plateau, the present study has shown an age-related tangential progression of overt fibrillation leading in older persons to extensive involvement of the bare area and of the meniscus-covered posterior segment. The quantitative data obtained for the bare area indicate that the rate of this tangential progression is comparatively slow in terms of the total life span of an individual. There is also some variation in the rate between different individuals, although a major proportion of the bare area had been affected in all the subjects by the time they have reached 61–88 years of age.

The initiation and tangential spread of fibrillation often implies only a superficial disintegration, affecting the surface layer without any major thinning of the cartilage. In contrast, vertical progression of the lesions is a more crucial phenomenon in terms of loss of the protective function of articular cartilage on the underlying bone. Such progression can thin the cartilage, potentially exposing bone, which is then liable to abrasive and other damage (Emery & Meachim, 1973). Previous studies have shown that this vertical progression of cartilage lesions is neither always inevitable nor, when it does occur, always relentless; but is instead dependent on the local biomechanical environment and other factors (Emery & Meachim, 1973). Moreover, the potential for vertical progression varies between different joints and between different individuals. In the case of the tibio-femoral articulation, bone exposure and

abrasive wear was found at necropsy during the present study in only 2 of 12 subjects aged 80–88 years, and in none of the subjects younger than this.

SUMMARY

A study has been made of the state at necropsy of the hyaline articular cartilage of the left tibial plateaux, with particular reference to the lateral plateau, in 47 adult white Europeans (24 men; 23 women) aged 21–88 years. The surface morphology and topographical distribution of the lesions is described for the bare area of the lateral plateau and its meniscus-covered segments, and quantitative point-counting data are presented for the amount, according to age, of overt fibrillation on the bare area.

A variety of cartilage lesions was encountered: macroscopically apparent 'parallel linear' minimal fibrillation; other patterns of minimal fibrillation; 'ravines'; overt fibrillation; localized incomplete defects of the cartilage; and full-thickness cartilage loss with bone exposure. Sites of superficial fraying and splitting of the hyaline articular cartilage are a normal finding on adult human tibial plateaux. Especially in younger adults, such sites are often accompanied by large areas of cartilage surface which are still intact.

On the lateral plateau, the bare area and the meniscus-covered posterior segment are more susceptible to overt fibrillation than are the meniscus-covered lateral and anterior segments. In contrast to the findings in other synovial joints, the peripheral rim of the upper tibial cartilage sheet is not particularly susceptible to overt fibrillation.

Tangential extension of the changes on the lateral plateau leads to widespread involvement of the bare area and the meniscus-covered posterior segment in older subjects. However, vertical progression of the changes, sufficient to give full-thickness cartilage loss with tibio-femoral bone exposure, was seen in only a minority of persons aged over 80 years.

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