A *post mortem* study of the hip joint

Including the prevalence of the features of the right side

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An investigation of the appearances of the hip joint at all ages was undertaken in order to study the pathogenesis of osteoarthrosis. The purpose of the investigation was partly to provide background experience for assessing the effects of osteotomy and partly to explore the thesis that the pathogenesis might be of more than one kind, an idea which is inherent in the clinical observation of Kellgren and Lawrence (1961) that osteoarthrosis is a heterogeneous condition.

It is a widely held opinion that all changes of a degenerative character are at least potentially 'arthritic'; Kellgren (1961) stated that the anatomical changes of osteoarthrosis became almost universal in the later decades of life. When expressions such as 'wear and tear' of cartilage and 'age changes' are used, they are generally employed with the connotation that such changes are part of, or the same as, the osteoarthrotic process. Such ideas are based on pathological studies; the work of Heine (1926), Bennett, Waine, and Bauer (1942), and Collins (1949) may be particularly mentioned. More recently Sokoloff (1967) has stated that no age correlated change has been found in nonarthritic cartilage after cessation of growth. The difficulty in interpreting such a statement as this is to know what is meant by nonarthritic cartilage.

Notwithstanding the foregoing, our preliminary observations of *post mortem* hip joints suggested that in this joint there are at least two types of alteration in cartilage: a commonly occurring type of limited progression that neither exposes bone nor gives rise to joint deformity, and a less frequent form in which bone is exposed and progressive anatomical deformity ensues. This led to the formulation of the hypothesis that there are limited changes in the cartilage of the hip joint related to the ageing process, and that, independently of these, there are progressive degenerative changes that can be regarded as a disease process. The relationship of osteophytes to these two processes was uncertain and remained open to investigation.

This study of *post mortem* hip joints is designed to test the above hypothesis. The work is based essentially on an anatomical study of the right hip joint together with radiographic information about the condition of other joints. The present paper reports the characteristics of the femoral head and the acetabulum in autopsy material unselected for osteoarthrosis. The stability of these characteristics has been tested and their association with age and sex established.

Methodology

MATERIAL

The specimens were obtained at autopsies carried out at the London Hospital. The planned procedure was to x-ray before *post mortem* examination the pelves and hands of all cadavers autopsied during one year and then to remove first the femur and then the acetabulum. Day-to-day circumstances determined the selection of bodies and the collection of specimens, both of which were irregular. Because of this the collection of material was extended to 2 years, during which time 375 right femoral heads and 363 right acetabula were obtained from 384 cadavers; this represented about half the autopsy examinations.

In addition the left femoral heads were obtained from 154 of these cadavers.

All specimens were preserved in 10 per cent. formalin. Pelvic x rays were obtained in 159 cases; 152 of these cases also had hand x rays. In 34 other cases the hands only were x-rayed, making a total of 186 hand x rays.

Table I (overleaf) shows the age and sex distribution of the population from which specimens were collected as well as the number and distribution of the specimens.

THE NORMAL JOINT

Femoral heads and acetabula without blemishes were considered normal (details below).

Table I *Age distribution of cadavers from which specimens were obtained, the right femoral heads and acetabula being also classified by sex*

Decades of age (yrs)			—9	—19	—29	—39	—49	—59	—69	—79	—89	*Total*
No. of cadavers			10	9	7	17	37	96	127	68	13	384
Femoral heads	Right	Male	7	7	2	9	20	52	77	31	8	213
		Female	3	2	4	8	17	42	47	34	5	162
		Total	10	9	6	17	37	94	124	65	13	375
	Left		0	1	2	2	15	36	56	35	7	154
Acetabula	Right	Male	7	7	2	8	20	51	73	31	8	207
		Female	3	2	4	8	16	40	45	34	4	156
		Total	10	9	6	16	36	91	118	65	12	363

FEATURES DIFFERING FROM NORMAL

A classification of these was made by studying successive groups of 25 to 30 specimens until no new appearances were discovered. Both maceration of some specimens and fine detail *x* rays of 3-mm. slabs of the remainder were used in the analysis.

The appearances were found to affect particular regions of the head or acetabulum, and to have a fairly constant and characteristic gross appearance which progressed through recognizable stages. The combination of anatomical site and gross appearance was used to define the features found (Figs 1 and 7). Simple size categories were also established. Feature cards were used to record the findings.

STABILITY OF THE ABNORMAL FEATURES

An assessment of observer variability was made at the end of the study. Although three observers took part in the work, one of these examined most of the specimens either jointly or in review, and the important aspect of stability is this observer's variability. This was assessed separately for each characteristic and the variation observed resembled that in most biological work.

For some of the features the alternatives were dichotomous, but for others they formed an ordered series. Unfortunately, in situations like this, there is no satisfactory index that assesses the effect of overall variability on the agreement observed. It thus seems more satisfactory to exemplify the variation observed with two features that are particularly germane to the hypothesis under test: Feature 9 for the femoral head and Feature 8 for the acetabulum. The data for this is shown in Table II. There was 73 per cent. complete agreement and a rank-order correlation coefficient of 0·83 for the first, and 84 per cent. complete agreement and a correlation coefficient of 0·74 for the second.

Table II *Patterns of agreement, showing results of calculations for complete agreement and rank-order correlation*

A *Femoral head, Feature 9*
 Between two trial readings by one observer of features in 37 heads

Stages	First reading					
	0	1	2	3	4	5
0		3	1			
1		17				
2			3	3		
3						
4		1		2	5	
5						2

(*Second reading* down the left)

Complete agreement—73 per cent.
Rank-order correlation coefficient—0·83.

B *Acetabulum, Feature 8*
 Between two trial readings by one observer of features in 26 acetabula

Stages	First reading				
	0	1	2	3	4
0	7	1	2		
1		8			
2			3		
3			2	2	
4					1

(*Second reading* down the left)

Complete agreement—84 per cent.
Rank-order correlation coefficient—0.74.

Results

The majority of the observations fall readily into two groups:

(1) Ossification of the margins of the cartilage (osteophytes);

(2) Breakdown and loss of cartilage.

The latter process took place at particular sites. In most places it was limited in its progression, did not go on to exposure of bone except in very rare instances, and caused no joint deformity. In a few sites the degeneration went on to bone exposure and to deformity of the femoral head.

In addition to the foregoing features, it was possible to make some observations about the shape of the head, about calcification and ossification of the articular cartilage where this did not form part of the definition of a feature, and about some miscellaneous findings.

In none of the features was there any real difference in prevalence according to sex. As a consequence the distinction between male and female has been omitted from Tables II to IV. Furthermore, no significant difference between right and left femoral heads was observed, and all the observations that were made about the right side were substantiated by the left; only the prevalence of observations on the right head are therefore recorded in Table III (overleaf). The classification of features by size did not reveal anything of significance: smaller lesions appeared earlier than larger ones and were more prevalent; these findings are also omitted.

Details of the findings in the femoral head and in the acetabulum are given separately in the following pages. The description of the normal is given first; this is followed by details of the changes due to marginal ossification (osteophytes) and then by details of the breakdown and loss of articular cartilage, first that of limited progression and then the progressive; finally there is a section on miscellaneous observations.

The femoral head (Fig. 1)

The normal femoral head

This was regarded as being round with a smooth articular cartilage with no evidence of marginal ossification. Variations in the colour of the cartilage when not accompanied by alterations in texture were regarded as normal; this was necessary as there was a
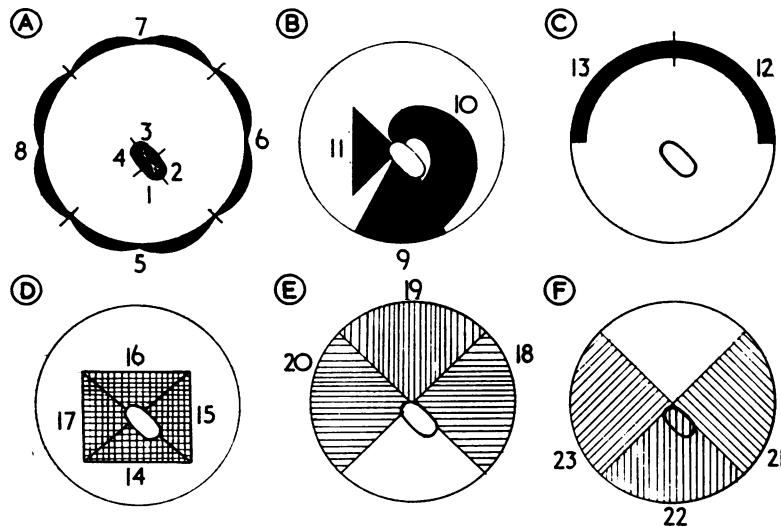

F I G. 1   *Schematic representation of medial side of right femoral head and of sites of features found.*
A: *Osteophytes around fovea (Features 1 to 4) and around outer margin (Features 5 to 8). The head was divided into quadrants for purposes of the investigation.*
There were some differences in prevalence of these features but their significance is doubtful so that beyond separating foveal and outer marginal osteophytes this detail is not included in the results (Table III).
B, C, D: *Alterations in cartilage of limited progression (Features 9 to 17). See text for details.*
E: *Progressive alterations in cartilage. It seemed probable that these lesions would be confined to the antero-superior part of the head (Features 19 and 20), but provision was made for recording lesions that might arise posteriorly (Feature 18). One was found at the latter site; this and Features 19 and 20 have been recorded merely as 'progressive lesions' in Table III.*
F: *Provision was made for recording changes that accompanied the progressive cartilage alterations of Features 18, 19, 20. The presence of Feature 20 excluded the possibility of 23, and that of 18 excluded 21. No Feature 18 was recorded; Features 21 and 22 have been recorded as 'accompanying changes' in Table III.*

good deal of variation in the exposure to air before fixation. The articular cartilage was of uniform appearance up to the margin where it disappeared. In fine detail x rays of 3-mm. thick slabs cut from the specimens, the subchondral plate was smooth right up to the margins where the articular cartilage, which was readily visible in these films, thinned either abruptly or gradually to meet it. It was not possible to measure anteversion, retroversion, and neck shaft angle in these specimens since they did not extend beyond the lesser trochanter.

Osteophytes
For purposes of classification the head was divided into quadrants (Fig. 1), giving four regions around the fovea and around the outer edge. The value of these divisions was doubtful so that they have not been preserved here or in the Tables. Any ossification of marginal articular cartilage was recorded as an osteophyte. When it was recognized, either grossly as a narrow pale marginal band in the cartilage or in fine detail radiographs as a marginal bony projection into cartilage, it was classed as Stage 1 if there was no evidence of growth (projection beyond the contour of the cartilage) or as Stage 2 if growth of the cartilage

had taken place (Figs 2, 4, 6). The recognition of osteophytes was assisted by the fine detail x rays in which both the bony and cartilaginous contours were readily seen. Notwithstanding this the recognition of the earliest osteophyte formation was difficult, as was the beginning of the second stage. In many of the heads the osteophytes did not extend all the way around the fovea or the outer margin. In the former position the inferior and posterior areas were more commonly affected (Fig. 2A, overleaf); on the other hand it was the inferior and anterior areas of the outer margin where osteophytes were more commonly seen. Confusion was particularly common at the attachment of the ligamentum teres, and at the anterior outer margin where the portion of the femoral neck lying beneath the psoas muscle is covered by irregular sessile bony protuberances.

Table III shows the number of cases in each decade affected by osteophytes. Occasional Stage 1 osteophytes are seen from the first decade around the fovea and from the third decade around the outer margin. They increase in prevalence until the fifth decade and are then relatively constant in both regions (foveal 66 per cent., marginal 33 per cent.). Stage 2 osteophytes appear about two decades later

Table III *Age prevalence of features of femoral head. Figures represent numbers of heads. For stages 3, 4,*

Stage		1									
Decades of age (yrs)		−9	−19	−29	−39	−49	−59	−69	−79	−89	*Total*
Total specimens		10	9	6	17	37	94	124	65	13	375
Osteophytes	Foveal		1	2	8	24	71	95	44	7	252
	Outer margin			2	6	11	20	42	22	5	108
Breakdown and loss of cartilage	Limited	1	1	2	8	21	48	65	22	7	185
					1	5	26	27	5	0	64
					2	1	19	24	9	2	57
					1	4	8	9	6	2	30
					2	2	21	37	14	5	81
						1	2	4	3	0	10
						2	3	9	8	0	22
					2	9	25	43	18	6	103
						2	6	5	4	1	18
	Progressive				1	1	2	3	3	0	10
	Changes accompanying progressive breakdown										

and are much less numerous, but also become more frequent with increasing age, reaching a prevalence of about 15 per cent.

Degenerative changes of articular cartilage
LIMITED PROGRESSION (Features 9 to 17)
These alterations in the articular cartilage were of two different kinds in their gross appearance. One group occurred in five different sites (Features 9 to 13, Fig. 1), while the other was seen in four sites (Features 14 to 17, Fig. 1). The sites of the latter group overlap some of those in the former; nevertheless they were distinguishable by differences in gross appearance.

Group 1. *Features 9 to 13*
The first group of these limited alterations is shown schematically in Fig. 1B and C:
9: An area lying below the fovea.
10: A crescentic area starting above the fovea and curving posteriorly.
11: A roughly triangular area in front of the fovea.
12 and 13: A narrow zone, lying adjacent to the outer margin, extending over the superior surface from approximately the mid-point posteriorly to the mid-point anteriorly, divided into two equal regions.

The five following stages could be distinguished in the development of these degenerative changes of limited progression (Figs 3 and 4, overleaf, pp. 21 and 22):
(1) Fine granularity.
(2) Superficial fraying, fissuring, and flaking.
(3) Loss of cartilage.
(4) Ossification at the site of cartilage loss.
(5) Exposure of bone in the base.

Fine detail x rays demonstrated that ossification sometimes occurred fairly early in the process of cartilage alteration, a fact that was recorded separately as ossification in lesions of Stages 1 and 2. As a matter of interest this was seen in roughly 5 per cent. of these lesions, but only in subjects above 50 years of age.

All these lesions seemed to begin in a similar way; their further progression was also alike, but Features 11, 12, and 13 did not progress so far as Features 9 and 10. Thus, while it was possible to recognize five stages of development (Fig. 3), all five were seen only in Features 9 and 10, while Features 11 to 13 rarely progressed beyond Stage 2. In Stages 3 to 5 the numbers of lesions became progressively fewer and Table III has been simplified by showing only the

and 5, only totals are given

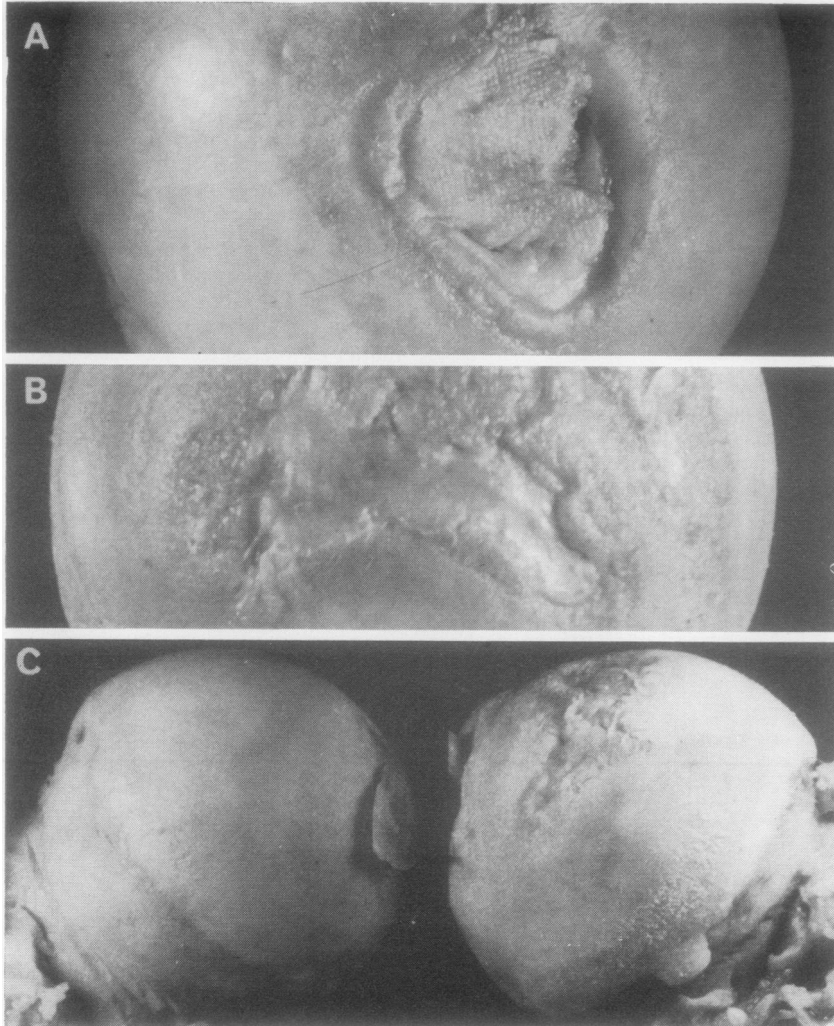| 2									3	4	5	Feature Nos.
−19	−29	−39	−49	−59	−69	−79	−89	*Total*	*Total*	*Total*	*Total*	
0	6	17	37	94	124	65	13	375	375	375	375	
			1	3	6	12	9	3	34				1-4
				2	2	7	15	12	5	43			5-8
		1	1	4	19	23	9	3	60	32	20	1	9
			3	3	8	15	10	3	42	16	28	2	10
				2	11	18	8	3	42	4	1		11
			2	1	0	5	5	1	14	4	2		12
			2	1	6	12	8	1	30	8	4		13
													14
													15
													16
													17
						2	4	0	6				−20
													21-23
						2	4	0	6				

FIG. 2 **A:** *Foveal osteophyte: Stage 1.*
B: *Foveal osteophyte: Stage 2.*
C: *Marginal osteophytes: Stage 1 on left; Stage 2 on right (at one point there is particularly prominent cartilage growth).*
The head on the right also shows Features 10 and 12.

total lesions in these Stages.

As has been indicated, Features 9 and 10 clearly showed progression through Stages 3 and 4; the details of the prevalence of these stages demonstrate that they were fewer in number and appeared at later ages than Stages 1 and 2.

Decade of age		−39	−49	−59	−69	−79	−89	Total
Feature 9	Stage 3	1	2	11	10	8		32
	4	1	2	2	3	12		20
10	3		1	3	8	4		16
	4		1	4	11	8	4	28

Stage 5, exposure of bone, was seen only three times in the right head and twice in the left. In three of these five instances the area of exposed bone was a few millimetres in extent, but in two it was very extensive and involved much of the area of Feature 10 (Fig. 3D). All the five patients concerned were in the 50-59 year age group.

From the above Table and Table III it is evident that these changes are common, and that they show a rise in incidence over three or four decades to arrive at a peak. As might be expected, the later stages of any lesion appear later in life, and are less common than the earlier stages.

Of the other three features (11, 12, and 13), Feature 12 was posterior and lay mainly within the acetabulum, while 13 ran anteriorly and was largely covered by capsule. Despite certain difficulties,
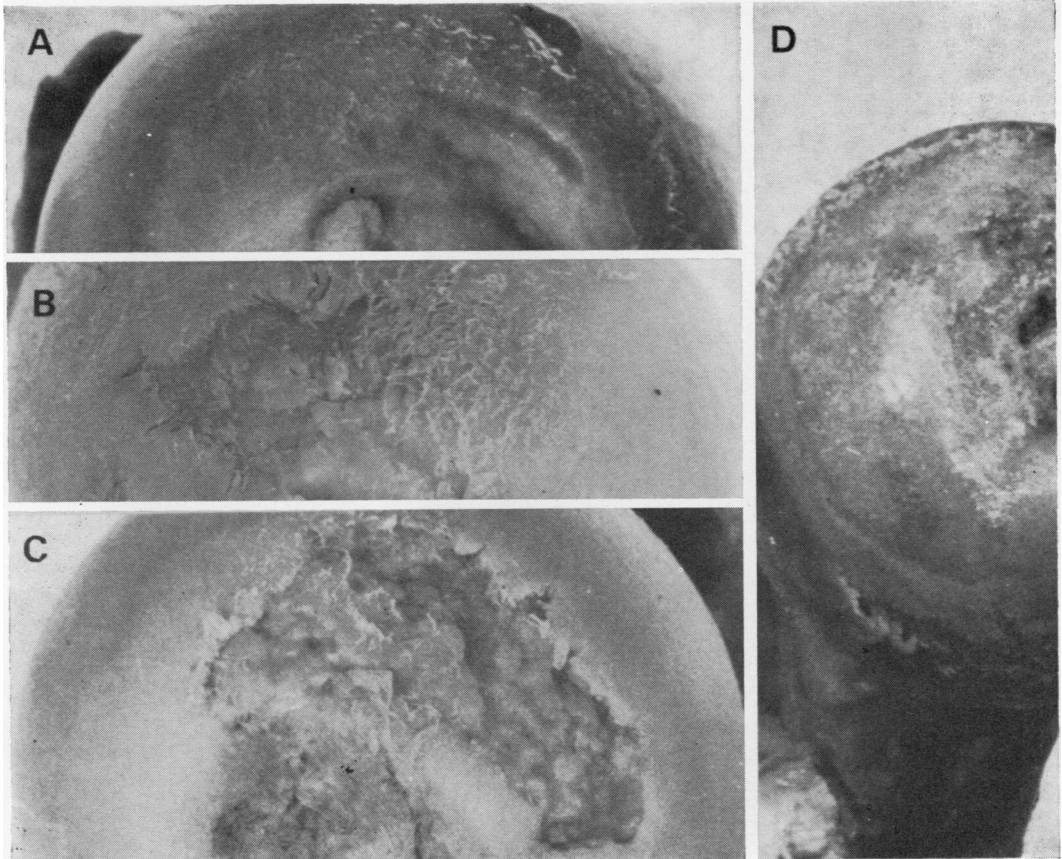
FIG. 3 *Stages in the development of limited cartilage degeneration.*
A: *Stage 1. A fine granularity of the cartilage. Slight fraying is evident, the start of Stage 2.*
B: *Stage 3. There has been loss of cartilage over an area on the right. The left side of the lesion shows fraying and fissuring of the cartilage as in Stage 2. The categorization of a lesion is based on its most advanced part.*
C: *Stage 4. In the base of the region of cartilage loss ossification of residual tissue has occurred as evidenced by the knobbly appearance.*
D: *Stage 5. A left femoral head with extensive bone exposure in the area of Feature 10. This was the most marked of five cases in which bone exposure was found in alteration of limited progression.*

particularly in deciding whether an alteration in the cartilage was in fact a manifestation of osteophyte formation, it was possible to be reasonably consistent in identifying these two features (Figs 1C, 2C). Although they appear first in the 30s with a fairly equal prevalence (10 to 20 per cent.), the lesion in the cartilage beneath the capsule is roughly two to three times as common in later years. The rather few examples of advanced stages emphasize the limited progression of these features.

Group 2, Features 14 to 17 (Fig. 1D)
These features were parafoveal, that is they were contiguous with the fovea and appeared as clearly-demarcated depressed areas of cartilage with a smooth soft tissue base beneath which ossification was frequently present. Quadrant divisions were employed for their identification, as it was found that

these changes were mainly in front or behind, above or below the fovea. No development of these lesions was noted beyond Stage 1; they seemed to develop by extension at their margins. The largest lesion seen was 2 cm. long (Fig. 5, overleaf), but the vast majority were under 1 cm. (Figs 4, 6). The ossification in the base of these lesions was most readily identified by fine detail x ray.

The lesion above the fovea (Feature 16) was the earliest to occur and was the most common.

PROGRESSIVE (Features 18 to 20)
In contrast to the lesions just described, where eventual exposure of bone was but rarely seen, there was a small number of lesions at other sites where this regularly happened (Fig. 1E). These were found in the antero-superior part of the cartilage, outside the areas that have been delineated above, with the
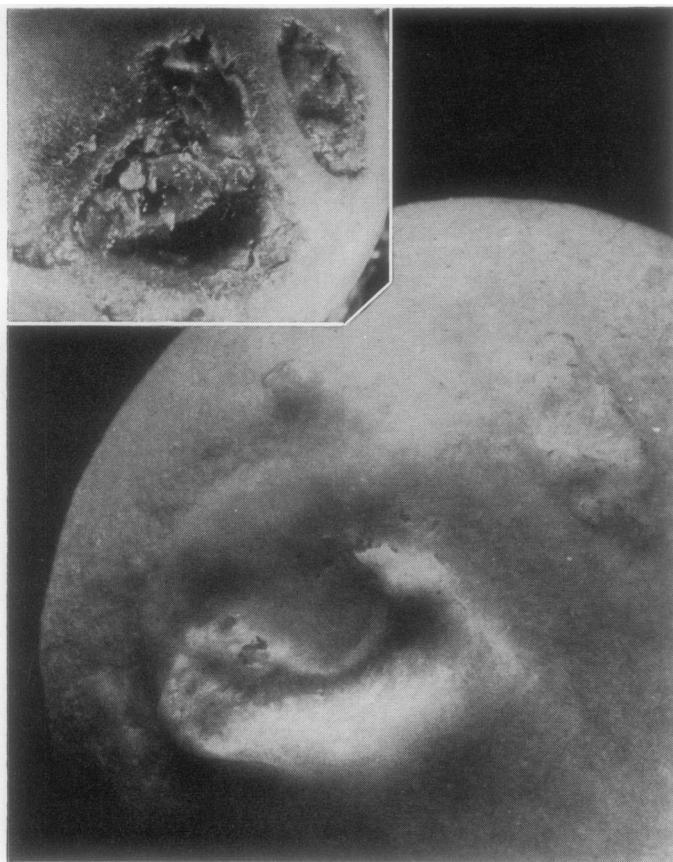
FIG. 4 *Inset shows fovea with Stage 1 osteophytes at lower edge; a smooth-based defect superiorly (Feature 16), and a small lesion of Feature 10, Stage 4, posteriorly. The large picture is the macerated head showing the ossification of all three lesions.*

FIG. 5 *Three very large parafoveal smooth-based defects corresponding to Features 15, 16, and 17. The appearance of these should be contrasted with Fig. 3C. Fig. 4 shows a small example of these lesions (Feature 16).*

exception of one case in which the postero-superior part of the head (and of the acetabulum) was affected. The earliest change found was a finely granular surface in a clearly-demarcated circular area, an appearance which suggested that the process was quite superficial (Fig. 6, opposite). This persisted until complete loss of cartilage occurred (Fig. 6). The

rather coarse fibrillation of Features 9 to 11 was not noticed. Of course the number of specimens was small so that it is possible that the entire range of appearances was not seen. In the early stages there did not seem to be any change in the subchondral bone. In the late stages all the well-recognized appearances of osteoarthrosis were present. No cases
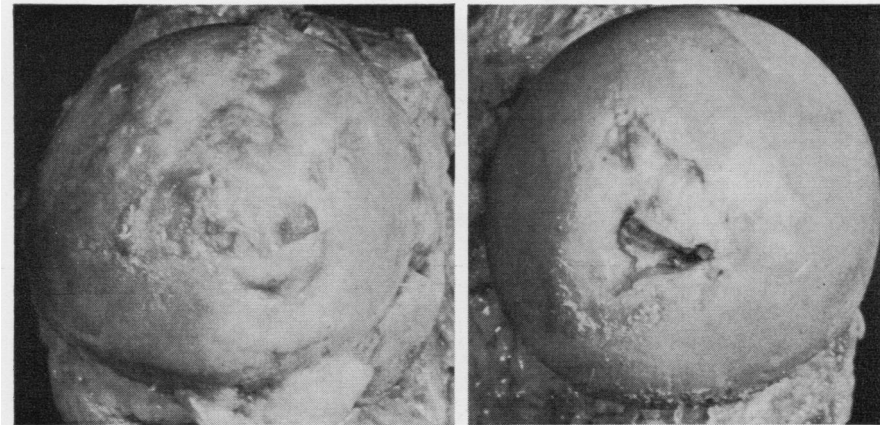
FIG. 6 *Progressive degeneration of cartilage and accompanying changes. Head on right shows an area of superficial cartilage degeneration antero-superiorly (top right); this corresponds with extensive antero-superior area of exposed bone on left-hand specimen. There are non-progressive cartilage alterations on the right-hand specimen (Feature 9, Stage 2; Feature 10, Stage 1; Feature 16), as well as foveal osteophytes, Stage 2. The left-hand specimen shows evidence of widespread cartilage ossification postero-inferiorly, described as 'accompanying changes' in the text and in Table III.*

of an intermediate stage were found.

The distribution of the sixteen cases with progressive lesions are shown in Table III. There were more of these in Stage 1 (10) than in Stage 2 (6); they appeared first in the 30s and had a more or less constant prevalence for four decades and then a rise in the 70 to 79 year decade.

CHANGES ACCOMPANYING PROGRESSIVE
DEGENERATION OF ARTICULAR CARTILAGE
(Features 21 to 23)

The progressive changes that take place in the superior portion of the head are, in their advanced stages, accompanied in most cases by widespread changes in the inferior part (Figs 1F and 6) which do not bear any resemblance to the features previously described. Only six cases were found which fitted this definition, and descriptive details of the pathogenesis of these changes await the examination of further cases. Experience of femoral heads resected in the treatment of osteoarthrosis indicates that frequently all cartilage of the postero-inferior part of the head undergoes ossification with the formation of large quantities of new bone. The appearances of Features 9 and 10 are not seen in such specimens, although their prevalence makes it highly probable that they must have been present in some. In one head of the current study showing progressive changes in the superior part, it was apparent that Feature 9, Stage 4, had been present and was being encroached on and submerged by cartilage growth and ossification which would eventually produce the extra bony tissue on the infero-posterior part of the head.

Miscellaneous observations

In the course of this study a number of minor observations were made which did not fall within the defined features. These were primarily apparently insignificant small alterations in the cartilage observed in some 47 specimens. In addition, chondrocalcinosis was observed seven times; all the subjects were over 50 years old and none showed progressive degenerative changes. An elliptical as opposed to a circular curvature of the upper surface of the head was seen in a few cases, but no evidence was adduced that this related to the progressive features. True cysts were found in the head in thirty cases; there was no evidence that they were related to any specific lesion in the cartilage.

The acetabulum

The normal acetabulum

This was considered to be hemispherical in shape, and lined by a horseshoe of smooth cartilage. The inner edge of the cartilage ended abruptly and framed the fovea as an unbroken line; the fovea was filled with fibro-fatty tissue with a smooth surface. The outer edge of the cartilage and the labrum blended without any distinctive demarcation. The latter was attached to the bone beneath, which in its turn had a smooth rounded edge (as seen in slab x rays or macerated specimens). The subchondral bone was assumed to be a smooth uniformly curved surface ending cleanly and abruptly at the edge.

Osteophytes

Ossification of marginal articular cartilage was recognized grossly on the inner aspect as a pale band

C

FIG. 7 *Schematic representation of right acetabulum.*
A: *Osteophytes around the fovea (1 to 3) and around the outer margin (4 and 5). Although these two sites were divided into regions as indicated, no significant difference was found in prevalence and only foveal and outer marginal osteophytes are recorded here.*
B: *Sites of alteration in cartilage of limited progression (Features 6 to 10). See text for details.*
C, D: *Sites where alterations in cartilage were noted but which seemed to be either normal (Features 15 and 16) or developmental (Features 11, 12, 13, 14, and 17). Features 11 and 12 have not been referred to in the text: these were notches in the foveal margin which do not appear to have any significance.*
E: *Progressive alterations in cartilage. It seemed probable that these lesions would be confined to the antero-superior part of the acetabulum (Features 19 and 20), but provision was made for recording lesions that might arise posteriorly (Feature 18). One was found at the latter site. Features 18, 19, and 20 have been recorded as 'progressive lesions' in Table III.*
F: *Provision was made for recording changes that accompanied the progressive cartilage alterations of Features 18, 19, and 20. The presence of Feature 20 excluded 23, and that of 18 excluded 21. Feature 18 was recorded once; but no alteration that could be classified as Feature 23 was found. Features 21 and 22 have been recorded as 'accompanying changes' in Table III.*

Table IV *Age prevalence of features of acetabulum. Figures represent numbers of acetabula. For stages 3 and*

Stage		1									
Decades of age (yrs)		−9	−19	−29	−39	−49	−59	−69	−79	−89	Total
Total specimens		10	9	6	16	36	91	118	65	12	365
Osteophytes	Foveal		1	2	8	21	42	71	32	7	184
	Outer margin		1	0	8	15	40	63	29	8	164
Breakdown and loss of cartilage	Limited		0	2	9	32	41	24	3	111
			0	0	4	9	13	16	3	45
			0	2	7	13	20	15	3	60
			1	2	6	12	9	3	0	33
			0	0	2	3	3	3	2	13
	Progressive								2		2
	Changes accompanying progressive breakdown										

at the edge of the cartilage, or as a projection beyond it (Figs 8, 9B, and 12). Fine detail x rays showed extension of bone beyond the normal contours (Fig. 8). They were graded as Stage 1 or 2 according to the absence or presence of evidence of cartilage growth. At the outer margin osteophytes were more difficult to recognize since the ossification takes place in the labrum. Only Stage 2 osteophytes were recognizable grossly (Fig. 8, overleaf); ossification without growth (Stage 1) could be detected only by fine detail x rays of slabs cut from the specimen.

For purposes of classification the foveal margin was divided into three regions (Features 1 to 3) and the outer margin into two (Features 4 and 5) (Fig. 7A). However the differences in prevalence between points around the fovea and around the outer margin were not significant and these distinctions have not been preserved in Table IV. Some Stage 1 osteophytes were found before the age of 30, and they were present in about a third of the population in the 40s, reaching about 50 per cent. in older subjects. The Stage 2 lesions were fewer, hardly affecting more than 10 per cent., and appeared at a later age.

Degenerative changes of articular cartilage
LIMITED PROGRESSION (Features 6 to 10)
The sites affected (Fig. 7B) by these changes were:
6 and 7: The tips of the horseshoe of cartilage.
8 and 9: The labrum-cartilage junction.
> **10:** An area of cartilage in the mid-region of the posterior limb of cartilage, contiguous with the fovea.

All these changes were characterized by fibrillation of the cartilage at an early stage. The first two (Features 6 and 7) progressed to a second stage where bone was exposed. The area affected by this was generally under 1 cm.; occasionally it was slightly more (Fig. 9A, B, overleaf).

Features 8 and 9 started as a linear defect between the articular cartilage and the labrum which progressed with undermining of one or both structures and degeneration of the cartilage (Figs 10, 9A, C). This resulted in partial detachment of the labrum and in smaller or larger flaps of articular cartilage. Sometimes the process was more or less continuous around the edge; but more often the foci were confined to anterior or posterior regions (Features 8 and 9). The alterations in Features 8 and 9 progressed through four stages (Fig. 10, overleaf, p. 28):

(1) A smooth depressed line of separation.
(2) A slightly wider line of separation brought about by fraying and disintegration of the articular cartilage.
(3) A much broader area of cartilage degeneration.
(4) Ossification in the base of the lesion in Stage 3.

Feature 10 was an area of cartilage in the mid-region of the posterior limb of the cartilage contiguous with the fovea where the degenerative change again went through four stages (Figs 10A, B; and 9C):

(1) Fine granularity.
(2) Coarse granularity and superficial fraying.
(3) Deep fissuring and loss of cartilage substance leaving a depressed area with a rough base of soft tissue.
(4) Ossification in the base of a lesion with a Stage 3 appearance.

The area affected was generally small, and even when

4, *features 8, 9, and 10, only totals are given*

2									3	4	*Feature Nos.*
−19	−29	−39	−49	−59	−69	−79	−89	Total	Total	Total	
0	0	16	36	91	118	65	12	365	365	365	
		0	0	2	10	7	1	20			1-3
		1	1	1	7	6	0	16			4 and 5
		1	0	2	2	3	0	8			6
		1	0	1	1	3	1	7			7
		3	12	24	39	17	1	96	31	3	8
		1	2	14	26	17	1	61	8	6	9
		0	1	8	12	6	2	29	23	23	10
					2	4		6			18-20
											21-23
					1	4		5			

FIG. 8 *Osteophytes: the photograph shows projecting foveal osteophytes, i.e. Stage 2. An earlier stage in osteophyte formation (no growth) can be seen in Fig. 10A. The superior part of the acetabular cartilage shows changes of Feature 17. The fine detail x ray of another specimen (inset) shows an osteophyte of the outer margin; although this is quite large it does not disturb the contour or projection of the labrum and is recorded as Stage 1. An osteolytic focus is included in this osteophyte. The ossification on the foveal side corresponds with the site of Feature 17 of which it forms a part, although the small bony spur may be classed as an osteophyte.*

larger than 1 cm. in diameter seldom if ever reached 2 cm. The margin was clear-cut and the sequence of changes were as described above. In a small percentage of cases the synovial membrane was attached more or less firmly to the margin or base of this lesion (Fig. 10B). The presence of this finding was not recorded.

All these features were of frequent occurrence. The actual numbers seen at the various stages are shown in Table IV. Feature 6 at the tip of the anterior limb of the cartilage affected more than one-third of the specimens in the 50 to 79 year age groups and was two to three times more frequent than Feature 7. The anterior feature at the outer rim, Feature 8, was also much more frequent than the posterior one, Feature 9, the respective figures at peak prevalence, between 50 and 69 years, being 50 and 25 per cent.

Feature 10 affected about one-quarter of the population between 50 and 69 years of age. With rare exceptions none of these lesions was seen in subjects below 30 years of age. These features showed a rising prevalence with age.

PROGRESSING TO DEFORMITY OF THE JOINT (Features 18 to 20) (Fig. 7C, D, E)
In a few specimens alterations in cartilage that were different in quality and in site from those already described, albeit they overlapped the sites of some of the latter, were found (Fig. 12). These lesions occurred in the antero-superior part of the joint, except in one instance where the lesion lay posteriorly. Two stages of development were recognized:
(1) Fraying of the cartilage.
(2) Subsequent exposure of bone.

Stage 1 was recognized with less precision because of the overlapping Features 8 and 9, 15 and 16 (described under miscellaneous observations below). Feature 17 (also described below) did not cause confusion. Only two cases of this early stage were noted, although there were ten examples of the early stage of the comparable lesion in the femoral head. It is difficult to draw reliable conclusions from so few cases; nevertheless one can say that careful scrutiny of further material and of the hypothesis is needed.

Stage 2 was more readily recognized and six of these cases were recorded; comparable lesions were found in the matching femoral head.

CHANGES ACCOMPANYING PROGRESSIVE DEGENERATION (Features 21 to 23)
In their second stage the progressive lesions described above were accompanied by changes in the inferior part of the acetabulum (Fig. 7F). These were less distinctive than in the femoral head, and consisted mostly of accentuated osteophyte formation which obliterated the fovea.

Miscellaneous observations
Several of these were defined as features by their site and appearance, both of which were relatively constant.

Two of these were areas of dark colour and of fine granularity of the cartilage affecting roughly oval areas in the anterior and posterior parts of the cartilage (Features 15, 16; Figs 7 and 10B). They were common, but never appeared to progress to even superficial cartilage loss and may well be part of the normal appearance.

Three other features appeared to be related to the growth and development of the acetabulum (Fig. 7D). Two of these were defects running across the anterior and posterior limbs of the cartilage (Features 13 and 14). Sometimes these were merely dark lines; at other times they were distinct smooth linear depressions which on occasion affected the full
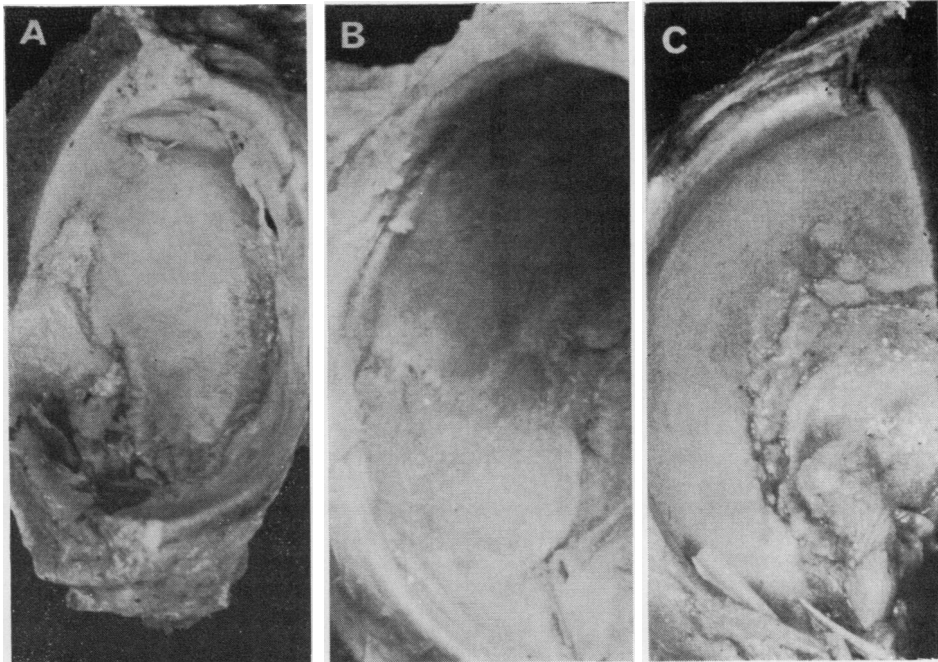
FIG. 9A *There is a small defect in the articular cartilage at the tip; Feature 6. Bone was not exposed in the base of this, i.e. Stage 1. Stage 1 foveal osteophytes; Feature 8, Stage 3; and Feature 17 are also present.*

FIG. 9B *There is an area of exposed bone in the tip of posterior limb of the cartilage: Feature 7, Stage 2. There is a linear defect (Feature 9, Stage 1) between the labrum and the articular cartilage.*

FIG. 9C *Feature 10, Stage 4. This photograph illustrates the end stage of the process whose beginnings can be well seen in Fig. 10A (Stage 1: granularity) and 10B (Stage 3: fraying and loss of cartilage): there is ossification in the base of a cartilage defect. Foveal osteophytes, Stage 2, are also present. At the upper edge along the cut surface it is possible to see the free edge of the labrum which is no longer continuous with the articular cartilage (Feature 9, Stage 2).*

thickness of the cartilage, thereby isolating an island of cartilage at the end of the articular surface; frequently the subchondral plate showed a linear defect (Fig. 11B). The third (Feature 17) (Fig. 7D), found in the roof of the acetabulum, was an area 5 or 10 mm. in size in which the cartilage was often of dark colour, or was slightly elevated with fine radiating lines and sometimes with a pin-point yellow nodule on or near it (Figs 8, 9A, 10B, 11A, and 12, overleaf).

These appearances were often associated with focal defects in the underlying subchondral bone: either a central small depression (Fig. 11A) or marginal ossification of cartilage (Fig. 8) was usual.

The prevalence of these three features is shown in the following Table:

Decade of age	−9	−19	−29	−39	−49	−59	−69	−79	−89
No. of specimens	10	9	6	16	36	91	118	65	12
Feature 13	0	0	0	4	9	13	14	7	3
14	0	0	0	0	1	3	2	1	0
17	2	4	4	8	27	73	96	48	12

In addition to the foregoing features, a number of observations were made of appearances that were seen in the anatomical site of a feature but had not formed part of its definition, or else were outside any defined anatomical site and were quite unexpected. They seemed not to have any relationship to the development and progression of the features described.

The following is a list of the descriptive names given to these and the number of acetabula in which they were found:

Ossification of cartilage	65
Osteolytic foci	48
Small focal cartilage alterations	33

The commonest among these, small foci of ossification of cartilage, were revealed by fine detail *x* ray.

Osteolytic foci in subchondral cancellous bone were also recorded from the slab *x* rays, and were not often noticed at the time the specimens were cut up, so that while they correspond with 'cysts' it is not known how many were in fact fluid filled. Since the site from which the slabs were taken was somewhat variable, the figures cannot be taken to represent all possible cysts. These lesions were mainly about 5 mm. in size. They were usually seen in association with some degree of degeneration in the overlying cartilage.
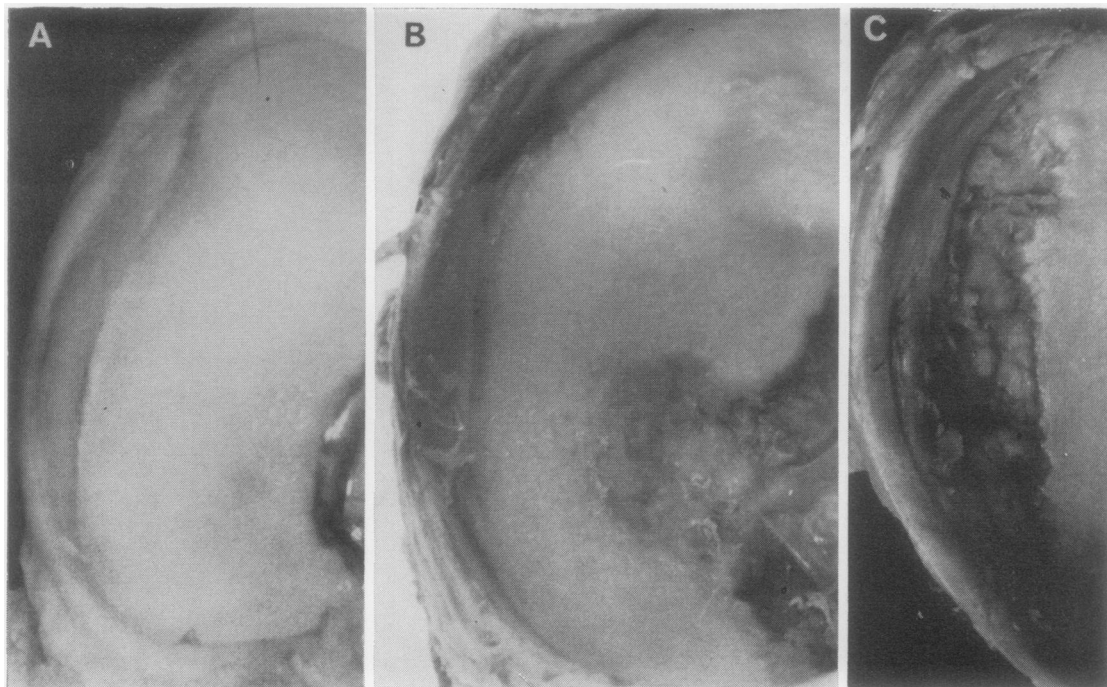
FIG. 10   *Stages in development of Feature 9 (the same for Feature 8).*
FIG. 10A   *Stage 1. Linear separation of labrum and cartilage.*
FIG. 10B   *Stage 2. Widening of separation by fraying and fissuring of articular cartilage.*
FIG. 10C   *Stage 4. Broad defect in cartilage with ossification in the base; fraying under inner edge of separated labrum. Defects of this sort without ossification graded Stage 3. In addition to the foregoing one can also see the following: in Fig. 10A—foveal osteophytes Stage 1 and Feature 10, Stage 1; in Fig. 10B—foveal osteophytes Stage 1; Feature 10, Stage 3; Feature 16 (an ill-defined dark area of the cartilage); Feature 17.*

None of these lesions was found more commonly in one sex. They occurred almost entirely in the 5th to 8th decades with the majority between the ages of 50 and 70 years.

Chondrocalcinosis was observed on six occasions and was not associated with any particular alteration of cartilage.

Conclusions

The hypothesis that was under examination in this study stated that limited degenerative changes of the hip joint are related to ageing, and that independently of these there are progressive changes that can be regarded as a disease process. The examination of all the specimens confirms the fact of cartilage changes with a limited progression, and shows them to have a high prevalence which increases with age after they first appear between childhood and the 30s; it also establishes the low prevalence of progressive degenerative changes, which are seen only in later years.

The hypothesis also states that these two groups of lesions occur independently of one another. The examination of this concept is made difficult by the

relatively small numbers of progressive changes. There was no evidence from the femoral heads studied of such a relationship; but it is necessary to acknowledge that in the acetabulum the independence of limited and progressive alterations of cartilage has not been established.

We thought at first that one of the distinctions between non-progressive and progressive changes would be that subchondral bone was not exposed in the former. It turned out in fact that small lesions developing in the tip of the cartilage horseshoe quite regularly had exposed bone in their base, and yet did not progress, and that in a few femoral heads exposed bone was found in sites of limited cartilage alteration. There can be no doubt that it would be of great value to study more closely the fate of these two lesions in relation to the changes which accompany the development of the progressive lesions.

The features in the femoral head that have been defined and recorded here do not differ from those noted by others (Heine, 1926; Collins, 1949; Harrison, Schajowicz, and Trueta, 1953). The acetabulum has never been subject to as much study as has the femoral head, but even so the features delineated
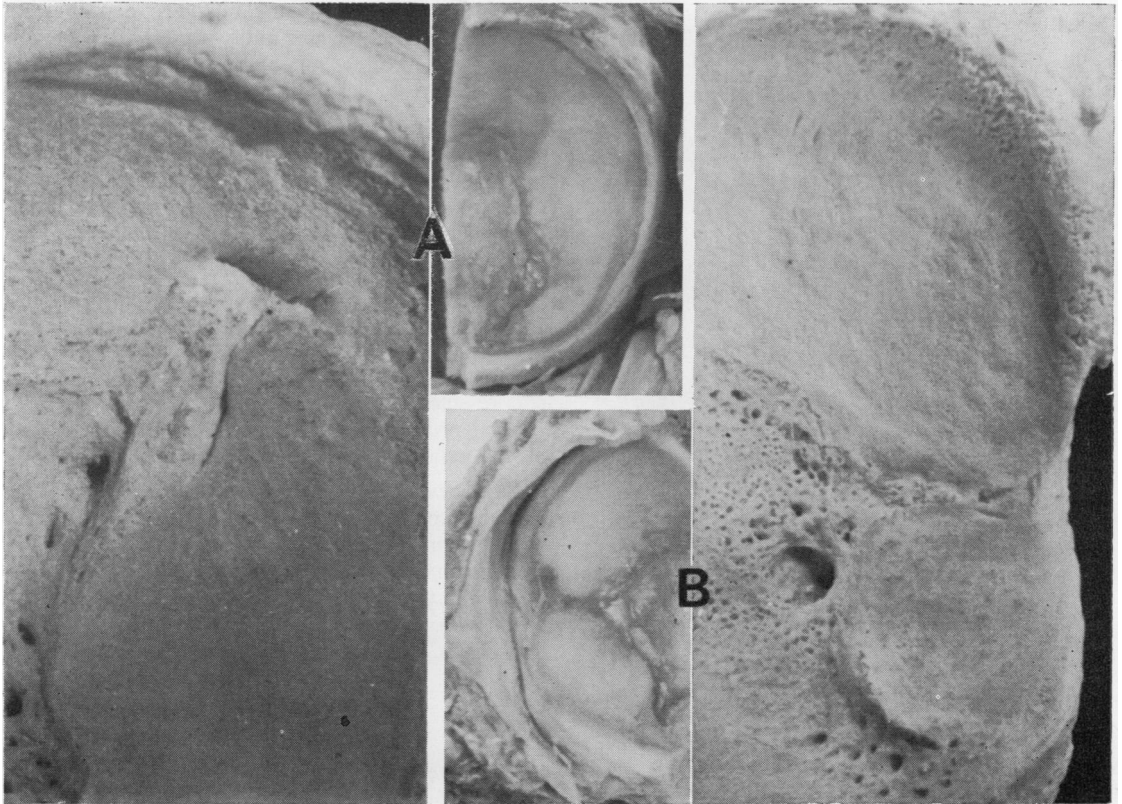
FIG. 11A *Small central photograph shows Feature 17; the larger photograph (left) shows the macerated specimen. In the smaller picture an osteophyte is present at the tip of the cartilage (Stage 1) and Feature 8, Stage 2.*
FIG. 11B *Central photograph shows Feature 14 while the larger photograph (right), a macerated specimen, shows the bony aspect of Feature 13 which has a comparable gross appearance. Feature 9, Stage 1, can also be seen in the smaller picture.*

here are probably not newly described. It is only the knowledge of their prevalence and fate which is new. The frequently occurring non-progressive changes are age-related in that they tend to occur in early or middle years and to increase in prevalence to a maximum which is then maintained. This fact coupled with their non-progressive character and seeming lack of interference with joint function, a statement which is in part an interpretation of the sites (presumably non-weight bearing) that they affect, indicates that they can reasonably be excluded from the category of disease and included in the category of ageing. Statements such as these can of course be very controversial, and their acceptance must depend on agreement over definition of 'disease' and 'ageing' and criteria for their recognition. The term 'age-related' may be applied to an event which occurs in the population from any early age onwards with increasing frequency; baldness in men is an example, in which nevertheless the determining factor is genetic with a sex-linkage. Though this phenomenon in men is accompanied by degrees of discomfort it is not regarded as a disease process

except in rare cases. In the context of the present paper disease of the femoral head is being defined in terms of the appearance of heads resected in the treatment of osteoarthrosis, a progressive disabling deformation of the joint. In a careful inspection of over 100 femoral heads resected in the treatment of femoral neck fractures the commonly occurring limited alterations in cartilage have been found frequently but never the progressive changes. On the other hand, in more than 400 femoral heads resected for the treatment of hip joint disease, the appearances nearly always fitted in with those of the progressive disorder and their accompanying changes. The reservation applies to two or three femoral heads where there was an area of exposed bone which corresponded to the area of Features 9 or 10. There were, in addition, heads in which Feature 9 was present but was being slowly engulfed by the widespread ossification of the posteroinferior articular cartilage that accompanies the progressive lesions.

The relationship of osteophytes to these processes was an open question at the outset of the investiga-
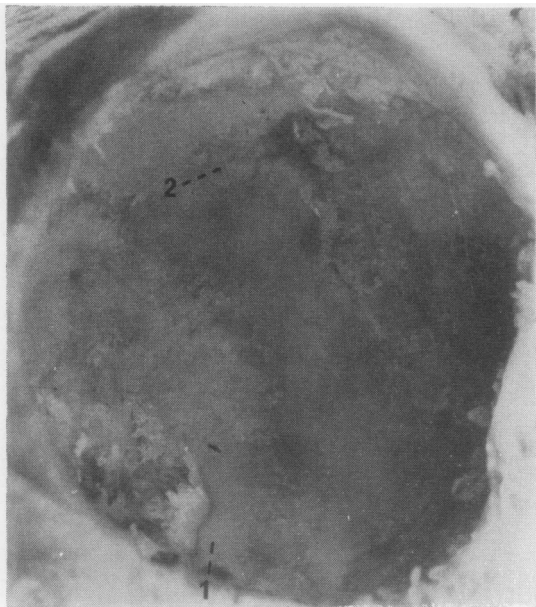
FIG. 12 *Progressive cartilage degeneration in outer superior part of acetabulum. A large osteophyte extends into the fovea at the bottom* (1). *A small focus of alteration in the cartilage at the top represents Feature 17* (2).

tion. Their prevalence has now been established. Minor and limited ossification of the margins of the articular cartilage is common in the femoral head, can be recognized from an early age, and soon reaches a peak prevalence of about 66 per cent. around the fovea and 33 per cent. around the outer edge; growing osteophytes occur later, and their prevalence is less but rises with age to something a little above 15 per cent.

In the acetabulum, ossification of marginal cartilage without growth was found to be very common; it could be detected from an early age, and reached a peak prevalence of about 50 per cent. in the middle years, and later; growth and ossification of cartilage occurred several decades later and its maximum prevalence affected only some 10 per cent. of the population.

It is clear from Tables III and IV that the presence of growing osteophytes does not imply the presence of progressive cartilage alterations elsewhere. On the other hand the larger growing osteophytes are clearly associated with the progressive cartilage disorder as they are found in the vast majority of femoral heads resected for osteoarthrosis. Altogether the significance of ossification of cartilage in adult joints remains an open question. The articular cartilage of the child grows and ossifies, and this process ceases when growth ceases without consumption of the cartilage as occurs in the epiphyseal plate. The cartilage clearly not only retains the ability to ossify for the remainder of its life span (and does so with great frequency at the margins and with less frequency at other selected sites) but also retains the power of growth.

A detailed study of the correlations between the various changes found is still to be completed, and may well provide some further theories. But it is already clear that a new hypothesis must be formulated which accommodates the several facts observed during this study:

That bone is exposed in regions of limited cartilage degeneration;

That such areas of bone exposure can be recognized as a component of changes in some resected arthritic heads;

That progressive changes in the acetabulum may be related to the non-progressive.

In any event it is apparent that not every cartilage alteration need be a sign of progressive disease; and that if non-progressive alterations do lead on to disease it means that some new event has taken place. Such reflections would be of importance in the interpretation of the results of the analysis, by whatever techniques, of cartilage changes.

Summary

(1) The sites, and gross and fine detail *x*-ray appearances of cartilage alterations of the right hip joint have been described.

(2) The age prevalence of these features has been established.

(3) The findings appear reasonably to substantiate the hypothesis that there are limited cartilage alterations related to age and progressive cartilage alterations that are due to a disease process. In the femoral head these two processes appear to be independent of one another; but this independance was not established as regards the acetabulum. This disparity, as well as the observation of exposed bone at unexpected sites, coupled with observations made in the examination of resected arthritic femoral heads, demands the formulation of a new hypothesis and further investigations.

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RÉSUMÉ

L'étude *post-mortem* de l'articulation de la hanche comprenant la fréquence des signes de la hanche droite

[1] Les détails minutieux et ceux plus marqués ainsi que l'endroit des altérations du cartilage vus aux rayons X ont été décrits.

[2] La fréquence de ces signes d'après l'âge a été établie.

[3] Les observations semblent établir raisonnablement l'hypothèse qu'il y a des altérations limitées du cartilage en relation avec l'âge et les altérations progressives du cartilage qui sont dues à un processus morbide. Dans la tête fémorale ces deux processus semblent être indépendants l'un de l'autre, mais cette indépendance n'a pas été établie quant à l'acetabulum. Cette différence, ainsi que l'observation de l'os exposé à des endroits inattendus, doublée de celle faite pendant l'examen des têtes fémorales arthritiques réséquées, demande la formulation d'une nouvelle hypothèse et des recherches supplémentaires.

SUMARIO

Un estudio *post mortem* de la articulacion de la cadera con preponderancia de la caracteristica del lado derecho

[1] Se han descrito los detalles minuciosos y otros indicios de alteraciones cartilaginosas de la articulación de la cadera derecha, observados con rayos equis.

[2] Se ha establecido la preponderancia de la edad en estas características.

[3] Estas observaciones parecen apoyar razonablemente la hipótesis de que existen ciertas alteraciones cartilaginosas relacionadas con la edad y alteraciones cartilaginosas progresivas que son debidas a enfermedad. En la cabeza femoral, estos dos procesos parecen ser independientes uno de otro; pero esta independencia no pudo ser establecida en cuanto se refiere al acetábulo. Esta disparidad, así como la presencia de hueso expuesto en lugares inesperados, junto con observaciones hechas durante el examen de cabezas femorales artríticas extirpadas, exige la formulación de una nueva hipótesis y otra serie de investigaciones.