Effect of age on thickness of adult patellar articular cartilage

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SUMMARY The thickness of left patellar articular cartilages after formalin fixation was studied in a series of autopsies on 82 subjects aged 25-96 years. For each specimen the minimal uncalcified cartilage thickness in a transverse patellar slab was determined separately for a 'lateral' segment and a 'central and medial' segment. In the women the cartilage from subjects more than 50 years old showed progressive thinning with increasing age. This was due to lesions causing disintegration of the tissue and not to matrix shrinkage. It had a strong potential to progress to full-thickness cartilage loss in the older women, and to give an appearance indistinguishable from osteoarthritis as seen in surgical excision specimens. This progression towards patellofemoral osteoarthritis in the elderly affects the female population generally, and not just a special subgroup; however, the incidence of clinical symptoms from this cause is not known. In men progressive thinning with age of patellar cartilage in subjects more than 50 years old was less severe, especially so in the case of the 'lateral' segment; a site of full-thickness uncalcified cartilage loss on the left patella at autopsy was seen only occasionally in the older men.

Breaks in surface continuity are a normal feature of adult human articular cartilage. Often the lesions are mild, and may then require indian ink staining *en face* or histology of vertical sections for their detection (Meachim, 1972); more severe lesions are macroscopically apparent on unstained surfaces.

A previous quantitative study has shown that during adult life there is an age-related increase in the percentage of the patellar articular surface area affected by 'histologically overt' fibrillation (Meachim and Emery, 1974). In terms of the functional effectiveness of cartilage as a covering material over bone, this tangential spread of the lesions is however less crucial than their vertical progression downwards into the tissue. Such vertical spread can cause matrix disintegration and lead to destructive cartilage thinning from tissue loss. This study of the patella was a quantitative investigation of this phenomenon in relation to age and sex.

The thickness of the uncalcified cartilage after formalin fixation was measured on left patellae from a series of adult autopsies. Minimal thickness was recorded as that at the thinnest site found on each of two topographically different cartilage

segments considered separately. The results indicate that there are differences between the evolution of degenerative changes in the patellofemoral joint and those described in the hip (Byers *et al.*, 1970); they also indicate that the severity of patellofemoral degeneration in older subjects differs between the two sexes.

Material and methods

Patellae from the left knee joint of 82 adult white European subjects (40 men, 42 women), aged 25-96 years, were collected from a series of autopsies in Liverpool. One further adult patella collected during the same period showed rheumatoid-type involvement, and was therefore excluded. The specimens were fixed in formol saline, and then sliced transversely as shown in Fig. 1. The slice was photographed in a plane vertical to the articular surface, using a Polaroid Land Camera set for an exact magnification of $\times 3$. From these prints, two observers independently measured the thickness of the uncalcified cartilage at various positions along the articular surface, in a plane vertical to the line of the surface at each position measured. Measurements were made to the nearest 0.33 mm of original thickness, this sensitivity corresponding to 1 mm on the $\times 3$ prints. The method was carefully selected

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Fig. 1 Topography of the two segments used for measurement of their minimal uncalcified thickness in a transverse patellar slice.

for this particular study, and gave good agreement between two observers working independently.

Minimal cartilage thickness was recorded as that of the thinnest site found on each of two topographically different segments of the transverse slice, considered separately and designated (as shown in Fig. 1) a 'lateral segment', excluding the lateral periphery, and a 'central and medial b' segment, excluding the more medial articular facet (medial 'area a'). The state of the cartilage of each segment was assessed by one or more of the following methods: macroscopical inspection *en face* and in the vertical plane; indian ink staining *en face* (Meachim, 1972) before fixation and slicing of the specimen; histology of vertically-cut paraffin sections. The same terminology was used to describe the histological appearance of the cartilage surface as in previous studies (Meachim, 1972; Emery and Meachim, 1973), and in addition a note was made if a cartilage lesion was macroscopically obvious *en face* before indian ink staining.

Results

Measurements of minimal uncalcified cartilage thickness after formalin fixation are shown for the lateral segment in Figs. 2 and 3, for the central and medial b segment in Figs. 4 and 5, and for the two segments compared in the same individual in Figs. 6 and 7. Macroscopical lesions of the cartilage, and

Fig. 2 Lateral segment minimal uncalcified thickness in women. ● = surface 'histologically intact' or with 'minimal fibrillation' only; ○ = 'histologically overt' fibrillation; × = cartilage lesion macroscopically apparent on unstained specimen. The regression line ($P < 0.001$) was calculated using only data from subjects more than 50 years of age.

Fig. 3 Lateral segment minimal uncalcified thickness in men. Symbols as in Fig. 2. The regression line ($P < 0.001$) was calculated using only data from subjects more than 50 years of age.

also sites of its full-thickness uncalcified loss (0 mm on the graphs), could involve either part or all of the affected segment. Some patellae from subjects more than 50 years of age showed osteophytic lipping, indicating a remodelling element accompanying, but contrasting with, the degenerative process.

The findings differed between the two sexes. In women over 50 years of age patellar articular cartilage showed progressive thinning with increasing age. This was due to lesions causing disintegration of the cartilage matrix, often visible macroscopically without indian ink staining of the cartilage surface, and was thus not attributable to matrix shrinkage. It affected both the segments studied (Figs. 2, 4, 6).

The lesions were mainly of fibrillation type, with tangential, oblique, and vertical splitting extending into the cartilage along the alignments of the collagen fibre framework. When severe, fibrillation was sometimes accompanied by one or more other degenerative lesions in the same specimen: smoother-surfaced destructive thinning (Emery and Meachim, 1973); major horizontal splitting along the interface between the uncalcified and calcified cartilage.

The frequency of older specimens with a minimal thickness of 0 mm indicates that the cartilage breakdown in women had a strong potential to progress so as to cause a site, initially localized, of full-thickness uncalcified matrix loss, and to give an *en face* and a

Fig. 4 Central and medial b segment minimal uncalcified thickness in women. Symbols as in Fig. 2. The regression line ($P < 0.001$) was calculated using data only from those subjects more than 50 years of age.

Fig. 5 Central and medial b segment minimal uncalcified thickness in men. Symbols as in Fig. 2. The regression line ($P < 0.01$) was calculated using only data from subjects more than 50 years of age.

Fig. 6 Correlation ($P < 0.001$) of minimal uncalcified thickness of the two segments compared in the same individual (women).

Fig. 7 Correlation ($P < 0.01$) of minimal uncalcified thickness of the two segments compared in the same individual (men).

histological appearance indistinguishable from destructive cartilage thinning of the sort seen in surgical excision specimens from osteoarthrotic joints (Meachim, 1976b). This progression towards a patellofemoral osteoarthrosis in the elderly affected the females generally, and not just a special subgroup. In women aged 50–80 years there was an age-related increase in the incidence of patellar osteophytosis, as noted in a previous study (Meachim and Emery, 1974). It has already been shown that in women from this age range there is a good correlation between progressive cartilage destruction and osteophytic remodelling.

In men over 50 years of age progressive thinning of patellar cartilage with age was less severe (Figs. 3, 5), particularly in the case of the lateral segment (Fig. 3). A site of full-thickness uncalcified matrix loss on the left patella was seen only occasionally in the older men. Previous study has shown (Meachim and Emery, 1974) that in men the correlation between severe cartilage destruction and osteophytic lipping is often poor.

Statistical analysis of the effect of age on minimal uncalcified cartilage thickness was carried out, separately for each segment and for each sex, by (a) taking the subjects from the whole age range studied; (b) taking only those subjects under 50 years of age; and (c) taking only those subjects over 50 years of age. For the calculations, 0 mm values had to be treated in relation to the corresponding age at the time of death, although the full-thickness cartilage loss represented by such values may, of course, have first developed at an earlier age than this in some of the subjects.

The results of regression analysis were as follows. (a) Taking all the subjects, there was a statistically significant regression of minimal thickness against age ($P < 0.001$ for each segment in the women; $P < 0.02$ for the lateral segment and $P < 0.001$ for the central and medial b segment in the men). (b) However, if the data only from subjects under 50 years of age were considered, no statistically significant change in cartilage thickness was shown ($P > 0.10$) for either segment or for either sex. (c) In contrast, the data from those subjects over 50 years of age showed a statistically significant regression of minimal thickness against age ($P < 0.001$ for each segment in the women; $P < 0.01$ for each segment in the men). The regression lines shown on Figs. 2–5 were calculated using only the data from this group of older subjects. For both segments the slope of the regression line is steeper in the older women than in the older men, and this is especially so in the case of the lateral segment.

Measurements of minimal thickness on the two segments compared in the same individual, using

data from the whole age range, showed a statistically significant correlation both in the women ($P < 0.001$) and in the men ($P < 0.01$).

Discussion

A series of autopsy subjects may not be representative of comparable age and sex groups among the living population. This applies particularly to data obtained from patients dying of disease in hospital, and in this study at least two-thirds of the subjects were in this category. However, our results agree with those from a previous series of the patellar specimens (Meachim and Emery, 1974) in which material was obtained from a variety of sources in Liverpool, including, as far as practicable, subjects dying from accidents and subjects dying outside hospital suddenly or unexpectedly from natural causes.

Measurements of uncalcified cartilage thickness were made on tissue obtained at autopsy and fixed in formalin, and do not take into account possible changes in the volume of the fresh cartilage which might occur after death and during tissue fixation. Thus the measurements given are not necessarily those of unfixed cartilage in the living person. However, statistical analysis confirms that the results reflect a genuine change in minimal cartilage thickness in the older subjects. In support of this conclusion, attention is also drawn to the female patellae with a minimal uncalcified thickness of 0 mm, since formalin fixation will not have affected the presence or absence of full-thickness uncalcified cartilage loss on such samples.

Previous qualitative and quantitative studies have indicated that patellar cartilage degeneration is not a uniform process throughout adult life (Emery and Meachim, 1973; Meachim and Emery, 1974). Inspection and statistical analysis of our data suggest that it may be pertinent to consider changes in patellar minimal cartilage thickness separately for persons younger or older than 50 years of age.

No conclusion can be drawn concerning minimal thickness changes before the age of 50 years. Indeed the possibility that patellar cartilage thickness in younger adults may increase rather than decrease or remain constant cannot be discounted. Thus, in the case of humeral head cartilage (Meachim, 1971) samples with histological evidence of surface fraying show a slight but statistically significant ($P < 0.02$) increase in thickness attributable to swelling of the underlying matrix, and this degree of surface fraying is often demonstrable on the patellae in young adults (Meachim and Emery, 1974). Similarly, a more overt lesion of the cartilage can be accompanied by matrix swelling: in our study two of the

segments with 'histologically overt' or macroscopically apparent fibrillation had a thickness above the usual range (Figs. 2, 5).

During the degenerative process the possible effects of matrix swelling on total tissue height will eventually be counteracted by tissue loss consequent to matrix disintegration. After the age of 50 years a statistically significant decrease in patellar cartilage minimal thickness was demonstrable for each of the two segments studied, and for each sex. Individual specimens with a minimal thickness below the range of measurements for 'histologically intact' or 'minimal fibrillation' were virtually confined to subjects over 50 years of age (Figs. 2-5).

The term 'osteoarthritis' ('osteoarthritis', 'OA') is accepted by clinicians and radiologists as a diagnostic label for a heterogeneous group of synovial joint disorders, collectively degenerative in nature. Among pathologists, however, there has been less agreement as to what constitutes an osteoarthrotic process. Some (e.g. Bennett *et al.*, 1942; Collins and McElligott, 1960) have suggested that most forms of noninflammatory cartilage lesions are 'osteoarthrotic'. In contrast, in a study of the hip joint Byers *et al.* (1970) suggested that the term should be restricted to those cartilage lesions which have a major potential to progress to bone exposure of the sort seen in surgical specimens from clinical osteoarthritis. Byers contended that many of the age-related cartilage lesions found in the general population have no major potential to progress vertically in this manner. A survey in Liverpool (Meachim, 1975) of cartilage lesions found at autopsy in various joints and compared with those in surgical excision specimens (Meachim, 1976b) partly supported Byers's hypothesis but suggested that the natural history of age-related lesions at the patellofemoral joint be taken into account.

There are differences between the knee and the hip in the evolution of degenerative changes. Our study indicates that age-related cartilage fibrillation at the patellofemoral articulation progresses to full-thickness uncalcified cartilage loss in older women, to give what is morphologically an osteoarthritis, and also confirms previous observations (Meachim and Emery, 1974) that this progressive destructive process in women of the age range 50-80 years is accompanied by an age-related increase in the incidence of patellofemoral osteophytic remodelling. The progression towards patellofemoral osteoarthritis affects the female population generally, and these results cannot be explained as the consequence of a phenomenon confined to a special subgroup; however, the incidence of clinical symptoms from this cause of patellofemoral osteoarthritis is not known.

Data from a previous study of autopsy material have shown that patellofemoral bone exposure can develop independently of bone exposure in the tibiofemoral component (Meachim, 1976a) of the knee joint, although no conclusion was reached as to whether or not osteophytosis also develops independently in the two components of the knee.

It may be said that the cartilage changes observed in the women were the consequence of an undisclosed rheumatoid arthritis. However, the frequency of rheumatoid disease in the Liverpool population, although not known exactly, is much lower than would account for the present findings (J. C. Woodrow, personal communication, 1976). During our investigation one patella did show rheumatoid-type involvement, but this specimen was excluded from the study. It may also be said that the age-related progressive lesions in women are the consequence of subluxation or other mechanical disturbance at the patellofemoral articulation, but if this is the case then the hypothetical mechanical factor must be so common in women that it is a normal feature of the environment of their cartilage.

The reason for the sex difference in the autopsy incidence of age-related patellofemoral osteoarthritis is not known. It is notable that there is also a preponderance of females among patients operated on in Liverpool for osteoarthritis of the hip; this observation is not due to a sex difference in the average age of such patients.

The age-related cartilage thinning observed in this study was due to matrix loss from fibrillation and allied lesions. A previous study, using cartilage samples from the shoulder joint (Meachim, 1971), has shown that aging has no appreciable effect on the thickness of adult human humeral articular cartilage provided that the surface of the material remains histologically intact.

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