ISOLATED TRABECULAR FATIGUE FRACTURES IN THE FEMORAL HEAD

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This paper describes lesions that have been found in the femoral head in cadaver specimens and in specimens taken from patients suffering senile femoral neck fractures, osteoarthritis and rheumatoid arthritis. It will be suggested that at least some of these lesions are uniting fatigue fractures of isolated trabeculae. So far as we are aware, lesions of this kind have not been described before.

MATERIAL

Twenty-seven femoral heads were obtained at operation from patients with osteoarthritis and two from patients with rheumatoid arthritis. Twenty of the osteoarthrotic and one of the rheumatoid patients were given oxytetracycline for between three and fourteen days immediately before operation. Oxytetracycline is deposited in newly formed bone and fluoresces yellow in ultra-violet light.

Seven additional femoral heads were removed at operation following subcapital fracture of the femur. Ten others were obtained after death from patients not having a clinical history of hip disease. Nine of these necropsy specimens (taken from cadavers in the age range thirty-seven to ninety) showed some fibrillation or ulceration of the articular cartilage and the bone was to a varying extent porotic. The remaining specimen (from a cadaver aged twenty) was normal.

METHOD

All operation specimens and nine of the ten cadaveric specimens were examined whole and then cut into slices between 3 and 5 millimetres thick before being macerated in boiling 5 per cent caustic soda. These macerated slices were examined under illumination by visible and, when appropriate, ultra-violet light.

The remaining cadaveric specimen was decalcified in 10 per cent formic acid and then sliced to a thickness of one millimetre on a bacon slicer. The resulting slices were examined macroscopically. Sections for microscopic examination were prepared by embedding and sectioning selected portions from the macerated and unmacerated specimens.

FINDINGS

In the macerated specimens characteristic lesions were found on some trabeculae (Fig. 1). It can be seen that each lesion consisted of an irregular accretion of bone surrounding the trabecula. The shape of these bony accretions varied considerably. In some cases the whole trabecula was involved so that it appeared grossly thickened in an irregular fashion. In other instances an apparently normal trabecula could be seen projecting from each side of the mass. The accretions occasionally occurred in groups but were more frequently dispersed. In specimens taken from patients who had received oxytetracycline some of the bony accretions fluoresced when illuminated by ultra-violet light (Fig. 2), suggesting active new bone formation in the mass.

When one side of an accretion was pared away the trabecula could be seen passing through the centre of the accretion. If the trabecula itself was also pared and then impregnated with Indian ink a discontinuity was sometimes seen in the trabecula (Fig. 3).
Numerous lesions were found in the decalcified unmacerated cadaveric femoral head (Fig. 4). Microscopic examination of sections of unmacerated lesions showed that the bony accretions were composed of woven bone surrounding the trabecula in the region of a fracture of the trabecula (Figs. 5 and 6). Examination under polarised light confirmed the woven nature of this surrounding bone (Fig. 7). The fact that the accretion surrounded the trabecular fracture showed that the fracture could not have been a sectioning artefact. There was no evidence of inflammation.
CONCLUSIONS

We have found aggregates of woven bone on trabeculae in the femoral head in osteoarthritis, rheumatoid arthritis and subcapital fracture, and in cadaveric specimens in which the articular cartilage showed degenerative changes and the bone was to a varying extent porotic. We do not propose to describe in this paper the frequency or the distribution of these lesions but it is relevant to note that, as yet, we have found them only in association with other pathological findings. The lesions consist of a mass of bone which on the basis of its appearance and oxytetracycline uptake frequently appears to be undergoing rapid deposition. Within some lesions a discontinuity is found in the trabecula where it passes through the bony mass. This discontinuity is bridged by a continuous mass of the newly formed bone of the lesion itself. It appears that only one explanation can be advanced to account for those lesions in which a discontinuity is present in the trabecula: that they represent callus around fractures of the trabeculae.

That these fractures are due to fatigue rather than to excessive static loading or impact is suggested by the fact that they were usually isolated and that no displacement of such a fracture was observed. Excessive static loading, as if the specimen was slowly crushed in a vice, is obviously scarcely relevant to the living femoral head. There was no history of impact in any patients except those who had sustained subcapital fractures (and even in these patients the nature of the violence seemed trivial). Moreover, the impact that produced the subcapital fracture cannot be held responsible for trabecular fractures showing advanced healing. Finally, impact would be expected to produce groups of lesions and signs of significant injury in the specimen as a whole. We found the lesions usually to be dispersed and no such evidence of a generalised injury was present.

The interpretation of the lesion as a fatigue fracture, based on its macroscopic and microscopic appearances, is supported by its occurrence in association with certain pathological processes affecting the specimen as a whole. Although the detailed nature of the association between these lesions and other recognised pathological processes is outside the scope of this paper, the lesions have so far been found only in circumstances which might be expected to
Two trabecular fractures surrounded by irregular woven bone taken from the one unmacerated femoral head. The presumed fracture lines are arrowed. The trabeculum shown in Figure 6 leaves the plane of the section to left and right. (Haematoxylin and eosin, × 100.)
lead to an increase in stresses borne by the affected trabeculae. In the osteoporotic femoral head the stress at a given load in the remaining bone must be abnormally high, and the possibility that such stresses may cause fatigue failure in the proximal third of the osteoporotic cadaver femur at load levels within the physiological range has been demonstrated by Griffiths, Swanson and Freeman (1971). Calculations of the stresses that may be encountered in the human femoral head if the articular cartilage is destroyed (Kempson and Freeman, in press), combined with measurements of the fatigue properties of human cortical bone (Freeman, Day and Swanson 1971), suggest that fatigue failure may occur in the femoral head when the cartilage is lost, as in osteoarthrosis, and in particular when the cartilage is lost and the bone is porotic as well, as in rheumatoid arthritis. If it is accepted that the lesions are associated with appropriately high mechanical stresses in the involved bone, it follows that the lesions themselves might well be fatigue fractures.

The absence of a discontinuity in some lesions requires explanation. Two possibilities may be advanced. The defect, previously present, may have disappeared as a result of consolidation within the callus. Alternatively in some trabeculae an accretion of bone may have occurred without fracture. It is conceivable that this process might take place if a trabecula was overstressed but not to the point of fracture. However, no experimental proof exists for the existence of such a process although in general there are grounds for supposing that bone does respond to increasing stress by increasing bone formation.

In the course of this study we have seen numerous coarsely thickened trabeculae. It seems possible to us that this coarse thickening may represent the final stages in the remodelling of the lesions described in this paper.
We believe that the lesions seen in these femoral heads may exemplify a fundamental pathological process in the evolution of subcapital fracture of the femoral neck and in the bony changes of osteoarthrosis and rheumatoid arthritis of the hip. Thus it seems reasonable to think that the progressive accumulation of isolated trabecular fractures at the junction of the femoral head and neck in patients with osteoporosis might eventually lead to frank subcapital fracture. Such a sequence of events would be compatible with the development of fatigue fractures at this level in the laboratory (Griffiths, Swanson and Freeman 1971). In osteoarthrosis these lesions might be responsible for several features of the bony pathology. The accumulation of such lesions might be expected to lead to progressive sclerosis in the femoral head, while areas of bone containing fractures might be weakened to the point of collapse with consequent deformation of the femoral head and occasionally the separation of a fragment of the articular surface. The latter sequence might be expected particularly in the porotic bone in rheumatoid arthritis. Finally it seems possible that areas of collapsed cancellous bone, perhaps containing ununited fractures, might lead to “cyst” formation within the femoral head. Little is known about the production of pain in bone but it is possible that these fractures may contribute to the pain felt in arthritis of the hip.

If, as appears probable from the work of Vernon-Roberts and others (Darracott and Vernon-Roberts 1971), these lesions are to be found in other areas of juxta-articular cancellous bone, excessive cyclical loading, sometimes to the point of causing fatigue fractures, may come to be seen as a pathological process of general and fundamental importance in the evolution of certain skeletal and articular diseases.

SUMMARY

1. The femoral head has been examined in specimens taken from cadavers, patients suffering subcapital fracture of the femoral neck and patients undergoing total replacement arthroplasty for osteoarthrosis and rheumatoid arthritis.
2. Lesions have been seen, some of which appear to be uniting fatigue fractures of individual trabeculae.
3. It is suggested that excessive cyclical loading, sometimes leading to fatigue fractures, may represent a fundamental pathological process of general importance in the evolution of certain skeletal and articular diseases.

REFERENCES