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THE SUBCHONDRAL BONE IN OSTEOARTHRITIS AND RHEUMATOID ARTHRITIS OF THE KNEE

A Histological and Microradiographical Study

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Specimens of the joint surfaces of the tibia from patients with OA and RA were examined for bone mineralization, bone formation, osteoid tissue and bone resorption. Judging from the appearance of the osteoblasts in OA the sclerotic changes are mainly focal with relatively little osteogenesis. No osteoclasia was seen in the sclerotic areas. Breakdown of the mineralized cartilage is followed by the development of cysts with highly cellular connective tissue with high osteoblastic activity and osteoclasia. Osteoid tissue is relatively sparse. The changes in RA are more diffuse with a more active osteoblastic activity and widespread zones of osteoid tissue as well as resorption by osteoclasts. It appears as if the increased uptake of ^{85}Sr in OA is more dependent on the occurrence of relatively inert osteosclerosis than on a rapid turnover of the bone tissue.

Key words: osteoarthritis; rheumatoid arthritis; knee joint; subchondral bone; microradiography

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The disease process of osteoarthritis involves not only the cartilage but also the subchondral bone. Even at a very early stage of the disease, metabolic changes of the subchondral bone can be demonstrated as an increased uptake of radioactive strontium (Danielsson et al. 1963, Andersson et al. 1967). As the osteoarthritis advances, the uptake of ^{85}Strontium becomes abnormally high in those areas where osteosclerosis is roentgenographically demonstrable. This may be due to a greater amount of bone in these areas or to an increased turnover of mineral. Isotope studies have shown that osteoarthritis is probably associated with an increased synthesis of bony tissue rather than a decreased resorption (Bauer & Smith 1969). As for the uptake of ^{85}Strontium in rheumatoid arthritis it has been shown to be high but less focal than in osteoarthritis (Holopainen & Rekonen 1966).

This paper concerns the histological and microradiographical evaluation of subchondral bone in bone formation and bone resorption, respectively, in osteoarthritis (OA) and in rheumatoid arthritis (RA). Special attention is directed to the occurrence of osteoid tissue, which

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as far as OA of the hip joint is concerned, has been studied by Batra & Charnley (1969).

MATERIAL AND METHODS

Specimens of the joint surfaces of the tibia were obtained from pieces of bone excised during various types of total arthroplasty of the knee (St. Georg's sledge prosthesis, Geomedic's and Guepar). The material consisted of 16 patients with OA and 11 with RA. Of the 16 patients with OA, all were operated upon unilaterally only, four with Geomedic's method (both condyles) and 12 with St. Georg's (1 lateral condyle and 11 medial condyles). Of the 11 patients with RA, two were operated upon on both sides, giving a total of 13 knees from which specimens could be obtained from both condyles.

The excised pieces of bone, consisting of the central parts of the respective condyles, were sawn into two sagittal slices. The anterior part of the first slice was fixed in formalin and decalcified in formic acid and used for histological examination. It was cut into 5–7 μ sections, which were stained with haematoxylin-eosin, van Gieson and Safranin-O. The second slice was cut into at least three sections, which were fixed in formalin, dehydrated and embedded in methyl methacrylate without decalcification. Sections 5 μ thick were cut with a bone microtome. These sections were stained with Goldner stain (Schenk 1965) and examined for osteoid tissue. Parts of the slice were embedded in methyl methacrylate, ground down to a thickness of 100 μ and used for microradiography. The pictures were taken with a Philips diffraction tube using 20 kV and 30 mA at a focal distance of 30 cm and with an exposure time of 10 minutes. The film used consisted of high resolution plates and the developer was a D 19 B.

FINDINGS

The roentgenograms of the knee joints showed a varying degree of OA and RA. The changes ranged from relatively mild unicondylar OA to severe bicondylar changes. Also the roentgenograms of RA showed varying stages of RA, though mostly severe destruction with or without secondary OA.

Osteoarthritis

The osteoarthritic changes of the cartilage varied from superficial fraying to

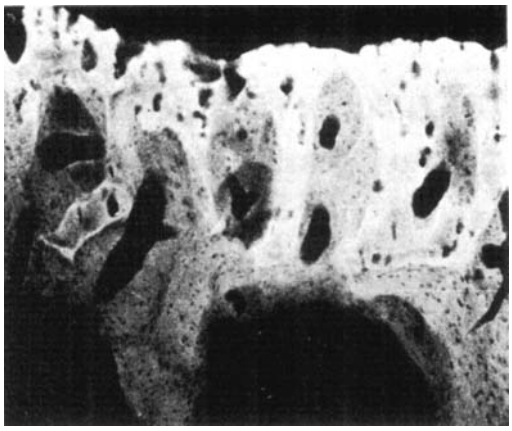

Figure 1. Microradiograph (×3.4). Osteoarthritis, subchondral bone and mineralized cartilage. The mineralized cartilage, which is very white in section, gives off processes extending into the subchondral bone.

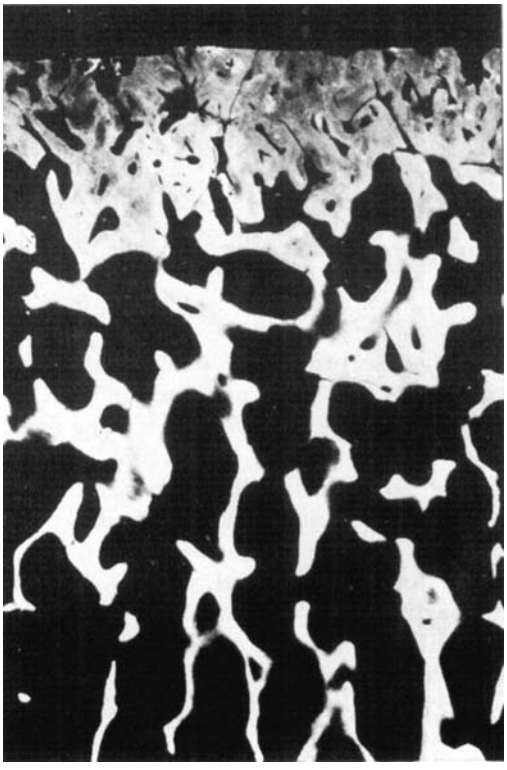

Figure 2. Microradiograph (×6.3). Osteoarthritis, sclerotic bone in the superficial layer under the denuded cartilage. Transition to spongy bone of fairly normal appearance is abrupt.

complete denudation. The weightbearing parts of the cartilage exhibited the greatest changes whereas particularly on the anterior margin of the tibial condyle the thickness of the cartilage was still normal even in fairly advanced cases. Clusters of chondrocytes were seen, especially basally, in the relatively intact cartilage. Necrosis of the chondrocytes was common, especially when the superficial layers of the cartilage had been destroyed. Staining with Safranin-O showed a considerable decrease in orthochromasia, particularly in the transitional and columnar layers, being less noticeable pericellularly and especially around the clusters. Also in histologically relatively intact parts of the cartilage the uptake of the dye was decreased. Sometimes the tidemark was double or multiple as has also been described by Green et al. (1970). The borderline between the mineralized cartilage and the subchondral bone was very irregular and each tissue showed extensions which fitted in between one another as has been described by Stougård (1974) (Figure 1). The subchondral bone had a strong tendency to undergo sclerosis in the form of thickening and confluence of the trabeculae to form massive blocks of bone containing single vessel canals. When the bone was completely denuded the surface layer exhibited necrotic osteocytes. The severity of the sclerosis clearly varied with damage to the overlying cartilage. When the cartilage was relatively intact the underlying trabeculae were of normal appearance. The thinner the cartilage the more massive the sclerosis. The sclerosis was clearly focal. The sclerotic changes varied in depth from 500–3000 μ but were

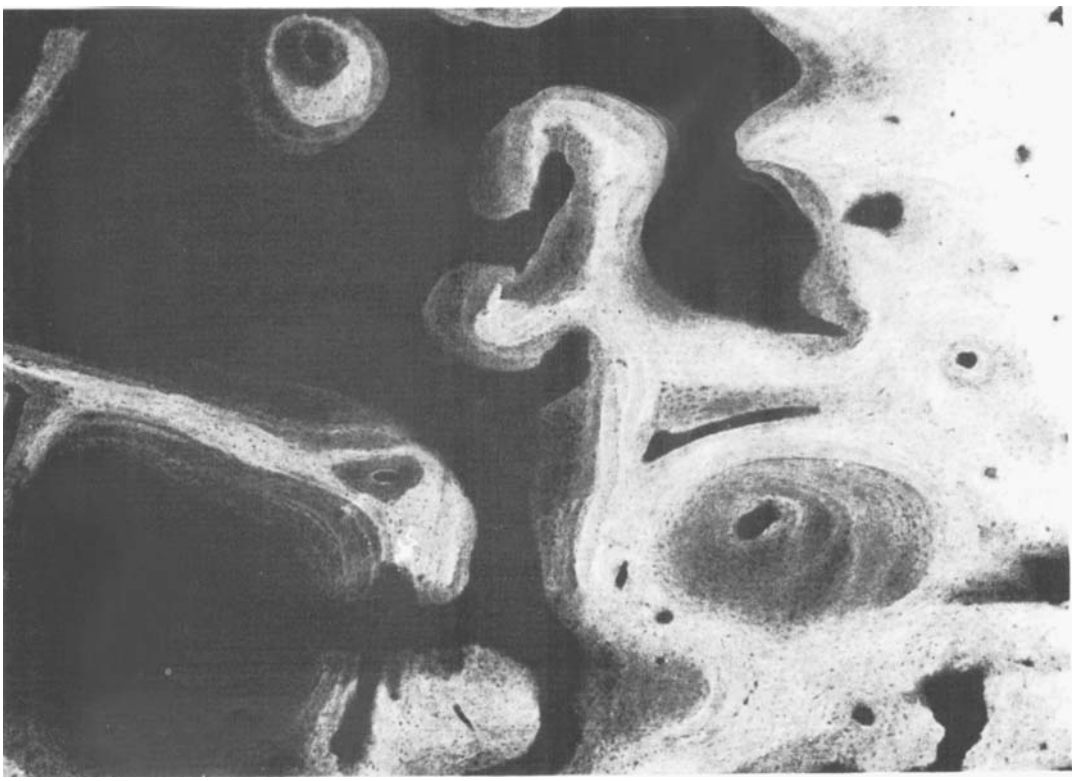

Figure 3. Microradiograph (× 22.6). Rheumatoid arthritis. Bone showing signs of pronounced bone reformation.

often abruptly bordered by spongy bone of normal appearance (Figure 2). No microscopic fractures or nodular aggregates ("birds nests") (Todd et al. 1972) were found in this spongy bone. The trabeculae were mostly highly mineralized without appreciable signs of remodelling of the bone. Where the OA was severe, it had locally broken through the mineralized cartilage, which otherwise appeared to be very resistant. In such cases resorption cavities extending downwards from the surface and filled with granulation tissue were visible. The spaces between the bone trabeculae contained fatty marrow, except where the trabeculae were sclerotic; here the tissue was fibromyxotic and poor in cells. The resorption cysts contained highly cellular tissue.

There were osteoblasts on the sclerotic trabeculae and to a lesser extent on the normal trabeculae. The osteoblasts were invariably flattened, suggesting low activity (so called resting osteoblasts). Only in the resorption cavities (cysts) were the osteoblasts more active and protrudent. The amount of osteoid tissue found in OA bone stained *ad modum* Goldner was small, but increased with the severity of the OA and was found particularly on trabeculae surrounding granulation tissue and in resorption cavities. These cavities also contained osteoclasts which were hardly ever seen elsewhere. New bone formation occurred inside the cysts.

The specimens contained very few osteophytes, but where they were found, they were seen to form on the remains of the mineralized cartilage, frequently with a persisting tidemark.

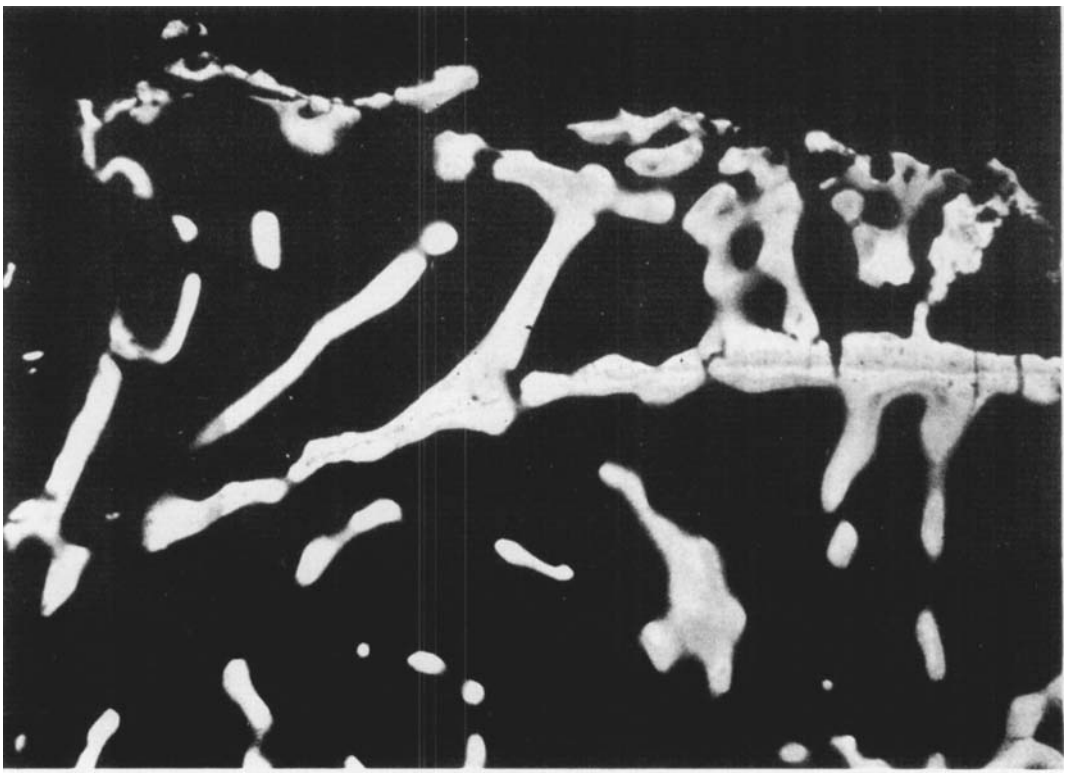

Figure 4. (Microradiograph (× 9). Rheumatoid arthritis, osteophytes on the old cartilage, whose mineralized part is visible as an undulating line across the entire section.

Rheumatoid arthritis

RA differed from OA in that the cartilage was damaged to a greater extent. The cartilage, often including the mineralized cartilage, was resorbed by massive granulation tissue, which often broke into the subchondral bone, where it filled large cavities. New bone formed in these cavities. There were also islands of relatively intact cartilage which, however, did not stain orthochromatically with Safranin-O. The tendency of the bone trabeculae to undergo sclerosis was less than in OA. Even when the cartilage had been completely destroyed, the trabeculae were still of roughly normal thickness. These trabeculae contained bone of a different degree of mineralization, i.e. the bone tissue was in a state of remodelling (Figure 3). However, some specimens of the knee with long-standing RA showed secondary OA with sclerosis of the subchondral bone. The bone marrow was to a large extent filled with highly cellular tissue, which had replaced the normal fatty tissue. Osteophytes were seen in a large number of preparations where they had the same appearance as in OA. The osteophytes had formed on relatively preserved mineralized cartilage (Figure 4).

Osteogenesis was much more active than in OA. Everywhere the bone trabeculae showed active osteoblasts standing on edge as well as abundant osteoclasts. In sections stained *ad modum* Goldner osteoid layers were seen under these osteoblasts (Figure 5). These layers were relatively thick and were made up of 2–3 layers of collagen fibrils demonstrable by polarized light.

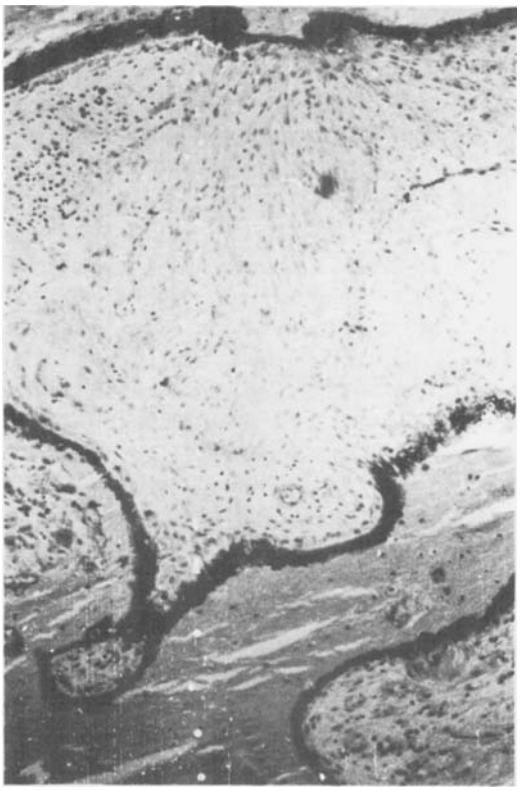

Figure 5. Microphotograph (× 42). Rheumatoid arthritis. Goldner-stain of non-decalcified bone showing active osteogenesis around spongy cavity with granulation tissue. The black zones denote osteoblasts + osteoid tissue.

DISCUSSION

Examination of specimens of the tibial condyle from patients with OA and RA showed that these diseases differ in the type of new bone formation in the subchondral bone of the knee. In OA the changes consist of focal changes of the subchondral bone, consisting mainly of relatively limited blocks of thick confluent trabeculae relatively abruptly outlined against more normal bone trabeculae. The osteogenesis on the sclerotic trabeculae appears to be relatively slow, judging from the appearance of the osteoblast. No osteoclasts were seen in any of the sclerotic areas. In those areas where the mineralized cartilage had been broken through, cysts arose in the bone with highly cellular connective tissue, and the trabeculae surrounding these cysts showed an appreciably increased osteoblastic activity in association with osteoclasia. These cysts contained also newly-formed cartilage and bone. Osteoid

tissue was seen only in those areas afflicted by advanced OA.

In RA there was a more diffuse change in the major part of the subchondral bone. The trabeculae there were of relatively normal thickness but showed different degrees of mineralization. There was strong osteoblastic activity as well as osteoclasia. The amount of osteoid tissue was appreciably higher than in OA. Judging from the present findings, in relation to those made in investigations with ^{85}Sr, the increase in the isotope uptake in OA can be ascribed to focal increases of the bone mass consisting of sclerotic areas without signs of bone resorption. Not until OA is at an advanced stage does the histological picture show evidence of a quicker turnover with resorption cavities and active osteoblasts.

The substantially increased uptake of ^{85}Sr in RA is reflected by the morphological picture with large areas with appreciably high activity of the osteoblasts and osteoclasts.

Osteoid tissue occurs in both OA and RA, but to a greater extent in RA. In OA, osteoid tissue occurs only in those areas where the OA is most advanced. The occurrence of osteoid tissue may perhaps be explained by osteogenesis being too rapid for normally mineralized tissue to form.

Lereim et al. (1974) have shown that the subchondral bone is less hard than normal in the tibial condyles in both OA and in RA and that the decrease in hardness is equal in both diseases. The histological picture does not offer any explanation as to why the decrease is equal in both diseases. The subchondral bone in RA is clearly osteoporotic, while in OA the subchondral bone is focally sclerotic, but otherwise relatively normal. The osteoarthritic bone has evidently undergone qualitative changes making it more brittle than normal bone.

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