

Structural Changes of the Femoral Head in Cases of Non-Union of the Femoral Neck

A. HULTH and S. JOHANSSON

Orthopaedic Department, Allmänna Sjukhuset, Malmö, and Departments of Plastic Surgery and General Surgery, Akademiska Sjukhuset, Uppsala, Sweden

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Prognostic tests in femoral neck fractures using intraosseus phlebogram (HULTH, 1956) or radioactive iodine (JOHANSSON, 1964) have demonstrated a good correlation between avascularity and non-union. Thus non-union should be looked upon as an avascular complication. The femoral head often shows a normal structure on roentgenograms in cases with non-union, but mottled appearance, diffusely increased density, or deformity may be seen. Therefore some authors state that there are two types of non-union — with or without necrosis of the femoral head — which can be differentiated in standard roentgenograms.

The roentgenological changes of necrosis can only occur after at least partial revascularization. If the teres vessels are inadequate or missing and the synovial bridges around the neck are torn, the head fragment is left as a loose body in the joint. It will keep its original structure for an indefinite period of time. The role of the revascularization in creating the roentgenological picture of femoral head necrosis was demonstrated by HULTH 1961. He compared the roentgenograms with microradiograms and histological slides in four cases of healed femoral neck fractures with subsequent necrosis. As the roentgenological diagnosis of necrosis was ascertained a greater part of the femoral head was already rebuilt after revascularization, sometimes with the exception of a sequestration of a portion of the healing head at the superior pole. The sclerotic parts represented areas with broad bone trabeculae, consisting of newly formed bone apposed on the old bony framework.

In order to put further light on the structural changes that appear in cases of non-union we have studied 15 cases representing different types with none, slight or massive roentgenological changes of the head fragment.

Material and Methods

The femoral heads in this study were specimens obtained during operative procedures either for replacement with a prosthesis or simple removal in cases of non-union with severe clinical symptoms.

The patients had been referred to the orthopaedic or surgical clinic in Uppsala from several different hospitals. In some cases a prognostic test had been performed at the time of nailing. Different types of nails had been used.

Roentgenograms were taken of the head fragment before and after sawing it sagittally in 5—10 mm thick sections. Of the two central sections one was used for histological studies after fixation in formaldehyde and decalcification in nitric acid. It was embedded in paraffin and slides measuring 10 μ were obtained. The other central section was fixed in alcohol and embedded in methyl metacrylate. After polymerization the block was sawed into thinner laminae and these were sanded until they had a thickness of approximately 150 μ . Microradiographic studies were then carried out using a PHILIP's diffraction unit with a Cu anode.

Classification of femoral head fragments was done after roentgenological appearance into three groups:

- I. no structural changes (5 cases),
- II. structural changes with normal contour (6 cases),
- III. structural changes with contour deformity (4 cases).

Results

I. Non-Union without Structural Changes

Case 1, male 93 years. At osteosynthesis the ^{131}I -test (JOHANSSON) had suggested a totally interrupted blood supply to the femoral head. 13 months later nails were removed and the femoral head taken out due to pseudarthrosis. *Microradiogram* showed normal bone trabeculae throughout. *Histologically* the cartilage had normal height but showed cavities and a frayed surface. The bone trabeculae were slender and the osteocytes lacked nuclei. The marrow contained no stainable cells; only at the base a sparse collagen tissue was seen. Although standard roentgenographic and microradiographic studies showed normal pattern the histological slides confirmed the fact that the whole femoral head was non-viable.

Case 2, female 81 years. ^{131}I -test showed partial vascular damage to the head fragment, redislocation 2 months after nailing, head fragment then removed. It looked *macroscopically* normal with intact cartilage. *Microradiogram*: mostly broad trabeculae. Near the fovea newly formed bone possibly in a nail channel was seen. Here the cavities between the broad trabeculae were crowded with thinner trabeculae with a lesser degree of mineralization. *Histologically* in most parts necrotic marrow and bone. A non-viable fragment with signs of revascularization from the fovea giving rise to the formation of new bone in this region.

Case 6, female 66 years. The fracture was not nailed due to medical complications. At operation after 4 months a phlebogram (HULTH) was positive. A prosthetic replacement was then performed. *Roentgenogram* showed normal structure in the head fragment as a whole though in pictures of the sawed sections there were zones of diminished density centrally and at the base. In *microradiograms* cavities filled with newly formed slender bone trabeculae were seen. *Histologically* most of the bone was necrotic with formation of dense connective tissue subchondrally. Basally there were zones of new bone formation in more vascularized connective tissue. This was a primarily non-viable femoral head with starting revascularization and regeneration. The positive venogram was probably a result of reestablished vascular channels at the time of operation.

Case 11, female 68 years. Venogram and ^{131}I -test indicated avascularity. Nails slipped after 6 months and then a prosthesis was inserted. The head fragment macroscopically and roentgenologically normal (Fig. 1a). *Roentgenogram* of a section showed somewhat increased density at the base. *Microradiogram* showed intensive new bone formation, especially in and around nail channels (Fig. 1b). *Histologically* mostly dead bone and marrow. Primarily this was a non-viable fragment with signs of regeneration especially along nail channels.

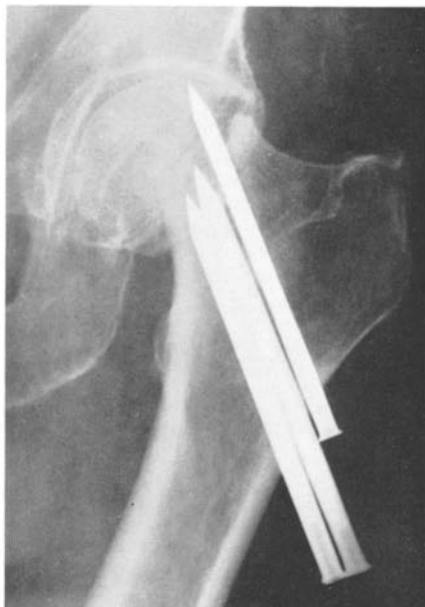
Case 17, female 64 years. Redislocation 5 months after nailing necessitating a prosthetic replacement. The head fragment appeared grossly normal with intact cartilage. *Microradiogram* showed varying density and newly formed bone in scattered areas. *Histologically* the cartilage was vital and so were the bone trabeculae with granulation tissue in the marrow cavities rich in vessels. This seemed to be a vital head fragment with no signs of bone necrosis.

Summary of group I cases: Four out of five cases of non-union with no structural changes on clinical roentgenograms showed head fragments which were almost totally necrotic. In three of these there were signs of starting reorganization. In the fifth case only the head fragment was viable throughout.

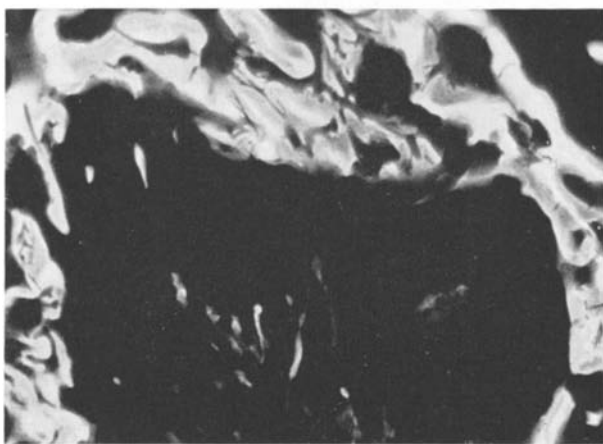
II. Non-Union with Structural Changes in the Femoral Head, with Normal Roentgenologic Contour

Case 2, female 61 years. 21 months after osteosynthesis there was a small dense head fragment and a fracture line was located within the base of the head, possibly a "Wanderungs-pseudarthrose" (ENDER). *Roentgenogram* of a central section of the head showed marked

sclerosis, especially near the area of pseudarthrosis (Fig. 2a). The cartilage showed some smaller defects on the surface. *Microradiograms* (Fig. 2b) showed normal structure of subchondral bone except near the fovea, where bone regeneration was seen. The fracture line was bordered by broad trabeculae, lined with newly formed bone. *Histologically* granulation tissue



a



b

Fig. 1a and b. Case 11, group I. Nails slipped after 6 months. No structural changes on standard roentgenogram (a). Histologically and microradiographically partly rebuilt necrotic femoral head with new bone formation especially in nail channels (b)

in the marrow around the fovea was rich in cells whereas more basally there was a fibrous connective tissue and coarse bone trabeculae. Viable appearing bone is found interspersed throughout the necrotic tissue. This specimen had initially been non-viable with partial secondary revascularization across the primary fracture line which healed. Later a new demarkation occurred in the base of the head and then the earlier rebuilt bone trabeculae of this region again became necrotic.

Case 3, female 66 years. 13 months after osteosynthesis non-union, perforation of nails and a dense head fragment. *Roentgenogram* of central section showed patchy density, that corresponds to areas with new formed bone layered on old trabeculae on *microradiograms*. Near the fovea signs of resorption of bone was seen. *Histologically* necrotic bone with massiv

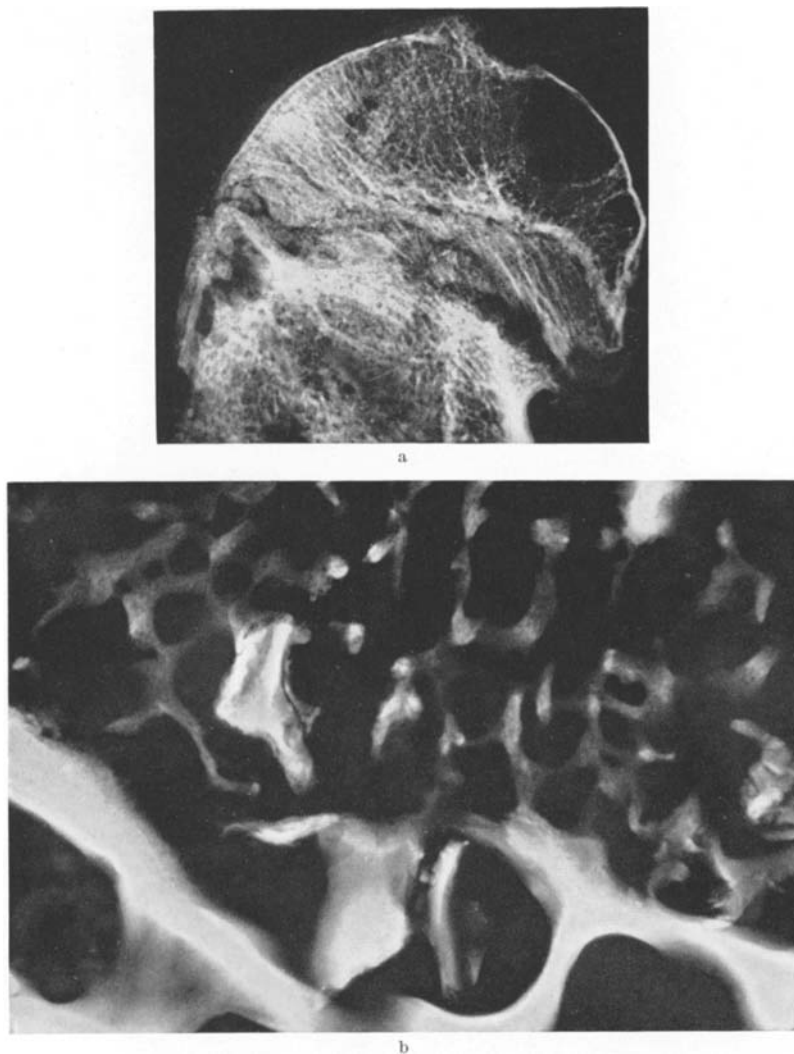
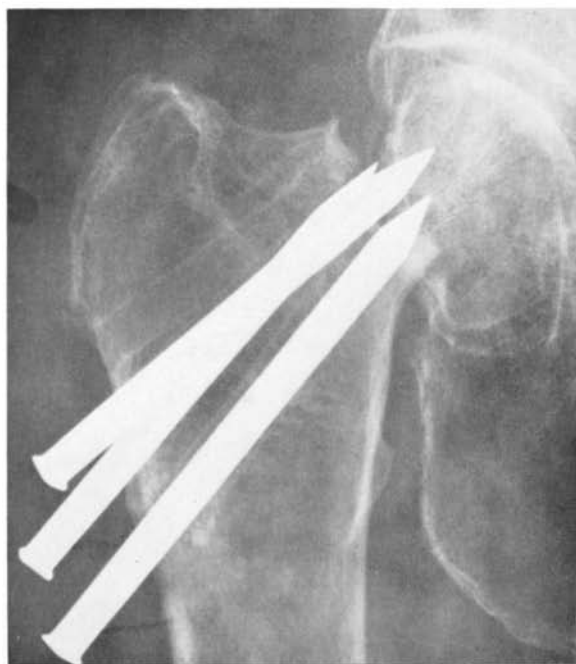


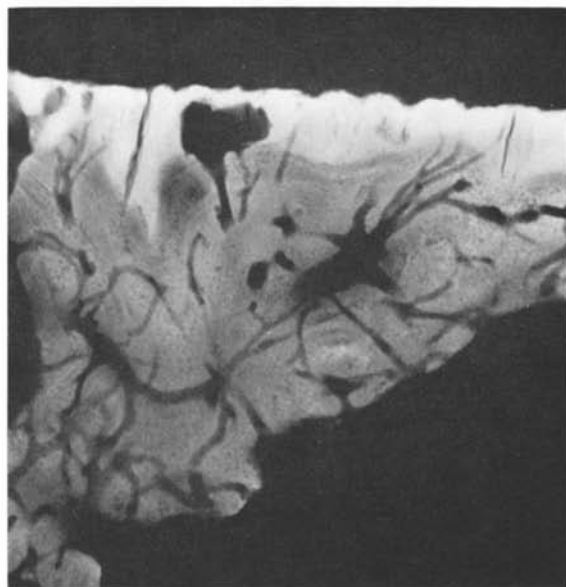
Fig. 2a and b. Case 2, group II. After 21 months sclerosis and "Wanderungspseudarthrose" in roentgenogram of central section of removed specimen (a). Necrotic and viable bone intermingled. Sclerosis is due to new bone laid down on the surface of old trabeculae as seen in the microradiogram (b)

filling of the marrow by connective tissue was seen. Some areas, though, showed a richer vascularization and here osteoblasts were seen. In this necrotic head fragment sparse areas of regeneration was seen.

Case 5, female 71 years. Valgus fracture with secondary dislocation after 2 months and then nailing. Venogram was positive but ^{131}I -test showed decreased circulation of the femoral head. 10 months later nails slipped and redislocation occurred. *Roentgenogram* showed irregular density in the central part and more evenly distributed density subchondrally. Roentgenogram of a central section showed hollows in the upper quadrant lined by sclerotic walls.



a



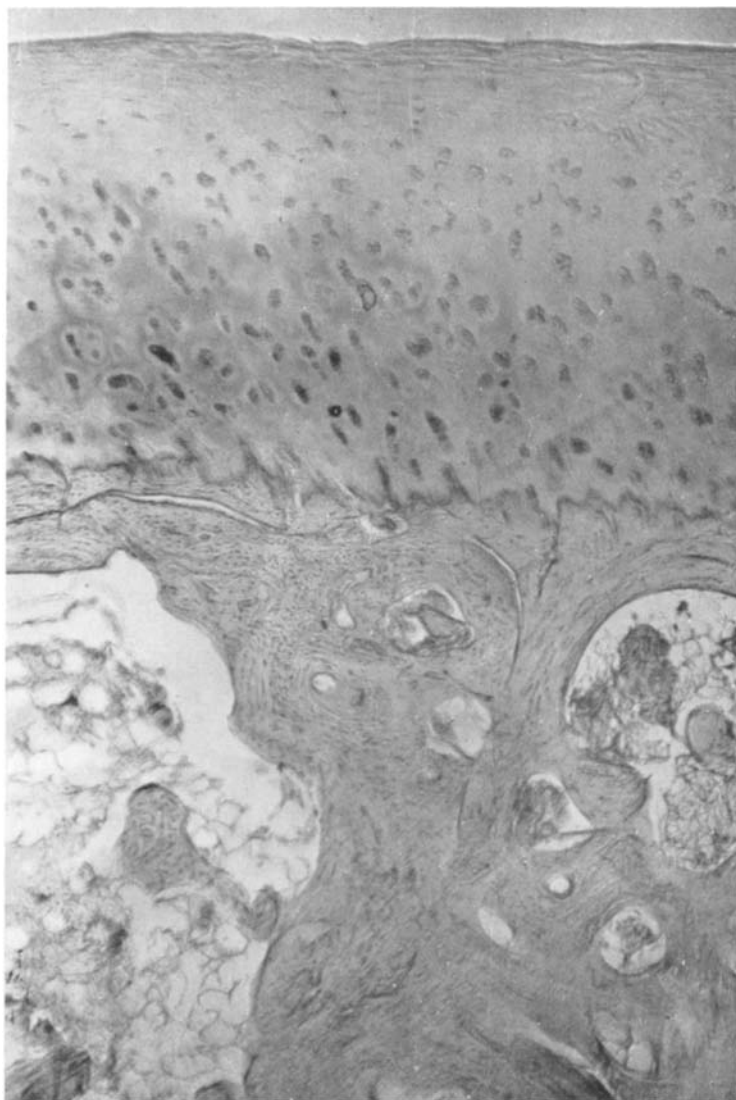
b

Fig. 3a—c. Case 5. Nails slipped after 10 months. Irregular density in roentgenogram (a). Sclerosis subchondrally caused by new bone formation (b)

Cartilage looked grossly intact. *Microradiogram* showed subchondrally new bone layed down on old trabeculae, and callus formation in nail channels and at the base. This specimen consisted of mostly necrotic bone with regenerative activity from the fovea spreading subchondrally

and from the fracture line spreading through nail channels (Fig. 3a, b, c). The positive venogram could be the result of starting revascularization at the time of nailing.

Case 7, female 73 years. An open fracture line and a dense head fragment was found 8 months after nailing. *Roentgenogram* of section showed increased density most marked



c

Fig. 3c. Cartilage and subchondral bone mostly vital in histological picture (c), though most of the femoral head in other parts was necrotic

basally; at the top, though there was a zone of decreased density. Cartilage looked intact except for a shallow defect centrally. In the *microradiogram* mostly normal looking thin trabeculae were seen. Along the nail channel and under the fovea there was new bone formation. *Histologically* the bone was partly vital under the cartilage which also looked normal.

From the fracture area a dense connective tissue has grown into the head fragment and here the bone was necrotic. This femoral head was dead except a small part subchondrally.

Case 8, male 71 years. Manifest non-union after 13 months. Gross defects were seen in the cartilage. Clinical roentgenogram had shown mottled appearance and in *roentgenogram* of central section the structure was irregular with basally increased and subchondrally decreased density. *Microradiogram* showed thick trabeculae apparently broadened by the apposition of new bone. At the fovea there were the gracile pattern of new bone formation in the marrow spaces. *Histologically* the cartilage was low and fringy. Basally and around the fovea there was ingrowth of connective tissue in the marrow which in other parts looked inactive. This was primarily a non-viable head fragment with signs of regeneration.

Case 15, female 62 years. Nailed with a gap of the fracture. Prosthetic replacement after 10 months, when there were no signs of healing and a irregularity of the density of the femoral head. *Roentgenogram* of removed specimen showed basally increased density, in other parts zones of decreased density. *Microradiogram* showed some newly formed bone near the fracture zone and along the nail channel. *Histologically* the bone was vital at the base and around nail channel and only subchondrally there were signs of bone necrosis. This head fragment was to a great extent viable non-union being due to insufficient contact between the fracture surfaces.

Summary of group II cases: In 5 out of 6 cases of non-union the structural changes of the femoral head are the result of a reorganization, starting from the fovea, but also from the fracture zone. Here the sclerosis is due to deposition of newly formed bone on old trabeculae. At the fovea the regeneration from the teres vessels shows another picture: resorption of old bone and formation of new slender trabeculae in the widened marrow spaces: *i. e.* a true creeping substitution. Also the nail channel shows the same type of reorganization. In one case only the greater part of the head fragment was found to be viable.

III. Non-Union with Structural Changes and Contour Deformity of the Femoral Head

Case 14, female 81 years. After 11 months nails had penetrated a dense femoral head, the base of which was resorbed. *Roentgenogram* of a cut section showed varying degrees of calcification in different parts. *Microradiogram* showed young bone around a nail channel but in other parts the ordinary trabeculae pattern was maintained. *Histologically* massive dense connective tissue was seen in the marrow and bone trabeculae were dead except for scattered small areas of new bone around nail channel.

Case 10, female 65 years. Penetration of nail after 6 months; cartilage mostly missing. *Roentgenogram* of sawed section showed a straight dense line across the middle of the femoral head. *Microradiogram* showed new bone formation under the remnants of cartilage, the defects of which had apparently allowed a pannus to form. The dense line consisted of new bone apposed upon old trabeculae. In other parts the trabeculae were sparse and non-viable.

Case 16, female 59 years. 19 months after nailing a sclerotic femoral head was removed. *Roentgenogram* of sawed section showed dense bone. *Microradiogram* showed thick trabeculae due to new bone formed on the old frame work. New bone was also seen as slender trabeculae in nail channels and in zones of demarcation toward dead parts where the original type of trabeculae persisted. *Histologically* a cellular marrow rich in osteoblasts, *i. e.* indicating a good regeneration of an initially non-viable head fragment.

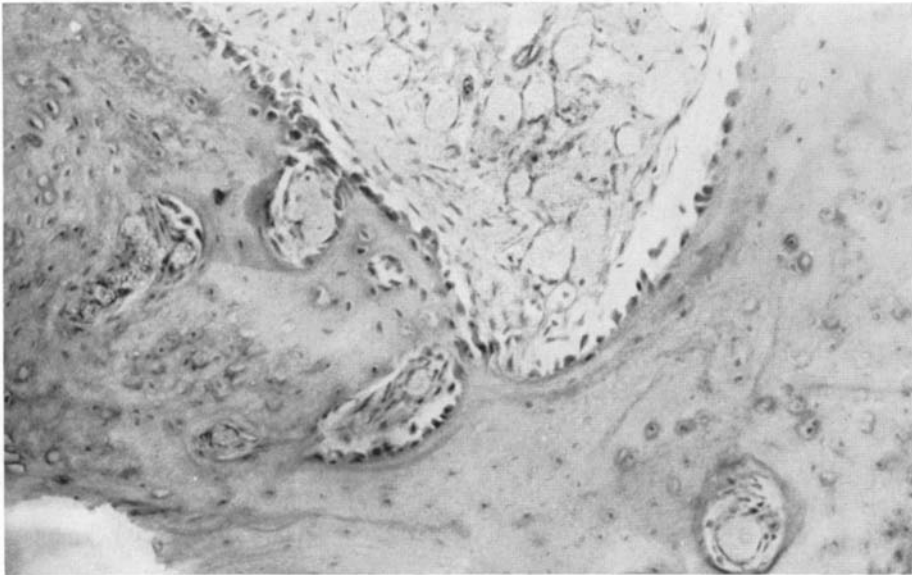
Case 18, female 60 years. After one year the femoral head is hypersclerotic with a marked demarcation line to the neck (Fig. 4a). *Microradiogram* showed areas with thick trabeculae due to apposition of new bone on old trabeculae. *Histology* showed scattered areas of intense new bone formation with layers of osteoblasts and vital osteocytes (Fig. 4b). The marrow cavity was filled by granulation tissue with varying richness of vessels.

Summary of group III cases: Out of four cases of non-union with structural changes and contour deformity of the femoral head, three showed penetration

of nails. All four head fragments were partly rebuilt; the reorganization taking place mainly along nail channels, but also from the foveal area, and in one case also from a pannus on the surface of the head where the cartilage was defective. Sclerosis indicated that reorganization and new bone formation has occurred.



a



b

Fig. 4a and b, Case 18. Non-union and increased density 12 months after nailing (a). In histological slide dispersed areas of new bone formation with osteoblasts (b)

Discussion

Some structural changes in the femoral head always occur after fracture of the neck, whether the fracture heals or not. If the head is viable those changes are mostly seen near the fracture and along the nails and as they are rather

discrete, they are seldom detected in standard roentgenograms. If on the other hand the head fragment is deprived of its circulation, the reparative process occurs as the fracture is healing by means of invasion of granulation tissue across the fracture line and the necrotic bone is rebuilt.

If healing is delayed or hindered by a gap in the fracture or by deficient immobilization this way of access of reorganization tissue is diminished. The femoral head will keep the original roentgenological appearance for an indefinite period of time in spite of the fact that it is totally necrotic if ingrowth of living mesenchyma does not occur. Along the nail (or nails), as along remaining synovial bridges there usually is a possibility for reparative tissue to reach the head fragment from the distal part of the femoral neck. Another pathway for reorganization is via the teres ligament and also in some cases via a pannus formation over areas, where cartilage is defective.

The reparative process is of different types in different parts of the femoral head. Near the fracture zone the picture is dominated by new bone laid down on the surface of old bone trabeculae, making these thicker with narrowing spaces, giving rise to the sclerosis seen in standard roentgenograms. Subchondrally the old bone most often is absorbed through osteoclast activity and then the new bone is laid down in the widened marrow spaces forming a reticular pattern with fine meshes of slender trabeculae. This type of reorganization, which is a true creeping substitution is also seen along the nail channel.

We never saw head fragments which were uniformly rebuilt; there are always greater or smaller parts without any signs of viability in the bony frame work. Here no signs of bone absorption was seen and the marrow cavity is filled out by a collagenous connective tissue with few cellular elements. It seems as if the ability of repair of dead bone by surrounding living mesenchyme is limited in time. After a certain period the non-viable bone apparently cannot stimulate the activity of osteoclasts or osteoblasts and the process of reorganization stops.

Summary

Our comparative studies of roentgenogram, microradiogram and histology of femoral heads in cases of neck fractures with non-union have shown: Changes of structure of the femoral head can occur in viable bone tissue although they are seldom seen in standard roentgenograms. When such changes are seen they almost always indicate that living tissue has invaded a non-viable head fragment, where bone resorption and new bone formation take place. Sclerosis always means new bone formation. There are two types of non-union; with and without structural changes. In cases with structural changes the head fragment is almost always viable. In cases without structural changes the head fragment may or may not be viable and thus roentgenograms do not tell whether the head fragment is viable or not in a case of non-union.

Strukturveränderung des Femurkopfes in Fällen von Nichtvereinigung des Femurhalses nach Fraktur

Zusammenfassung

Strukturveränderungen des Femurkopfes können in lebensfähigem Knochengewebe auftreten, doch sind sie selten in den gewöhnlichen Röntgenogrammen

zu sehen. Wenn man Veränderungen sieht, so weisen sie fast immer darauf hin, daß lebendes Gewebe ein totes Fragment durchsetzt hat, in dem dann Knochenresorption und Knochenneubildung stattfinden; Sklerose bedeutet immer Knochenneubildung. Es gibt zwei Typen der Nichtvereinigung: mit und ohne Strukturveränderungen. In Fällen mit Strukturveränderungen ist das Kopffragment fast immer lebensfähig; in Fällen ohne Strukturveränderungen kann das Kopffragment lebensfähig sein oder nicht, so daß also Röntgenogramme nichts darüber aussagen, ob in Fällen von Nichtvereinigung das Kopffragment lebensfähig ist oder nicht.

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Dozent Dr. ANDERS HULTH
Orthopädische Abteilung, Allmänna Sjukhuset
Malmö/Schweden