# Macroscopic and microscopic findings of areas with radiologic erosions in human temporomandibular joints

Lennart Flygare, Madeleine Rohlin and Sigvard Åkerman

Department of Oral Radiology and Department of Stomatognathic Physiology, Centre for Oral Health Sciences, Lund University, Malmö, Sweden

Flygare L, Rohlin M, Åkerman S. Macroscopic and microscopic findings of areas with radiologic erosions in human temporomandibular joints. Acta Odontol Scand 1992;50:91–100. Oslo. ISSN 0001-6357.

The aim was to describe the macroscopic and microscopic findings of areas with radiologic erosions in the human temporomandibular joint. An autopsy material of 40 human joints, removed as blocks, was examined with tomography, and an erosion was found in 37 areas. A macroscopic and a microscopic examination focused on the presence of the calcified cartilage zone (CCZ) was performed in these areas. In the condyle 13 of 14 areas with a radiologic erosion showed denudation of bone macroscopically. Microscopically, these areas were covered by a thin fibrocellular tissue, and the CCZ was absent. In the temporal component, only 1 of the 23 areas showed bone exposure macroscopically. Microscopically, the soft tissue in these areas varied in thickness. The CCZ was missing in 13 of the 23 areas, even in some areas that appeared normal macroscopically and were microscopically covered by intact soft tissue. Thus, in areas with a radiologic erosion the macroscopic and microscopic appearance differed between the condyle and the temporal component. The nature of the findings is discussed. □ *Osteoarthrosis; roentgenography; temporomandibular joint; temporomandibular joint diseases; tomography*

*Lennart Flygare, Department of Oral Radiology, Centre for Oral Health Sciences, Carl Gustafs väg 34, S-214 21 Malmö, Sweden*

Osteoarthrosis represents the final common pathway of various mechanisms, all of which involve an imbalance between the stress applied to joints and the normal ability of the various tissues to attenuate this stress so that the cartilage can tolerate it (1). According to some theories about the etiopathogenesis of osteoarthrosis, the common factor is either a defective biomaterial that disintegrates in the process of normal wear as a function of aging or a normal biomaterial that fails in response to single or multiple excessive traumatic events (1). The traditional way of describing the sequence in osteoarthrosis of the temporomandibular joint (TMJ) is that a trauma or an excessive load on the joint surface leads primarily to degenerative changes of the cartilage and secondarily to changes of the underlying bone tissue, such as erosions. According to Åkerman et al. (2), erosion and sclerosis are typical radiologic findings of degenerative disease of the TMJ, whereas concavity, flattening, and osteophytes seem to be signs of progressive or regressive remodeling. In an observer performance study it was shown that about two-thirds of the reports of an erosion were true, whereas sclerosis was most frequently a false-positive finding (3). Radiologically diagnosed erosions, however, sometimes cannot be verified by macroscopic examination of the articular surfaces in autopsy specimens (2, 4). This might be an indication that bone tissue changes can also occur in the TMJ before articular soft tissue changes, in accordance with the findings in other joints that the initial event in osteoarthrosis may be a disturbance of the bone tissue (1). The calcified cartilage zone (CCZ) has also been considered of importance for the development of degenerative changes in different joints (5–7). The function of the calcified cartilage—that is, the tissue in the borderline between cartilage and bone tissue—is, however, not clearly understood.

The aim of this study was to describe the macroscopic and microscopic findings in areas with a radiologic erosion in human TMJs. The microscopic examination in these areas was carried out with special attention to the presence of the CCZ.

## Materials and methods

From an autopsy material of 42 TMJs, 2 joints from 1 individual with totally destroyed condyles were excluded. The remaining material, comprising the right and left TMJs from 20 individuals with a mean age of 75 years (range, 60–88 years) was examined. The specimens were removed as blocks in 8 women and 12 men who before death had donated their bodies to research. Immediately after removal the TMJ specimens were fixed in a 10% neutralized, buffered formalin solution.

### *Radiologic examination*

Corrected sagittal tomography was performed with the long axis of the condyle perpendicular to and corrected frontal tomography with the long axis of the condyle parallel to the tomographic plane. The tomography was performed with a Polytome U unit (Massiot, Philips, France) with hypocycloidal movement. Exposure data were 60 kVp, 20–33 mA, and 6 sec. A multi-film cassette with five pairs of $CaWO_4$ screens and five films was used. Four exposures were made for each TMJ, two for sagittal tomographic images and two for frontal tomographic images. The tomographic layer was moved 10 mm between the two exposures for each projection.

The same observer evaluated all tomograms. Since the mediolateral and the anteroposterior dimensions of the condyle and temporal components and the interspace between the tomographic sections were known, the location of the erosive findings could be determined. The topographic distribution of the findings was recorded in areas shown in Fig. 1.

The radiologic evaluation was made independently of the macroscopic and microscopic examinations. A reference tomogram of another TMJ autopsy specimen, depicting a radiologic erosion that was macroscopically and microscopically verified, was available during the readings. The findings were classified in accordance with the following definition: erosion = a local area with decreased density of the cortical joint surface and adjacent subcortical bone (Figs. 2a and 3a).

### *Macroscopic examination*

The appearance of the articular surface of the condyle and the temporal component was judged by naked-eye examination by two of the authors. The changes were classified into four stages in accordance with a modification of the principles of Byers et al. (8): 0 = no changes of the type described below; 1 = mild changes such as superficial flaking or fraying—that is, disruption of the articular soft-tissue lining (fibrillation); 2 = moderate changes such as local reduction of the articular soft-tissue lining; and 3 = severe changes such as loss of the articular soft-tissue lining with bone exposure.

### *Microscopic examination*

The specimens were demineralized in 0.5 M ethylenediaminetetraacetate ($Na_2H_2$–EDTA) for 16–20 weeks and then embedded in paraffin. Microtome sections, 6 μm thick, were cut sagittally at every millimeter from the most lateral aspect of the joint to the most medial. Histologic staining was performed with Mayer's hemalum-eosin solution (9). Microscopic evaluation of the soft tissue and the hard tissue separately in areas corresponding to areas with a radiologic erosion was done by one of the authors. The direction of collagen fibers of the soft tissue was examined with the aid of polarized light.

At the examination of the hard tissue, special attention was paid to the presence of the CCZ, and the findings were classified in accordance with the following criteria: 0 = no changes of the type described below; 1 = mild changes such as thinning and/or minor irregularity of the CCZ; 2 = moderate changes with an irregular, locally absent CCZ; and 3 = severe changes such as CCZ

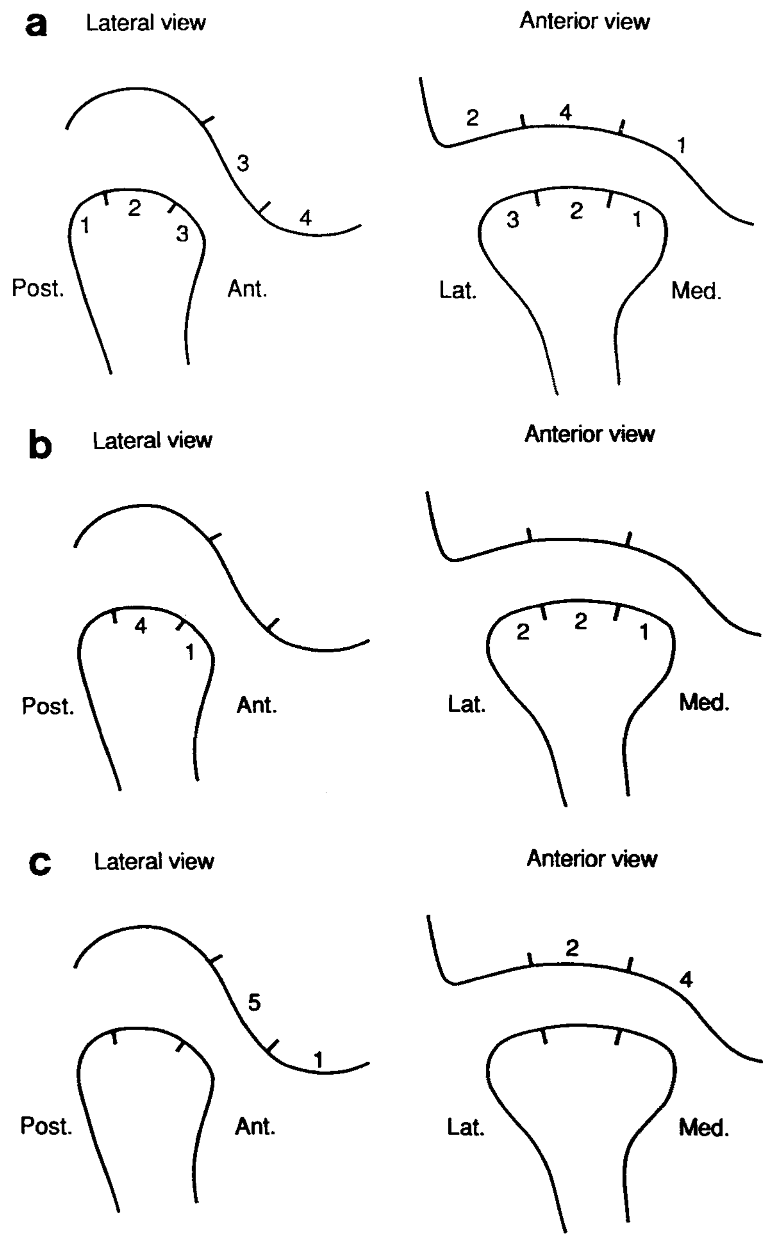


Fig. 1. Topographic distribution of radiologic erosions verified to have microscopic hard-tissue changes of stage 2 (moderate changes) or stage 3 (severe changes). 1a. Distribution of erosions found in joints with erosion both in the condyle and in the temporal component. 1b. Distribution of erosions found in joints with erosion only in the condyle. 1c. Distribution of erosions found in joints with erosion only in the temporal component.

totally absent and/or open marrow spaces filled with cell-rich connective tissue.

The findings of the articular soft tissue were classified in accordance with a modification of the descriptions given by Byers et al. (10): 0 = no changes of the type described below; 1 = mild changes such as localized fraying or mild fibrillation; 2 = moderate changes such as extended fraying, fibrillation, occasional splitting, and atypical appearance of the different zones of the articular cartilage; and 3 = severe changes such as irregular thickness or no soft tissue, severe splitting, fibrillation, and connective tissue.

Table 1. Findings of the macroscopic and microscopic examination of the hard tissue in areas with radiologic erosion in human temporomandibular joints ($n = 40$)

| Macroscopic findings in hard tissue | Microscopic findings in hard tissue | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Condyle area | | | | Temporal component area | | | |
| stage | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| 0 | 1 | | | | 5 | 5 | 4 | 3 |
| 1 | | | | | | | | 4 |
| 2 | | | 1 | 1 | | | | 1 |
| 3 | | 2 | 5 | 4 | | | | 1 |

Classification of macroscopic and microscopic findings: 0 = no changes; 1 = mild changes; 2 = moderate changes; and 3 = severe changes.

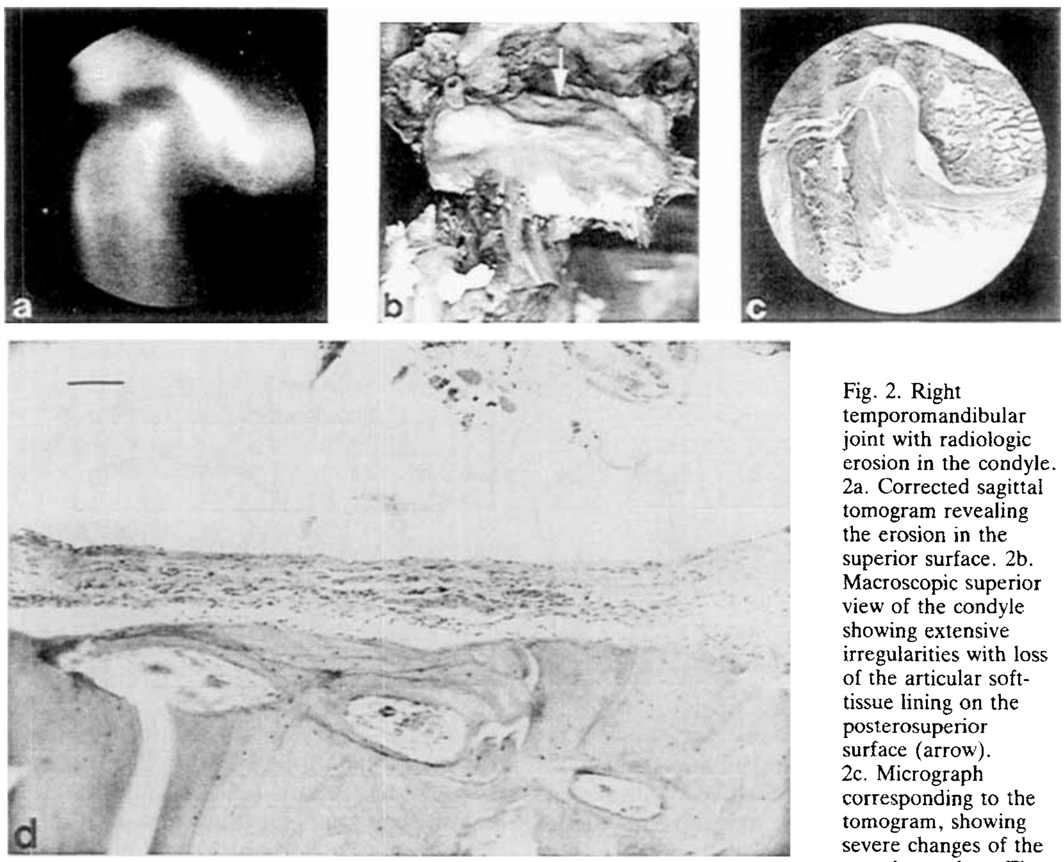

Fig. 2. Right temporomandibular joint with radiologic erosion in the condyle. 2a. Corrected sagittal tomogram revealing the erosion in the superior surface. 2b. Macroscopic superior view of the condyle showing extensive irregularities with loss of the articular soft-tissue lining on the posterosuperior surface (arrow). 2c. Micrograph corresponding to the tomogram, showing severe changes of the superior surface. The deformed disc is anteriorly positioned and perforated. Arrow indicates area magnified in Fig. 2d. 2d. Detail of Fig. 2c, showing a very thin connective tissue layer covering the irregular surface of the subchondral bone. The calcified cartilage layer is absent in this area. Bar = 0.1 mm.

## Results

Totally there were 37 areas with a radiologic erosion, 14 in the condyle and 23 in the temporal component. The topographic distribution of 24 areas with a radiologic erosion which were microscopically observed to have moderate or severe hard tissue changes is shown in Fig. 1. Of these 24 areas, 13 erosions were found in joints with erosions both in the condyle and in the temporal component, whereas 11 erosions were found in joints with an erosion in either the condyle or the temporal component. There were thus erosions in both the condyle and the temporal component of four joints (Fig. 1a). Five erosions were seen only in the condyle of three joints (Fig. 1b) and six erosions only in the temporal component of five other joints (Fig. 1c).

There was concordance on the severity of the macroscopic and microscopic changes in areas with a radiologic erosion in the condyle. In the temporal component, however, the microscopic examination generally showed more severe changes than were revealed by the macroscopic examination.

As presented in Table 1, most areas with a radiologic erosion in the condyle (Fig. 2a) showed moderate (stage 2) or severe (stage

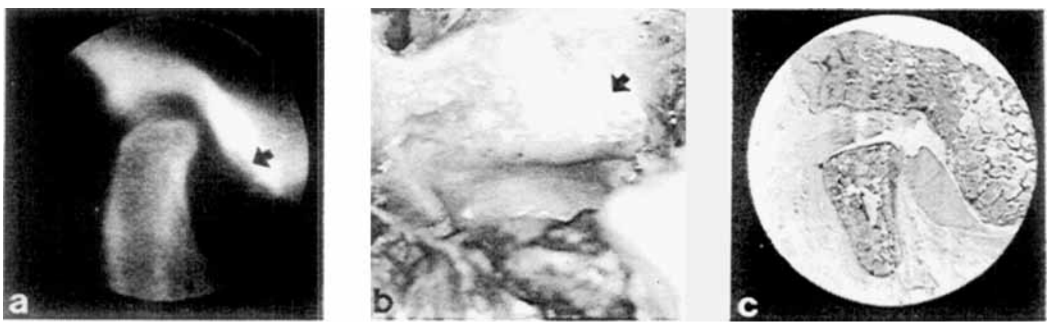

Fig. 3. Right temporomandibular joint with radiologic erosion in the temporal component. 3a. Corrected sagittal tomogram showing erosion of the posterior slope (arrow). 3b. Macroscopic anteroinferior view of the posterior slope, showing a concavity with loss of the articular soft-tissue lining (arrow). 3c. Micrograph corresponding to the tomogram, showing irregular thickness of the soft tissue. The deformed disc is anteriorly positioned, and there is a perforation. 3d. Detail of Fig. 3c, showing the posteroinferior part of the tubercle. The outline of both soft- and hard-tissue layers is irregular. The soft tissue layer is of irregular thickness, and the calcified cartilage layer is absent. Bar = 0.1 mm.

Table 2. Findings of the microscopic examination of the soft and hard tissue in areas with radiologic erosion in human temporomandibular joints ($n = 40$)

| Microscopic findings in soft tissue stage | Microscopic findings in hard tissue | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Condyle area | | | | Temporal component area | | | |
| | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| 0 | | | | | 4 | 2 | 1 | 1 |
| 1 | 1 | 2 | 2 | | 1 | 3 | 2 | 2 |
| 2 | | | 2 | 1 | | | 1 | 3 |
| 3 | | | 2 | 4 | | | | 3 |

Classification of microscopic findings: 0 = no changes; 1 = mild changes; 2 = moderate changes; and 3 = severe changes.

3) changes, with exposure of the bone tissue macroscopically (Fig. 2b). Microscopically, five of the condyles (Figs. 2c and 2d) showed severe changes of the hard tissue, and the CCZ was absent (stage 3). The bone tissue was microscopically not naked towards the joint space but was always covered by a thin connective tissue layer. In six condyles the CCZ was irregular and locally absent (stage 2), and the three remaining condyles presented no or mild microscopic changes (stages 0 or 1). In the temporal component only 1 of 23 areas with a radiologic erosion (Fig. 3a) presented bone exposure macroscopically (Fig. 3b). Microscopically, however, 13 of the areas in the temporal component showed moderate or severe changes of the hard tissue similar to the changes shown in Figs. 3c and 3d. In the remaining 10 areas there were no or mild hard-tissue changes.

Table 2 presents the microscopic findings of the soft and the hard tissues in areas with a radiologic erosion. In the condyle the severity of the microscopic changes in the soft tissue was comparable to the severity of the changes in the hard tissue. In areas with moderate or severe hard-tissue changes the soft-tissue lining was generally replaced by a thin connective tissue layer. In the temporal component there was a discrepancy between the microscopic findings of the hard tissue and those of the soft tissue in some areas. Thus, in six areas of the temporal component with no or mild soft-tissue changes there were moderate or severe hard-tissue changes, with the CCZ locally or totally absent (Figs. 4a–4d). These areas, which were localized to the posterior slope or inferior part of the eminence, were filled with a cell-rich highly vascularized connective tissue, the predominant cell type being small fibroblast-like cells. Some of the cells appeared in clusters. The rim of the subchondral bone was mostly serrated, and osteoclasts were observed (Fig. 4d). The changes of the overlying articular cartilage were subtle. A difference in the direction of the collagen fibers towards the lesion of the subchondral bone was, however, seen under polarized light. The direction of the fibers of the superficial zone of the articulating layer remained unchanged.

## Discussion

In this study the tomographic finding of an erosion was correlated to the macroscopic and microscopic findings of the same area. Microscopic examination is generally regarded as an excellent gold standard for radiographic examinations. However, a high diagnostic accuracy of a diagnosis on the basis of microscopic examination is not self-evident. As high accuracy is related to well-defined criteria for a diagnosis, we tried to establish such criteria for the microscopic findings indicative of an erosion. However, we had difficulties defining which vertical and horizontal extents of a bone irregularity observed in the microscopic section should correspond to the definition erosion or bone lacuna. As the criteria for osteoarthrosis and

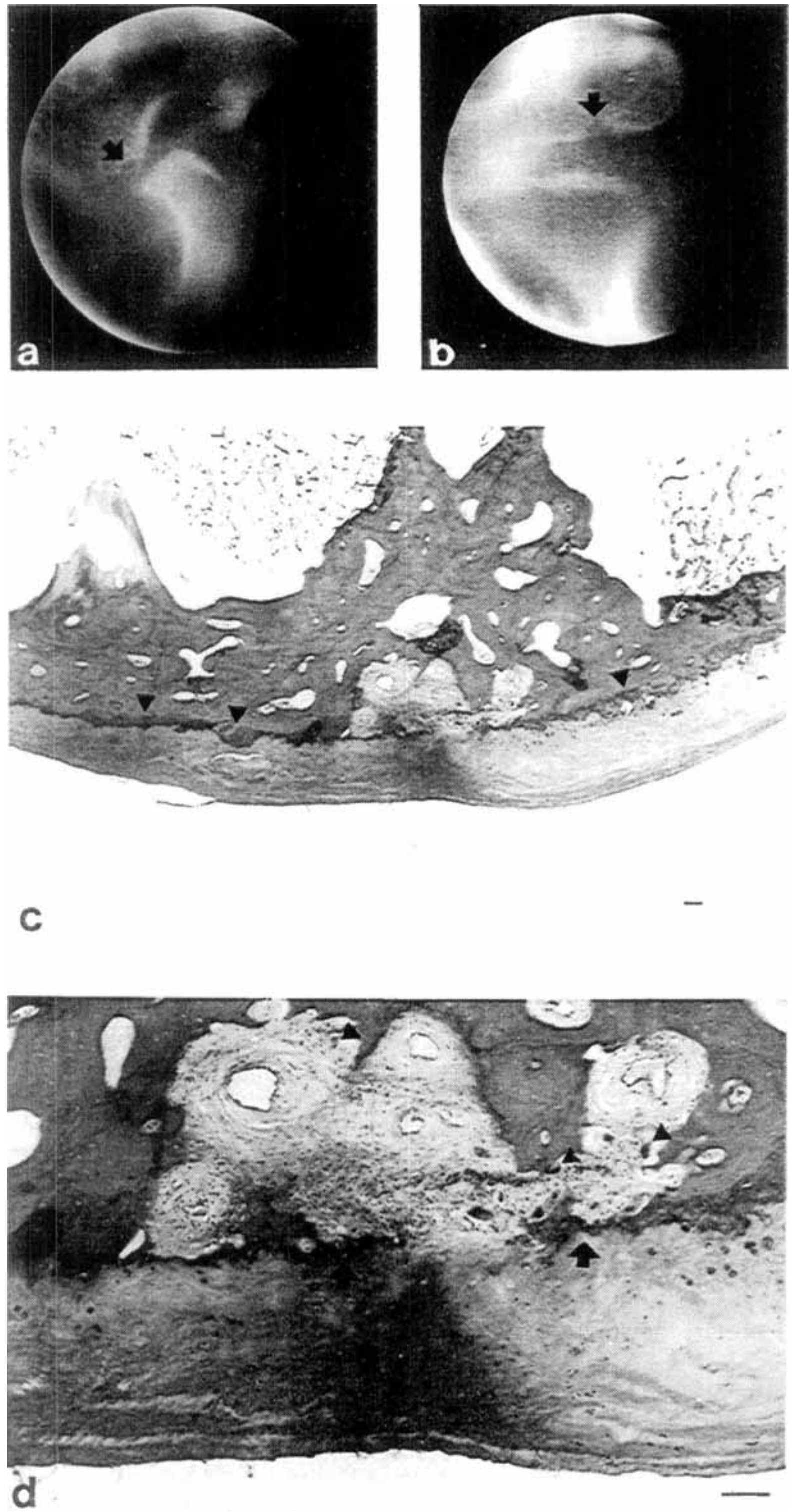


Fig. 4. Left temporomandibular joint with radiologic erosion in the temporal component. 4a,b. Corrected sagittal tomogram (a) and frontal tomogram (b), showing the erosion in the posterior slope (arrow). 4c. The micrograph shows an intact soft-tissue articular lining with severe changes of the hard tissue. The calcified cartilage is visible as a zone between the soft and hard tissue (arrowheads). Bar = 0.1 mm. 4d. Detail of Fig. 4c, showing open marrow spaces with vascularized cell-rich connective tissue and remnants of the calcified cartilage zone (arrows). The outline of the hard tissue is serrated, and osteoclasts are present (arrowheads). Bar = 0.1 mm.

the definition of degenerative changes of synovial joints (10, 11), including the TMJ (12, 13), have been questioned, we considered the histologic characteristics, including the presence or absence of the CCZ to be a more useful marker of the features in the joint. As early changes of the joint have been proposed to occur in the deeper zones of the articular cartilage (14, 15) or in the subchondral bone (1), we focused on the features of the CCZ, which constitutes the tissue between cartilage and bone.

To judge from the macroscopic examination, severe changes were more frequent in the condyle than in the temporal component. This finding seems to support the statement by Blackwood (16) that changes can be seen in the articular tissues of the glenoid fossa and the articular eminence first when disc perforation has been caused by the rough exposed bone of the condyle. This is in contrast to the results of the studies by Moffett et al. (17) and de Bont et al. (15), which indicated that the earliest changes indicative of osteoarthrosis occur in the temporal component. However, from the microscopic findings of our study, it is evident that severe changes can occur in the condyle together with an unaffected temporal component and vice versa, and that the frequency of severe changes in the temporal component and the condyle was about the same. Altogether, our findings do not support the hypothesis that the early degenerative changes of the TMJ occur predominantly in one of the components.

In areas with a radiologic erosion localized to the condyle there were macroscopically moderate or severe changes except for one area. Furthermore, in most of these areas the microscopic changes of the soft and hard tissues were consistent with the macroscopic findings. However, in areas where the bone tissue seemed to be exposed macroscopically, the microscopic examination always showed the uneven bone surface to be covered by a thin connective tissue layer, which was also found in two other studies of the TMJ (15, 18). Bone eburnation has been reported to take place in the human TMJ by Blackwood (16), but the illustrations presented by Blackwood to support his statement in our view show a thin connective tissue layer covering the bone tissue. In other joints, especially the hip joint, however, bone eburnation is said to be characteristic of late-stage osteoarthrotic changes (19). The thin connective tissue layer in the TMJ might be identical to the surface layer of the original articulating soft tissue. As the cells of the surface articular zone are inactive (20) and renewed independently of underlying articular zones (21), it may be assumed that this layer persists even on severely degenerated articular surfaces. The thin connective tissue layer described by Meachim (19) as a reparative element attempting to re-cover exposed bone might also have another origin, namely cells from the fibrovascular tissue of degenerative medullary subchondral compartments (11). The thin connective tissue layer is of interest as it might be part of the mechanism preventing the two bony components of the TMJ from being ankylosed in severe arthrosis or arthritis.

In nearly half of the areas with a radiologic erosion in the temporal component no macroscopic change and no or a mild microscopic change were seen. These radiologic findings might be considered false-positive radiologic diagnoses. Even when the tomographic examination of the joints en bloc was optimal, it seemed that the changes of the temporal component were harder to diagnose than those of the condyle, because of the anatomy and the resulting ghost images. However, about half of the radiologic erosions that could not be verified macroscopically were microscopically seen to be hard-tissue changes covered by soft tissue of the same thickness as that of surrounding areas. Such changes of the subchondral bone together with an intact articular zone have previously been reported for the TMJ by Blackwood (16), Bean et al. (4) and de Bont et al. (15).

The nature of these changes in the bone tissue is unclear. One possible mechanism involving the bone and leaving the articular layer unaffected is, according to Moffett et al. (17) and Guralnick & Keith (22), regressive remodeling. The first recognizable changes of regressive remodeling occur at the junction of cartilage and the subchondral plate, and later a defect of the bone is produced (17). Besides the ongoing remodeling, the bone plate can undergo another change during adult life, namely degeneration. The relationship between remodeling and degenerative changes is debated, but both entail alteration of the osteochondral junction, and both are influenced by biomechanical factors. These erosion-like lesions could thus also be interpreted as evidence that the initial event in degenerative joint disease might be a disturbance of the activity in the subchondral bone. The early degenerative changes of the TMJ have been reported to occur in the deeper zones, whereas the superficial and intermediate zones of the articular cartilage remained unaffected (15, 16, 23). A primary role of changes in the subchondral bone in the process of osteoarthrosis has also been emphasized for other joints (1, 5, 8, 24). Cartilage breakdown is assumed to be induced by a reduction of the bone resilience due to microfractures, and only when the osteochondral junction is breached and subchondral bone affected does osteoarthrosis progress and cause clinical disability (1, 8). Experimental studies of the knee have shown that repair tissue may arise as a natural consequence of healing of microfractures in the subchondral bone or from an attempt to reestablish continuity of a disrupted subchondral plate (11). Meachim & Roberts (25) have previously shown that gaps in the subchondral plate in osteoarthrotic hips are filled with granulation tissue, which was interpreted as evidence of recovery from early osteoarthrosis. These mechanisms for repair of other joints might also apply to the TMJ, as fibrovascular tissue was observed in most of the lesions in the temporal component in the present study.

A more thorough knowledge of the zone between the subchondral bone and the cartilage, the calcified cartilage zone, of both normal and degenerative TMJs seems necessary to elucidate the tissue reactions in this area. The changes of the subchondral bone with an unaffected articular zone were only found in the temporal component. This finding may be of significance, indicating a different biologic reaction of the temporal component than of the condyle. To support such a concept, not only areas with radiologic erosion but also the other joint surfaces have to be studied microscopically.

*Acknowledgement.*—The autopsy material was kindly placed at our disposal by the Department of Anatomy, Lund University. This study was supported by grants from the Faculty of Odontology, Lund University, Malmö, Sweden.

## References

1. Radin EL, Paul IL, Rose RM. Osteoarthrosis as a final common pathway. In: Nuki G, editor. The aetiopathogenesis of osteoarthrosis. Tunbridge Wells: Pitman Medical Publishing Co Ltd, 1980:84–9.
2. Åkerman S, Kopp S, Rohlin M. Macroscopic and microscopic appearance of radiologic findings in temporomandibular joints from elderly individuals. An autopsy study. Int J Oral Maxillofac Surg 1988;17:58–63
3. Cholitgul W, Petersson A, Rohlin M, Tanimoto K, Åkerman S. Diagnostic outcome and observer performance in sagittal tomography of the temporomandibular joint. Dentomaxillofac Radiol 1990;19:1–6.
4. Bean LR, Omnell K-Å, Öberg T. Comparison between radiologic observations and macroscopic tissue changes in temporomandibular joints. Dentomaxillofac Radiol 1977;6:90–106.
5. Hough AJ, Banfield WG, Mottram FC, Sokoloff L. The osteochondral junction of mammalian joint. Lab Invest 1974;31:685–95.
6. Pedley RB, Meachim G. Topographical variation in patellar subarticular calcified tissue density. J Anat 1979;128:737–45.
7. Meachim G, Allibone R. Topographical variation in the calcified zone of upper femoral articular cartilage. J Anat 1984;139:341–52.
8. Byers PD, Contepomi CA, Farkas TA. A post mortem study of the hip joint. Including the features of the right side. Ann Rheum Dis 1970;29:15–31.
9. Romeis B. Mikroskopische Technik. Munich: R Oldenburg Verlag, 1968:164.
10. Byers PD, Contepomi CA, Farkas TA. A post mortem study of the hip joint. II. Histological basis for limited and progressive cartilage alterations. Ann Rheum Dis 1976;35:114–21.
11. Radin EL, Burr DB. Hypothesis: joint can heal. Semin Arthritis Rheum 1984;13:293–302.
12. Åkerman S, Rohlin M, Kopp S. Bilateral degenerative changes and deviation in form of temporomandibular joints. An autopsy study of elderly individuals. Acta Odontol Scand 1984;42:205–27.
13. Stegenga B, de Bont LGM, Boering G. Osteoarthrosis as the cause of craniomandibular pain and dysfunction: an unifying concept. Oral Maxillofac Surg 1989;47:249–56.

14. Blackwood HJJ. Pathology of the temporomandibular joint. J Am Dent Assoc 1969;79:118–24.
15. de Bont LGM, Boering G, Liem RSB, Eulderink F, Westesson P-L. Osteoarthrosis and internal derangement of the temporomandibular joint. A light microscopic study. J Oral Maxillofac Surg 1986;44:634–43.
16. Blackwood HJJ. Arthritis of the mandibular joint. Br Dent J 1963;115:317–24.
17. Moffett BC, Johnson LC, McCabe JB, Askew HC. Articular remodelling in the adult human temporomandibular joint. Am J Anat 1964;115:119–42.
18. Pullinger AG, Baldiocea F, Bibb CA. Relationship of TMJ articular soft tissue to underlying bone in young adult condyles. J Dent Res 1990;69:1512–8.
19. Meachim G. Ways of cartilage breakdown in human and experimental osteoarthrosis. In: Nuki G, editor. The aetiopathogenesis of osteoarthrosis. Tunbridge Wells: Pitman Medical Publishing Co Ltd, 1980:16–28.
20. Blackwood HJJ. Study of the growth of the mandibular condyle of the rat using tritiated thymidine. Arch Oral Biol 1966;11:493–500.
21. Blackwood HJJ. Cellular remodelling in articular tissue. J Dent Res 1966;45:480–9.
22. Guralnick W, Keith DA. Osteoarthrosis of the temporomandibular joint. In: Moskowitz RW, Howell DS, Goldberg WM, editors. Osteoarthrosis diagnosis and management. Philadelphia: W B Saunders, 1984:523–30.
23. Toller PA. Temporomandibular arthropathy. Proc R Soc Med 1974;67:153–9.
24. Sokoloff L. The pathology of osteoarthrosis and the role of ageing. In: Nuki G, editor. The aetiopathogenesis of osteoarthrosis. Tunbridge Wells: Pitman Medical Publishing Co Ltd, 1980:1–15.
25. Meachim G, Roberts C. Repair of the joint surface from subarticular tissue. J Anat 1971;109:317–27.

Received for publication 11 September 1991