Microscopy and tomography of erosive changes in the temporomandibular joint

An autopsy study

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Thirty-nine temporomandibular joint autopsy specimens were examined by microscopy and tomography for erosive changes. We found two types of erosive changes, an extensive type with complete loss of cartilage and a local type with retained articular cartilage. On microscopic examination nearly twice as many temporal components as condyles were eroded. The erosions were generally more extensive in the condyle. Erosions in the condyle were evenly distributed. In the temporal component there was a slight predominance of erosions located to the lateral part of the tubercle. The radiologic investigation underestimated both the presence and the extent of the erosions. Positive predictive values and negative predictive values were 0.70 and 0.83, respectively, for erosions in the condyle and 0.91 and 0.68 for erosions in the temporal component. It is suggested that the initial event in osteoarthrosis of the TMJ can occur as a subarticular hard-tissue change. The need for more accurate diagnostic tools than radiography should be stressed. □ *Degenerative joint disease; predictive value of tests; radiography, oral; temporomandibular joint disease*

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In osteoarthrosis of the temporomandibular joint (TMJ) the changes of the subchondral bone tissue present a mixed appearance of bone formation with osteophytes and bone resorption with erosive changes and cystic degeneration. It has been hypothesized from the results of studies on femoral heads and components of other joints that the changes in the subchondral tissues may constitute the primary genesis in osteoarthrosis (1–4). This places greater importance on primary changes in the subchondral bone tissue. In a previous microscopic study of radiologically detected erosions in human TMJs (5) we found erosive bone changes underlying normal cartilage. It was suggested that these findings might constitute early degenerative changes starting in the subchondral bone. We therefore considered it worthwhile also to investigate the joint surfaces that radiographically appeared normal, to elucidate the nature and frequency of these changes.

Conventional tomography has for the last three decades been the routine examination for depicting erosive changes in symptomatic TMJ. Although both computed tomography (CT) and magnetic resonance imaging (MRI) have been proposed for TMJ hard-tissue imaging in several reports over the past decade (for reviews see Raustia & Phytinen (6) and Larheim (7)), conventional tomography still holds a position as the first-hand examination of TMJ hard tissue owing to accessibility, low cost, and low radiation dose as compared with CT (8). Eckerdal (9) reported on the possibilities and limitations of tomography of the TMJ from extensive experimental studies. With macroscopic examination of TMJ autopsy specimens as the gold standard, Rohlin et al. (10) calculated the diagnostic outcome of conventional tomography to depict osteoarthrosis. However, microscopic examination is a more accurate method than macroscopic examination for evaluating hard-tissue changes of the TMJ (5). As far as we know, the diagnostic value of conventional tomography of the TMJ has not yet been studied using microscopic examination as the gold standard.

The aims of the present study were to investigate the distribution of erosive changes in human TMJs as shown by light microscopy, to describe the tissues within and around the erosive changes and to determine the diagnostic value of conventional tomography to show these changes.

Materials and methods

The material examined consisted of 39 TMJ autopsy specimens removed as blocks. The joints comprised the right joint from 1 individual and both joints from 19 individuals (8 women and 12 men) who before death had donated their bodies to research. The mean age was 75 years, with a range of 60–88 years. Data on the cause of death and previous medical history were limited. One individual (No. 16) was, however, known to have a diagnosis of rheumatoid arthritis. Immediately after removal, the TMJ specimens were fixed in a 10% neutralized buffered formalin solution.

Radiologic examination

Corrected sagittal tomography of the specimens was performed with a Polytom U unit using hypocycloidal movement as described in a previous paper (5). The tomograms were evaluated for the presence of erosive changes. Erosive change was defined as a local area with decreased density of the cortical joint surface and adjacent bone tissue. Reference tomograms of other TMJ autopsy specimens, one depicting a normal joint and one depicting an erosive change, which were macroscopically and microscopically verified, were available during the readings. The same observer evaluated all tomograms independently of the microscopic examination. Since the mediolateral and the anteroposterior dimensions of the condyle and temporal component and the interspace between the tomographic sections were known, the approximate location of the erosive changes could be determined.

Histology

The specimens were demineralized in 0.5 M ethylenediaminetetraacetate (Na_2H_2-EDTA) for 16–20 weeks and then embedded in paraffin. Microtome sections, 6–10 μm thick, were cut sagittally at every millimeter from the most lateral aspect of the condyle to the most medial. Histologic staining was performed with Mayer's hemalun-eosin solution (11). Some selected sections were stained with toluidine blue or Mallory's trichrome in accordance with Ladewig (12).

Analysis

Microscopic examination of the hard tissues for the presence of erosive changes was performed at every millimeter in at least 15 sections of each joint. Microscopically, an erosive change was defined as a hard-tissue change with a loss of cortical lining, absence of a calcified cartilage layer, and signs of osteoclastic resorption (Figs. 1, 2, and 3). The tissues overlying the erosive change were described.

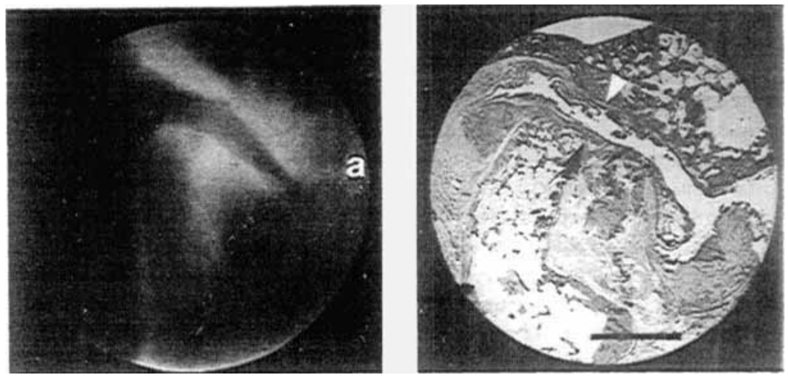

Fig. 1. Right temporomandibular joint with erosive change with complete loss of cartilage. 1A. Corrected sagittal tomogram showing an erosive change in the superior surface of the condyle. Osteophyte anteriorly on the condyle. a = anterior. 1B. Corresponding histologic section presenting the hard-tissue changes of the condyle. Anterior disk position and somewhat changed disk configuration. (Hemalum and eosin. Bar represents 5 mm.)

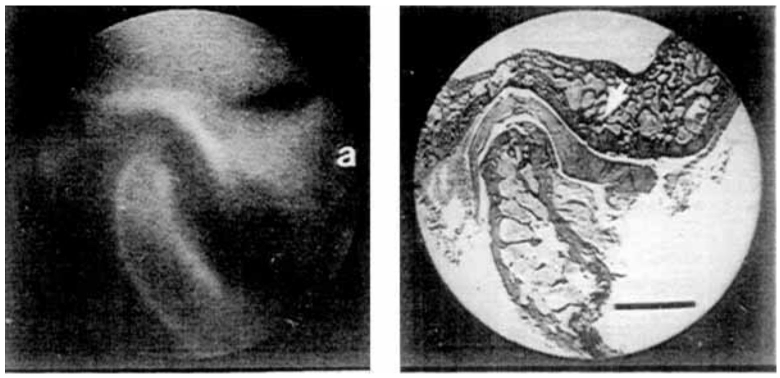

Fig. 2. Right temporomandibular joint with local erosive change with overlying cartilage. 2A. Corrected sagittal tomogram showing decreased density of the posteroinferior part of the tubercle interpreted as an erosive change. There is blurring of the tubercle in this region due to neighboring structures, making the radiographic interpretation more difficult. a = anterior. 2B. Corresponding histologic section showing an irregular bone surface with overlying cartilage of regular thickness. Anterior disk position and changed disk configuration. (Hemalun and eosin. Bar represents

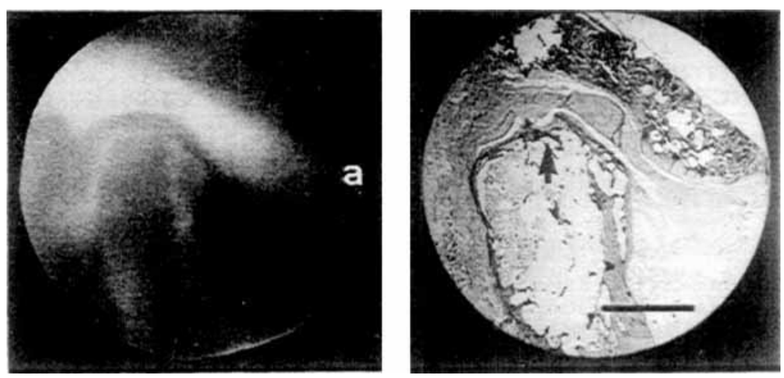

Fig. 3. Right temporomandibular joint with extensive erosive changes from individual with rheumatoid arthritis. 3A. Corrected sagittal tomogram showing gross changes with extensive flattening of the joint surfaces and a large anterior osteophyte of the condyle. The surfaces of both joint components are flattened and delineated. a = anterior. 3B. Corresponding histologic section presenting the V-shaped tubercle and flattened surfaces of both joint components. The osteophyte is somewhat inferiorly displaced compared with the tomogram. There are only remnants of the disk anteriorly and posteriorly to the condyle. There is overgrowth of the articulating surfaces by synovial tissue and granulation tissue (pannus). (Hemalun and eosin. Bar represents 5 mm.)

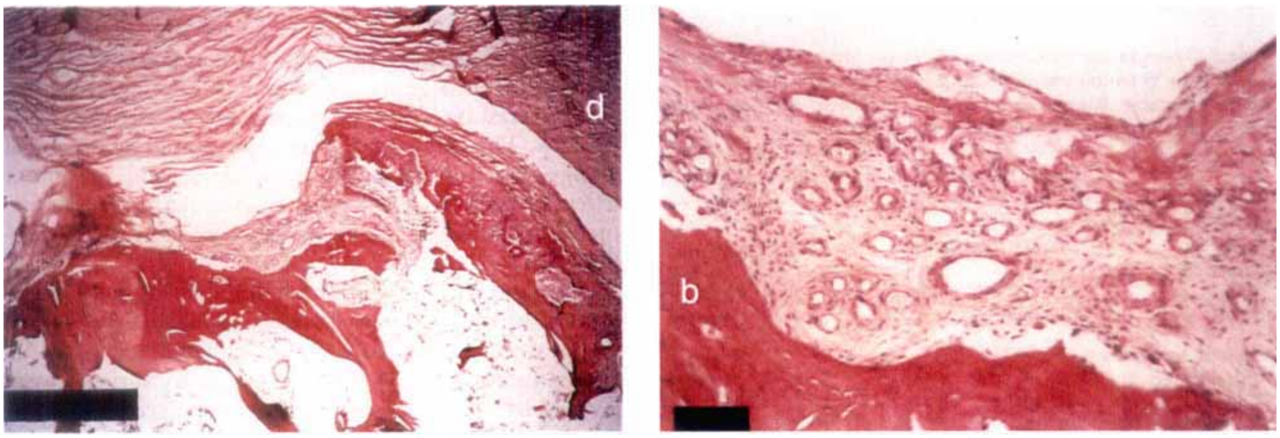

Fig. 1C. Magnification of area indicated by arrow in Fig. 1B. Within and around the erosive change the articular cartilage is replaced by a thin connective tissue. There is a connection between the connective tissue and the subcortical marrow space. d = disc. (Hemalum and eosin. Bar represents 1 mm.) 1D. Magnification of central area in Fig. 1C. The connective tissue is cell-rich and contains numerous vessels. b = bone. (Hemalun and eosin. Bar represents 0.1 mm.)

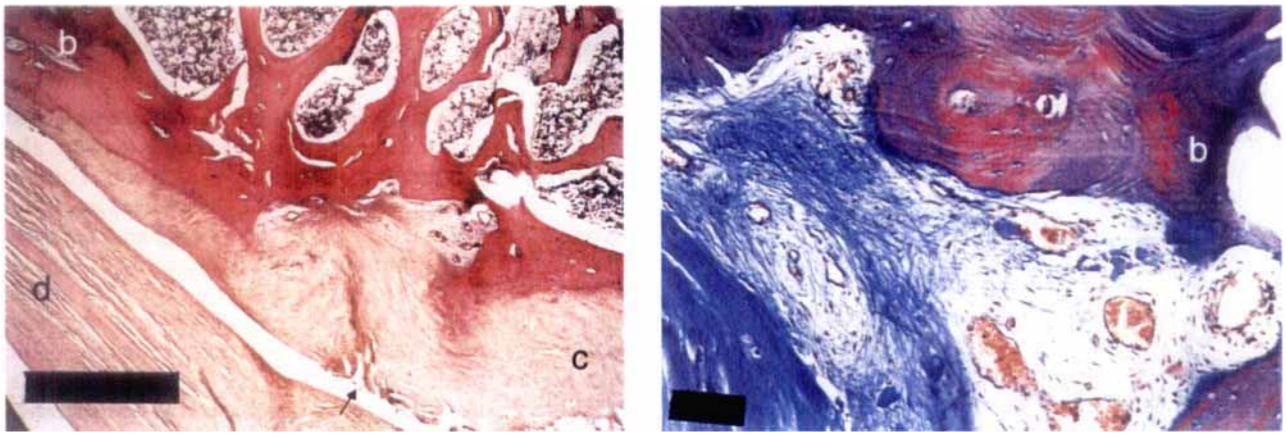

Fig. 2C. Magnification of area indicated by arrow in Fig. 2B. Note clefts (arrow) and superficial fibrillation of the cartilage overlying the erosive change. b = bone, c = cartilage, and d = disc. (Hemalun and eosin. Bar represents 1 mm.) 2D. Magnification of neighboring section corresponding to central area in Fig. 2C. The fibers in the center of the change differ in appearance from the overlying cartilage. There are several vessels, and adjacent to the bone surface osteoclasts are observed. The calcified cartilage layer is absent. b = bone. (Mallory's trichrome. Bar represents 0.1 mm.)

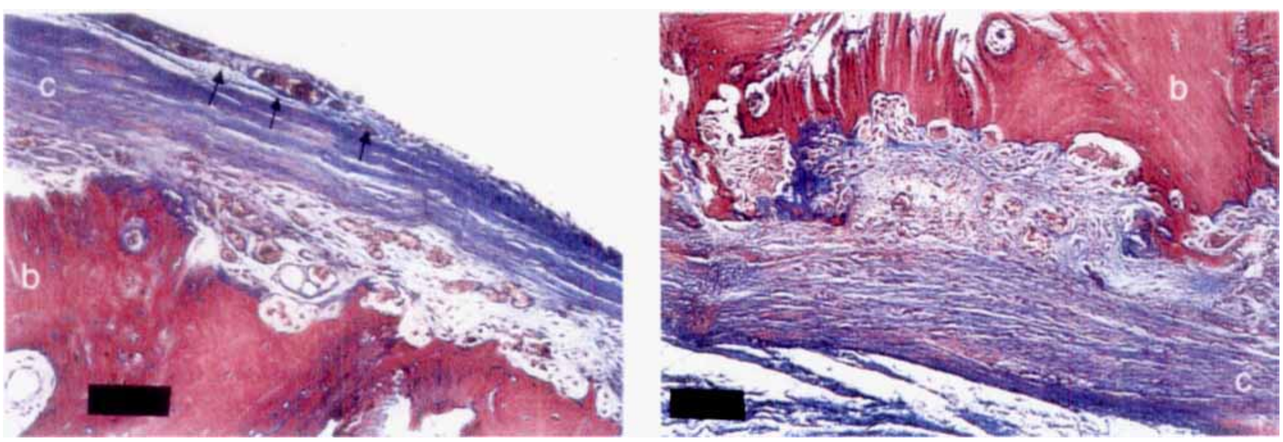

Fig. 3C. Magnification of neighboring section corresponding to area indicated by arrow in Fig. 3B on the superior part of the condyle. The bone surface is scalloped and lined with vessels and osteoclasts, indicating ongoing resorption. Note also the synovial tissue crammed with blood vessels covering the articular surface (arrows). b = bone and c = cartilage. (Mallory's trichrome. Bar represents 0.1 mm.) 3D. Magnification of neighboring section corresponding to area indicated by arrowhead in Fig. 3B on the posterior slope of the tubercle. The bone surface is scalloped and lined with osteoclasts. No calcified cartilage layer. b = bone and c = cartilage. (Mallory's trichrome. Bar represents 0.1 mm.)

Table 1. Topographic distribution of erosive changes found microscopically in 39 temporomandibular joints. The figures represent the number of erosive changes, and the figures in parentheses the number of these erosive changes covered by articular cartilage

	Lateral	Central	Medial	Total
Condyle				
Anterior	3 (1)	3 (1)	4 (2)	10 (4)
Superior	7 (3)	7 (2)	5 (1)	19 (6)
Posterior	4 (1)	9 (2)	5 (2)	18 (5)
Total	14 (5)	19 (5)	14 (5)	47 (15)
Temporal component				
Inferior part	9 (6)	7 (4)	3 (1)	19 (11)
Posterior slope	6 (2)	6 (3)	4 (2)	16 (7)
Roof of fossa	5 (2)	1	1	7 (2)
Total	20 (10)	14 (7)	8 (3)	42 (20)

The findings at the microscopic examination were compared with the findings at the radiographic examination. All areas with microscopic and/or radiographic findings were reexamined once by microscopy. The diagnostic outcome of the radiologic examination was calculated by the method of Weinstein & Fineberg (13). Sensitivity was defined as the true-positive rate—that is, the frequency of positive test results (tomography) in a joint component with a microscopic erosive change. Specificity was defined as the true-negative rate—that is, the frequency of negative test results in a joint component without microscopic erosive changes. Positive predictive value was defined as frequency of changes in those with positive test results, and negative predictive value as frequency of nonchanges in those with negative test results.

Results

Microscopic examination

Microscopically, erosive changes were observed in the condyle in about one-third (31%) of the TMJs and in the temporal component in almost half (49%) of the TMJs. In only two joints was an erosive change found in the condyle exclusively, whereas nine joints exhibited erosive changes only in the temporal component. Table 1 presents the topographic distribution of the erosive changes. In the condyle the changes were evenly distributed, whereas the changes in the temporal component presented a slight predominance for the lateral third of the tubercle. More than two-thirds of the erosive changes in the condyle lacked overlying cartilage. In the temporal component there was an even distribution between changes with and without cartilage loss.

Table 2 presents the results of the microscopic examination in detail. Eight of the 13 individuals with erosive changes of the TMJ had changes of both the left and the right joints. One type of erosive change extended over the major part of the joint components. These changes showed generally complete cartilage loss but were covered by a thin, cell-rich connective tissue (Figs. 1B–1D). The other type of erosive change was a local change, often with retained cartilage and an intact articular surface. These local erosive changes were frequently confined to the temporal component (Figs. 2B–2D).

One joint from the individual (No. 16) with rheumatoid arthritis showed microscopically severe erosive changes, anterior osteophyte in the condyle, and a V-shaped tubercle (Figs. 3B–3D). The bony surfaces were covered by a cell-rich connective tissue, crammed with blood vessels, and occasional overgrowth by the synovial lining over the articulating surfaces. Erosive lacunae with osteoclasts indicating resorptive activity were prominent (Figs. 3C and 3D).

Comparison between findings at the tomographic and microscopic examinations

Table 3 presents the findings of the tomographic and microscopic examinations for the condyle and the temporal component in a two-by-two table. Tomography underestimated both the presence and the extent of the erosive changes in the TMJ. The sensitivity was low for both joint components, whereas the specificity was high. The positive predictive value was higher for changes in the temporal component than for those in the condyle, whereas the negative predictive value was higher for the condyle.

Table 2 shows that there was basically no difference in radiologic detectability between erosive changes with and without injuries and loss of articular cartilage. In four joints with extensive microscopic changes, tomography showed no changes or changes only in limited areas, even when reexamined. Radiographically, the surrounding bone surfaces were even. The microscopic examination of corresponding areas showed high cellular activity and ongoing resorption (Fig. 3).

Discussion

As far as we know, this is the first microscopic study of erosive changes of the entire TMJ. Previous studies have been based on macroscopic examinations of the entire TMJ (14–17) or on microscopic examinations of selected parts of the TMJ (18, 19). Therefore, the percentage of joints with erosive changes (49%) found in the present study could only be roughly compared with those reported in previous studies on TMJ autopsy specimens. The material of this study is, however, almost identical to that of the macroscopic study reported by Rohlin et al. (10). The percentage of joints with bone exposure and/or disc perforation was about 40%, a figure similar to those reported by Öberg et al. (14) and Westesson & Rohlin (20) for other materials. Pereira et al. (17) reported a 50% prevalence of

Table 2. Erosive changes found on microscopic and tomographic examination in the lateral, central, and medial thirds of 39 temporomandibular joints (TMJ) of 20 individuals

	Left TMJ						Right TMJ					
	Condyle			Temporal component			Condyle			Temporal component		
Individual	Anterior	Superior	Posterior	Inferior tubercle	Posterior slope	Roof of fossa	Anterior	Superior	Posterior	Inferior tubercle	Posterior slope	Roof of fossa
1												
2								m				L+
3			L+				L+		L−C−	L−	l L+	
4					c L−C−M+			L+			l L+	
5	—	—	—	—	—	—						
6												
7												
8		c m L−C−M−	C−M−	c L+C−M−	L−	L−	C+	l c m C−	C−	C−	l C−	
9												
10					M+							
11		l L−C−M−	L−C−M−	L+C+M+	l c C+						C+	
12												
13				C+				m				
14				L+C+						L+		
15	l c L−C−M−	L−C−M−	C−	L−	l L−	L−	M+	c m L+C+M+	C−M+		c M−	
16	M+	L+C+	c C+	L+C+	l		L−C−M−	l c m L−C−M−	L−C−M−	L−C−M−	l c m L−C−M−	L−C−M−
17			M+									L+
18			C+	L+				c	c			
19					C+							
20					c							

LCM = microscopic findings and lcm = radiographic findings, where L, l = lateral, C, c = central, and M, m = medial third of joint. + = microscopic erosive change with covering cartilage, and − = microscopic erosive change without covering cartilage.

Table 3. Tomographic and microscopic findings of 39 temporomandibular joints. The figures outside the parentheses represent the findings of the condyle, and those within parentheses the findings of the temporal component

	Microscopy					
	Erosive change		No change		Total	
Tomography	C	(T)	C	(T)	C	(T)
Erosive change	7	(10)	3	(1)	10	(11)
No change	5	(9)	24	(19)	29	(28)
Total	12	(19)	27	(20)	39	(39)

Sensitivity = 0.583 (0.526).
Specificity = 0.888 (0.95).
Positive predictive value = 0.700 (0.909).
Negative predictive value = 0.828 (0.679).

osteoarthrotic TMJ changes among elderly individuals. On the basis of the results of these studies, it might be assumed that the prevalences of joints with erosive changes are roughly similar for TMJs of aged individuals. Furthermore, we anticipate that the figures reported are comparable to the prevalence of joints with erosive changes in patient samples referred for TMJ radiography.

Erosive changes were found in the temporal component of almost twice as many joints as changes localized to the condyle. It seems that if there is an erosive change in the condyle, then as a rule there is also an erosive change in the temporal component. In the condyle the erosive changes were evenly distributed over the joint surface, and in the temporal component there was a slight predominance for the lateral part of the tubercle. This topographic distribution of the erosive changes is in fair agreement with the results reported by Bean et al. (21), who focused on subarticular hard-tissue lesions. Our findings are, however, in contrast to the findings of macroscopic studies by Öberg et al. (14) and Hansson & Öberg (15), who stressed that local osteoarthrosis is situated in the lateral part of the TMJ.

Judged from the microscopic examination, there were two types of erosive changes, an extensive type with loss of articular cartilage and another type of local change with retained articular cartilage. In areas with extensive erosive changes bone exposure was not found, but the hard tissue was always covered by a cell-rich fibrovascular tissue. This is in contrast to the findings in human hip joints reported by Meachim (22). Osteoarthrosis is described as consisting of three elements: a destructive element with cartilage breakdown and bone exposure, a progressive element with remodeling, and, thirdly, a 'reparative element, seen as attempts to re-cover the exposed bone site by a surface layer of new non-osseous tissue'. The fact that bone exposure was not observed in the TMJs with severe osteoarthrotic changes may indicate a difference in biologic reaction of the TMJ as compared with other synovial joints.

It can be argued whether the local erosive changes with retained articular cartilage represent an initial stage of degenerative joint disease or merely an adaptive physiologic remodeling of the joint surface, as claimed by Öberg et al. (14). A reshaping of the articular bone surface has been described both for the TMJ (23) and for other joints (2, 24–27). It has been proposed that the remodeling, when it exceeds the rate at which cartilage can accommodate to the change in shape, is the basic process in osteoarthrotic degeneration (4, 24, 25, 27). The question is whether the surface of the articular cartilage remains intact while the bone surface changes in shape. In other joints initial changes in degenerative joint disease may occur as changes of the hard tissue before extensive changes of the articular cartilage (2–4, 27). Our findings, in particular in the temporal component, together with similar observations made by de Bont et al. (18), may indicate that such a sequence of events is possible in the TMJ.

Articular cartilage, unlike most other tissues, is avascular. Within the erosive change of many TMJs, however, the tissue contained numerous blood vessels. Isberg et al. (28) reported formation of hyperplastic tissue with vessels and nerves in the posterior attachment of painful joints with long-standing internal derangement. They suggested that the pain reaction in such TMJs may be released by compression or tension of nerves. It is conceivable that the pain sometimes associated with osteoarthrosis of the TMJ is attributable to the ingrowth of vessels with accompanying nerves—albeit not stained for in this study—into the articular cartilage.

Tomography yielded low sensitivity in detecting erosive changes. The positive and negative predictive values were, however, high. Although sensitivity and specificity are important characteristics of a diagnostic test, the predictive values are more relevant to the clinical situation since we usually need to know the possibility of a change, given positive or negative test results, when evaluating an individual patient. The positive predictive value of the tomographic examination was higher for the temporal component (0.91) than for the condyle (0.70), whereas the negative predictive value was higher for the condyle (0.83) than for the temporal component (0.68). Applied to the clinical situation, these values indicate that there is a high probability that a tomographic finding of an erosive change in the temporal component is a true finding, whereas a radiologically intact condyle with high certainty is free from erosive changes. Clinically, the diagnostic outcome of tomography may be lower, as blurring might affect the detectability of the changes.

One key factor for the tomographic detectability was the extent of the erosive change. There was an underestimation not only of the presence but also of the extent of the changes. In the four joints in which even reexamination of the tomograms failed to show the extensive erosive changes found microscopically, the bony surfaces seemed radiographically defined. Clinically, such a finding is usually regarded as a sign of a calm state in the degenerative joint disease. It is, however, important to recognize that radiographs do not depict the ongoing process but rather the rough result of previous processes.

The erosive changes covered by articular cartilage were shown by tomography to the same extent as those without overlying cartilage. When interpreting tomograms of the TMJ, it should be kept in mind that erosive changes might differ in significance. It is widely recognized that only a small proportion of the many persons developing radiographic signs of early osteoarthrosis in the hip joint progress to advanced disease (29). Thus, although the properties of computerized tomography for the diagnosis of joint disease have been improved over the past decade, radiography is probably not sensitive enough to separate the erosive changes with articular cartilage from those without overlying cartilage. To study early degenerative joint disease in the TMJ, more sensitive diagnostic tools have to be developed. Initial results from joint fluid analyses in other synovial joints (30, 31) have been promising, and such analyses may in the future be feasible also in the TMJ.

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