Tomography as an aid to detect macroscopic changes of the temporomandibular joint

An autopsy study of the aged

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The aim of this study was to evaluate the possibility of detecting macroscopic changes of the temporomandibular joint with the aid of tomographic examination. Forty-four autopsy specimens were examined with corrected sagittal and frontal tomography. The tomograms were evaluated without comparative assessment of the macroscopic appearance. The diagnostic sensitivity, specificity, and predictive values were calculated. Diagnostic accuracy depends on the severity, extent, and localization of the macroscopic changes. All joints with severe and extensive macroscopic changes were identified on tomograms; two thirds of the joints with moderate changes were correctly diagnosed. Macroscopic changes of the condyle were more frequently detected than those of the temporal component. The specificity for single areas of the joints was higher than the sensitivity—that is, normal areas were more easily assessed than areas with changes. □ *Diagnostic errors; osteoarthritis; X-ray tomography*

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Radiographic examination of the temporomandibular joint (TMJ) is often included in the diagnosis and treatment planning of disorders in the stomatognathic system and in the follow-up of therapeutic effects. Comparative radiographic and macroscopic studies of the TMJ (1–4) have presented the true-positive and false-negative diagnoses and emphasized the risk of underdiagnosis. The performance of a diagnostic test is, however, not completely described by its aid in detecting pathological conditions—that is, its sensitivity; also needed is its aid in excluding patients without pathological findings—its specificity. The guidelines for these diagnostic decisions are presented by McNeil et al. (5), Wulff (6), and Weinstein et al. (7), among others.

The purpose of the present study was to evaluate the value of tomography in detecting TMJs with and without macroscopic changes.

Materials and methods

From the autopsy material, two joints from the same individual with totally destroyed condyles were excluded. The remaining 44 TMJs from 22 cadavers were examined tomographically as blocks. The specimen material was from 8 women (mean age, 77; range, 67–88 years) and 14 men (mean age, 73; range, 60–86 years).

Radiographic examination

Radiographic technique. During the examination the specimens were attached to a positioning device described by Westesson et al. (8). The TMJ was oriented with the tomographic plane perpendicular to the long axis of the condyle—that is, corrected sagittal tomography (9). By a 90° rotation of the positioning device without displacing the specimen, the frontal tomographic image was made parallel to the condylar long axis, as described by Omnell (10). Tomography was performed with a Philips Universal Polytome (Massiot, Philips, France) with a Siemens Bi 125/30/50R tube, a nominal focus size of 0.6 mm × 0.6 mm, a focus–film distance of 1.50 m, and a magnification fac-

tor of 1.3. A hypocycloidal movement was used with a tomographic angle of 48° without a grid. The diameter of the circular collimator was 1.5 cm, resulting in a field size diameter of 6.5 cm in the film plane. Exposure data were 60 kVp, 20–33 mA, and 6 sec.

A multi-film cassette with five pairs of $CaWO_4$ screens (last pair of screens were Saphir and the others Rubin, Siemens–Elema, Sweden) and five films (Ilford Rapid R, Ilford, England) was used. The interspace between the different tomographic sections was 2.5 mm, which covered an overall thickness of 10.0 mm. Four exposures were performed for each TMJ, two for corrected sagittal tomographic images and two for frontal tomographic images. The tomographic layer was moved 10 mm between the two exposures for each projection.

Interpretation of tomograms. The same observer (M. Rohlin) evaluated all tomograms. Since the mediolateral dimensions of the mandibular and temporal components and the interspace between the tomographic sections were known, corrected sagittal tomograms showing the lateral, central, and medial thirds of the TMJ could be selected. A similar procedure was made for the frontal tomographic images.

The corrected sagittal tomograms were first evaluated and the findings recorded in the areas as seen in Table 1. The frontal tomograms were then evaluated. All recordings were made independently of the macroscopic examination.

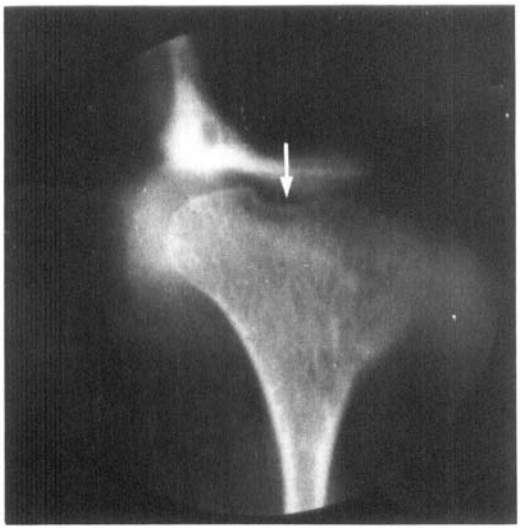


Fig. 1. Frontal tomogram of a TMJ, depicting a concavity (arrow). Macroscopically there was a local reduction of the soft tissue layer in the corresponding area.

The following findings on the tomogram in lateral and anteroposterior projections of the mineralized tissues were recorded:

Concavity: a hollowed-out area on the bony contour with a well-defined cortical outline of the joint surface (Fig. 1);

Cyst: a well-defined, local area of bone

Table 1. Topographical distribution of radiographic findings of 44 temporomandibular joints from 22 cadavers

	Corrected sagittal tomography			Frontal tomography		
	Lateral	Central	Medial	Lateral	Central	Medial
Condyle						
Anterior	30	23	17			
Superior	11	21	14	10	13	7
Posterior	7	13	10			
Total	48	57	41	10	13	7
Temporal component						
Anterior slope		3	10			
Inferior part	6	12	11	6	9	3
Posterior slope	22	37	25	1	1	
Roof and wall of fossa	1	2				
Total	29	54	46	7	10	3

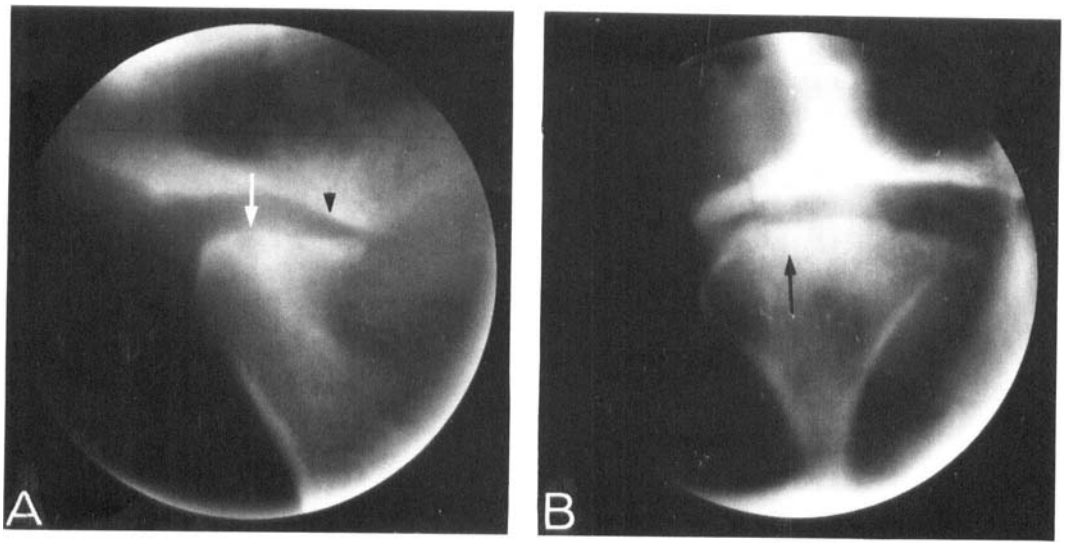


Fig. 2. Tomograms of a TMJ radiographically diagnosed as a pathologic joint. A. Corrected sagittal tomogram depicting a cyst (arrow) in the superior part and an osteophyte in the anterior part of the condyle. The posterior slope of the temporal component is flattened (arrow head). B. Frontal tomogram showing a sclerotic area of the condyle (arrow).

rarefaction underneath an intact cortical outlining of the joint surface (Fig. 2A);

Erosion: a local area with decreased density of the cortical joint surface and adjacent subcortical bone (Figs. 3A and B);

Flattening: a flat bony contour deviating from the convex form (Figs. 2A, 3A, and 4A);

Osteophyte: a marginal bony outgrowth (Figs. 2A and 3A); and

Sclerosis: local area with increased density of the cortical bony joint surface extending into the subcortical bone (Fig. 2B).

Reference tomograms of TMJ autopsy specimens depicting these radiographic findings were selected by all three authors by consensus. These reference tomograms were used during the readings.

A comprehensive diagnosis based on a subjective evaluation of the condition of the entire joint was also made in accordance with the following criteria:

Normal joint: well-defined cortical outline and convex form of the bony joint surfaces, or minor deviation in form such as flattening, small osteophyte, and concavity of the bony joint surfaces (Fig. 4).

Pathologic joint: changes such as sclerosis, erosion, and cyst (Figs. 2 and 3).

Macroscopic examination

The articular surface of the condyle and temporal component was examined for deviation in form and for macroscopic changes of sufficient severity to be readily visible by naked-eye examination. Their position and extent were recorded by two of the authors (M. Rohlin, S. Åkerman) on the chart for the areas (Table 2).

Macroscopic changes. Changes in the condyle, disc, and temporal component were classified into four stages in accordance with a modification of the principles of Byers et al. (11): 0 = no changes of the type described below (Fig. 4C); 1 = superficial flaking or fraying; 2 = local reduction of soft tissue layer; and 3 = total loss of soft tissue with bone exposure (Fig. 3C) and/or perforation of the disc.

An index for macroscopic changes (MC_i) was calculated with the following formula:

$$MC_i = \frac{\text{sum of changes stages 1–3}}{\text{total number of areas recorded}}$$

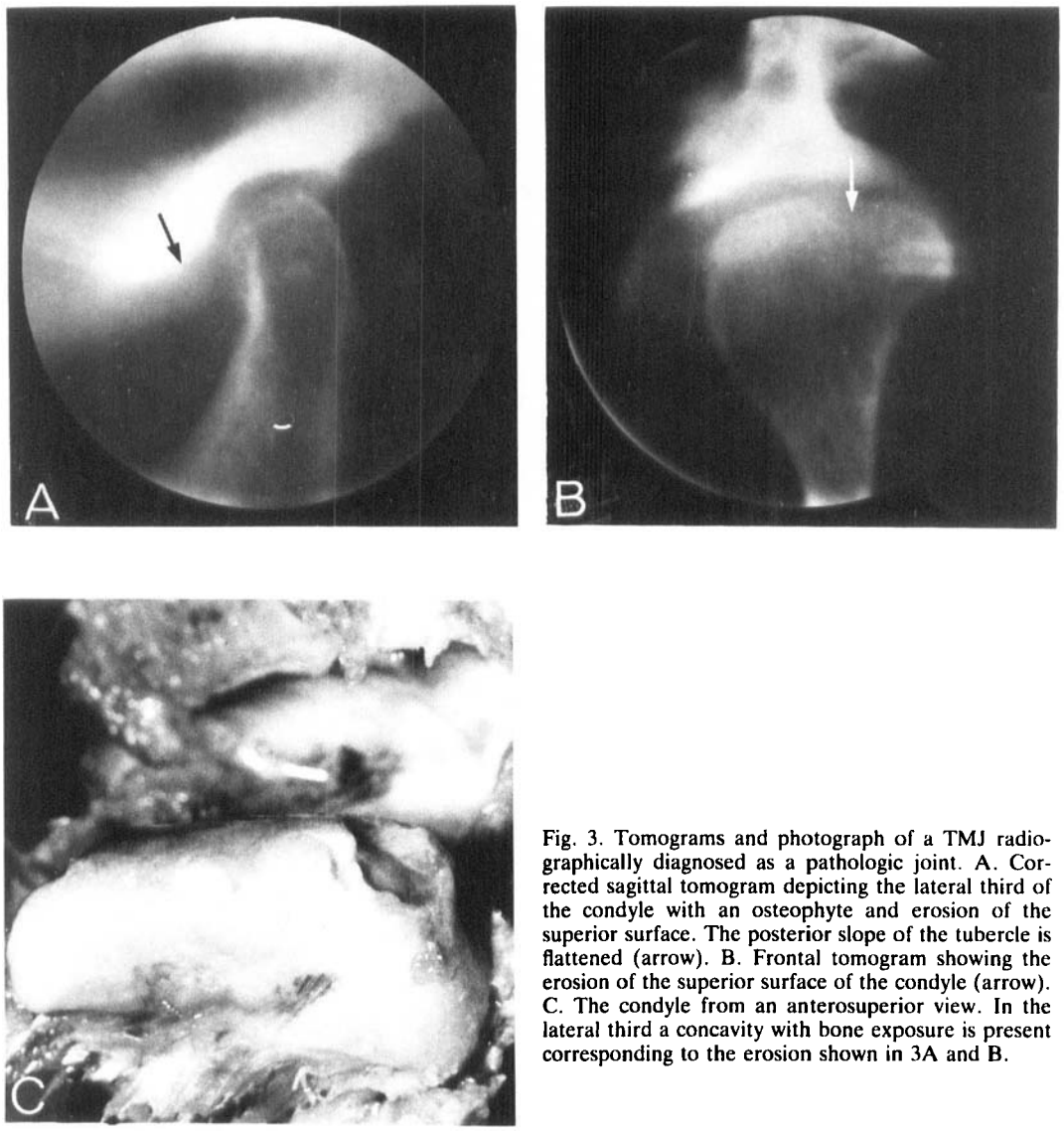


Fig. 3. Tomograms and photograph of a TMJ radiographically diagnosed as a pathologic joint. A. Corrected sagittal tomogram depicting the lateral third of the condyle with an osteophyte and erosion of the superior surface. The posterior slope of the tubercle is flattened (arrow). B. Frontal tomogram showing the erosion of the superior surface of the condyle (arrow). C. The condyle from an anterosuperior view. In the lateral third a concavity with bone exposure is present corresponding to the erosion shown in 3A and B.

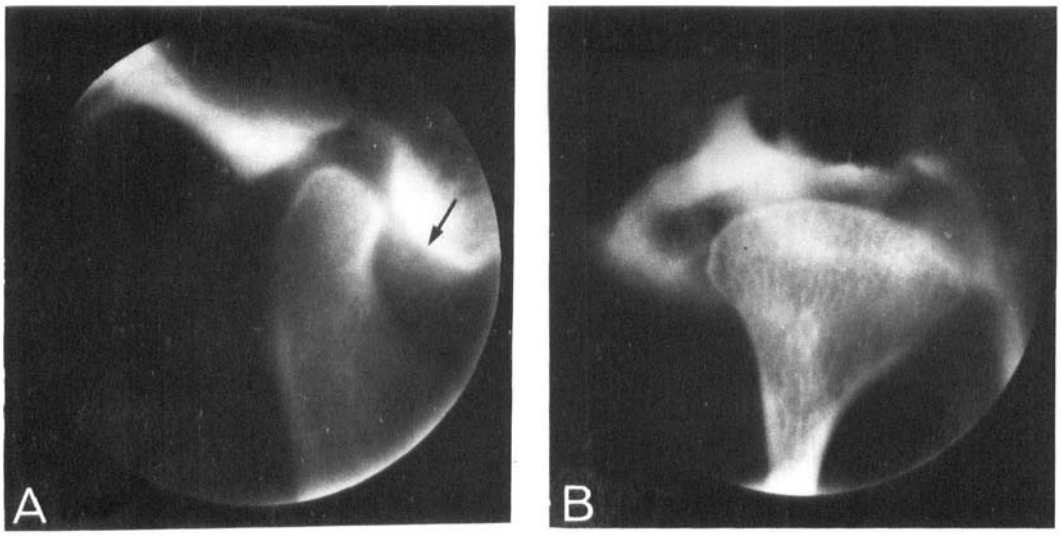
Determination of sensitivity, specificity, and predictive values

The radiographic findings were evaluated for the possibility of detecting macroscopic degenerative changes of stage 3 and stages 2 + 3 and for different values of MC_i. Evaluation was made for the comprehensive diagnosis of the entire TMJ and for the areas stated in Tables 1 and 2. The sensitivity, specificity, and predictive values were defined and calculated in accordance with Weinstein et al. (7):

Radiographic examination	Macroscopic examination	
	Joint or area with macroscopic changes	Joint or area without macroscopic changes
Positive	a (true-positive)	b (false-positive)
Negative	c (false-negative)	d (true-negative)

Sensitivity: true-positive rate is the proportion of joints/areas with disease which have a positive test result $a/(a + c)$.

Specificity: true-negative rate is the pro-



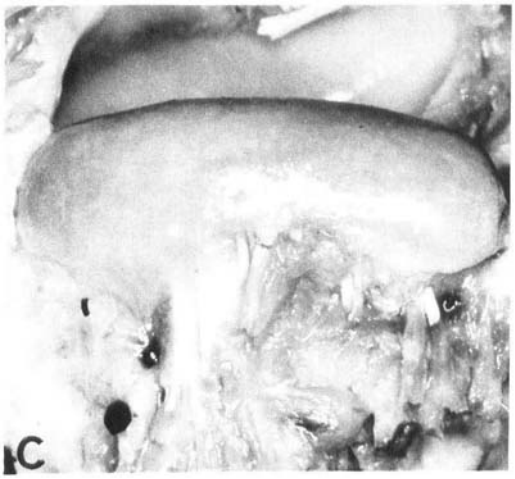


Fig. 4. Tomograms and photograph of a TMJ radiographically diagnosed as normal. A. Corrected sagittal tomogram showing a flattening of the posterior slope of the temporal component (arrow). B. Frontal tomogram showing a well-defined cortical outline and convex form of the condyle. C. The condyle from an anterosuperior view. No pathologic changes were found.

portion of joints/areas without disease which have a negative test result $d/(d + b)$.

Predictive value positive of the test is the probability that a joint/area with a positive test result actually has disease $a/(a + b)$.

Predictive value negative of the test is the probability that a joint/area with a negative test result actually does not have disease $d/(d + c)$.

An ideal diagnostic test has a sensitivity of 1.0, a specificity of 1.0, and predictive values of 1.0.

Results

Radiographic examination

The topographical distribution of the radiographic findings is shown in Table 1. In the corrected sagittal tomograms 275 radiographic findings were recorded. In addition, 50 findings were recorded in frontal tomography. Radiographic findings were as frequent in the condyle as in the temporal component in both projections.

Table 2. Topographical distribution of macroscopic changes of stages 2 and 3 of 44 temporomandibular joints from 22 cadavers. In parentheses, the number of areas with corresponding radiographic findings. The examined number of areas was 394 for the condyle and 551 for the temporal component

	Lateral		Central		Medial		Total	
	Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3
Condyle								
Anterior	4(3)	6(5)	3(3)	4(3)	5(3)	4(3)	12(9)	14(11)
Superior	5(2)	8(5)	7(4)	6(4)	3(1)	7(5)	15(7)	21(14)
Posterior	5(1)	5(1)	6(3)	2(1)	3(1)	4(1)	14(5)	11(3)
Total	14(6)	19(11)	16(10)	12(8)	11(5)	15(9)	41(21)	46(28)
Temporal component								
Anterior slope	1	2		3		1	1	6
Inferior part	2(1)	6(2)	2(1)	4(3)		1(1)	4(2)	11(6)
Posterior slope	2(1)	7(3)	2(1)	3(3)		1(1)	4(2)	11(7)
Roof and wall of fossa	1	4	1	3(1)	2	2	4	9(1)
Total	6(2)	19(5)	5(2)	13(7)	2	5(2)	13(4)	37(14)

Macroscopic examination

The posterior attachment of the disc was frequently attached to the posterior wall of the mandibular fossa. The posterior wall was therefore not examined, and 109 areas of the temporal component and 2 areas of the condyle were not evaluated. The topographical distribution of macroscopic changes of stages 2 and 3 is shown in Table 2. About the same number of changes was found on the condyle as in the temporal component. Local reduction of the soft tissue layer (stage 2) was recorded in a few areas of the temporal component. Bone exposure and/or disc perforation (stage 3) was observed in 17 of the 44 joints (39%). Bone exposure was recorded for 46 of 394 areas (12%) for the condyle and 37 of 551 areas (7%) for the temporal component. Deviation in form was recorded for all joints.

Correlation of radiographic and macroscopic examination

Table 3 shows the correlation of the comprehensive radiographic diagnosis and the macroscopic examination. The findings for 28 of the 44 joints (63%) were correctly diagnosed when tomography was used as an aid to identify joints both with and without bone exposure and/or disc perforation (stage 3). In five of six joints with false-negative diagnoses, the macroscopic changes of stage 3 were limited to a single area of either the fossa or the disc. Of ten joints with false-positive diagnoses six joints showed widespread macroscopic changes in terms of local reduction of the soft tissue layers (stage 2).

With stages 2 and 3 combined, the number of false-positive diagnoses was reduced, and the number of false-negative diagnoses increased compared with stage 3. Of the joints with stage 2 changes, those that were tomographically identified as pathologic joints showed more extensive changes than the joints tomographically interpreted as normal. Four joints with false-positive diagnoses only showed deviation in form macroscopically. For these joints the radiographic diagnosis was based on erosions and sclerosis found in the temporal component. The predictive value positive means that about 80% of the joints radiographically diagnosed as pathologic could be expected to have macroscopic changes of stage 2 or 3.

The joints with index $MC_i > 5$ included most joints (32/44), even those with superficial changes, whereas those with $MC_i > 50$ (12/44) only included joints with deep and/or extensive changes. The higher the index chosen, the more joints were correctly diag-

Table 3. Number of temporomandibular joints with different stages of macroscopic changes and their comprehensive radiographic diagnosis (+ = pathologic joint, − = normal joint). MC_i = index of macroscopic changes. Sensitivity, specificity and predictive values of the radiographic diagnosis in detecting macroscopic changes of different stages (n = 44 joints)

	Macroscopic examination							
	True-positive	False-negative	False-positive	True-negative	Sensitivity	Specificity	Predictive value positive	Predictive value negative
	Stage 3*		Stages 0 + 1 + 2					
Radiographic examination	+	−	+	−				
	11	6	10	17	0.65	0.63	0.52	0.74
	Stages 2 + 3*		Stages 0 + 1					
Radiographic examination	+	−	+	−				
	17	12	4	11	0.59	0.73	0.81	0.48
	$MC_i > 5$		MC_i 0–5					
Radiographic examination	+	−	+	−				
	17	15	4	8	0.53	0.67	0.81	0.35
	$MC_i > 10$		MC_i 0–10					
Radiographic examination	+	−	+	−				
	16	10	5	13	0.62	0.72	0.76	0.57
	$MC_i > 15$		MC_i 0–15					
Radiographic examination	+	−	+	−				
	15	7	6	16	0.68	0.73	0.71	0.70
	$MC_i > 25$		MC_i 0–25					
Radiographic examination	+	−	+	−				
	13	5	8	18	0.72	0.69	0.62	0.78
	$MC_i > 50$		MC_i 0–50					
Radiographic examination	+	−	+	−				
	10	2	11	21	0.83	0.66	0.48	0.91
	$MC_i > 75$		MC_i 0–75					
Radiographic examination	+	−	+	−				
	10	0	11	23	1	0.68	0.48	1

* Number of joints with at least one area with stage 3 and stages 2 + 3, respectively.

nosed tomographically, 25 of 44 joints (57%) for $MC_i > 5$, compared with 33 of 44 joints (75%) for $MC_i > 75$. In particular, the number of false-negative diagnoses was reduced with increased severity and/or extension of the macroscopic changes. In Fig. 5 the sensitivity is plotted versus the specificity for different values of MC_i. With increasing MC_i, the predictive value positive decreased, and the predictive value negative increased.

Table 4 shows radiographic findings as signs of macroscopic changes for single areas of the joints. Both the sensitivity and the predictive value positive were higher for the condyle than for the temporal component. In areas with bone exposure a radiographic finding was recorded in about two thirds (61%) of condylar areas and only in about one third (38%) of the temporal areas. More than half the macroscopic changes of stages

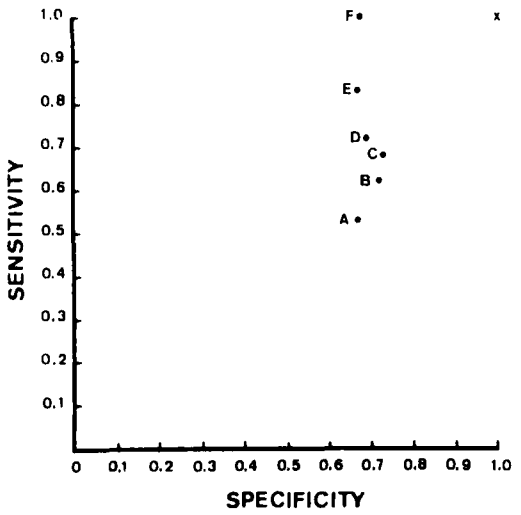


Fig. 5. Sensitivity plotted versus specificity for the radiographic diagnosis in detecting temporomandibular joints with different values of MC_i (index for macroscopic changes). A = $MC_i > 5$; B = $MC_i > 10$; C = $MC_i > 15$; D = $MC_i > 25$; E = $MC_i > 50$; F = $MC_i > 75$. X = ideal values.

2 or 3 of the condyle were seen tomographically irrespective of their location (Table 2). In the central third of the temporal component half of the macroscopic changes of stage 2 or 3 were also detected, whereas only one fourth of these changes were seen in the lateral and medial thirds of the temporal component by tomography (Table 2). The specificity demonstrated that in 77–81% of the areas recorded as stage 0 or 1 there were no radiographic findings (Table 4).

Discussion

In this study the frequency of TMJ with bone exposure and/or perforation of the disc (39%) was similar to the figures reported in previous autopsy studies (12–14) in cadavers of persons 60 years of age or older. The dental status of the examined individuals and the macroscopic findings were reported in detail in a previous study (15). No correlation was found between the number of remaining teeth and the index of macroscopic changes.

Sagittal tomography was chosen on the basis of information from previous clinical studies—that is, sagittal tomography yields the largest amount of diagnostic information (9, 16–19). From TMJ autopsy studies (2–4, 20) it can also be concluded that sagittal tomography is superior to the lateral oblique transcranial projection in detecting macroscopic changes. The tomographic examination also resembles a clinical radiographic examination, whereas the superimpositions

Table 4. Number of areas with macroscopic changes localized in the condyle and temporal component and the presence (+) or absence (−) of radiographic finding(s). Sensitivity, specificity, and predictive values of radiographic finding(s) at detecting macroscopic changes. Examined number of areas: for the condyle, 394; for the temporal component, 551

	Macroscopic examination							
	True-positive	False-negative	False-positive	True-negative	Sensitivity	Specificity	Predictive value positive	Predictive value negative
	Stage 3		Stages 0 + 1 + 2					
Radiographic examination	+	−	+	−				
Condyle	28	18	93	255	0.61	0.73	0.23	0.93
Temporal component	14	23	100	414	0.38	0.81	0.12	0.95
	Stages 2 + 3		Stages 0 + 1					
Radiographic examination	+	−	+	−				
Condyle	49	38	72	235	0.56	0.77	0.40	0.86
Temporal component	18	32	96	405	0.36	0.81	0.16	0.93

resulting in the transcranial projection would be more difficult to imitate. Because only the central two thirds of the joint region is clearly imaged by sagittal tomography (2), frontal tomograms were included to image the most lateral and medial parts of the joint.

When tomography was used in this study to identify joints with and without bone exposure and/or disc perforation, the findings from 28 of the 44 joints (63%) were correctly diagnosed. This value indicates a rather lower diagnostic accuracy than the values (80–85%) calculated from the tomographic studies by Bean et al. (4) and Lindvall et al. (3). In the latter studies it appears as if a parallel comparative assessment of the radiographic and macroscopic findings was performed. This approach might have led to a higher diagnostic accuracy than that of the present study, in which the radiographic and macroscopic findings were compared independently. Joints with macroscopic changes in terms of local soft tissue reduction were sometimes tomographically interpreted as pathologic and sometimes as normal joints. Some of these joints might, as Bean et al. (4) found, have sustained extensive destruction of the subarticular compact bone plate even though the soft tissue was intact.

The index for macroscopic changes was calculated, taking into consideration both the stage and the extent of the change. For the highest index three of four joints had a correct diagnosis, which might be considered a satisfactory diagnostic accuracy. However, more than two thirds of the joints with and without moderate macroscopic changes ($MC_i > 15–25$) were also correctly diagnosed. The diagnostic ability in the early phase of disease was, however, limited, which is in agreement with a clinical study of TMJ arthritis (21). The decrease in the predictive value positive and the increase of the predictive value negative with higher MC_i mainly reflect the changed prevalence for the different values of MC_i. The predictive values or so-called posterior probabilities have to be revised to the prevalence of the disease in the population (5–7).

Generally, in the tomographic examination, macroscopic changes localized in the condyle were more frequently detected than those in the temporal component. Furthermore, this relation is probably even more pronounced in clinical practice, when the surrounding structures are more disturbing for the image of the temporal component than of the condyle.

The specificity for single areas of the joint was higher than the sensitivity, implying that there was greater possibility of diagnosing normal areas correctly than detecting areas with macroscopic changes. This is an important asset of radiography. In clinical practice an early radiographic examination serves the purpose of excluding pathologic conditions in patients with TMJ pain/dysfunction (22).

In conclusion, the diagnostic accuracy in tomography of the TMJ is influenced by the severity and extent and by the localization of macroscopic changes. A major disadvantage in the clinical situation with the tomographic technique studied is, however, its low sensitivity in detecting early pathologic changes. A significant capacity of tomography, previously not calculated, is to assess normal areas of the joint. This capacity might be further improved if we follow the rule not to report when in doubt whether a radiographic finding is present. At any level there will be some false diagnoses. These, however, might be reduced when there is more knowledge of the diagnostic significance of different radiographic findings. In clinical practice the radiographic interpretation might also be influenced by the physical examination and history, and the radiographic findings are combined with findings of other diagnostic tests. Another important point to consider, according to McNeil et al. (5), is that the threshold for diagnostic tests must be chosen for each clinical condition, which depends on the relative costs associated with classifying patients with disease as normal versus classifying normal patients as diseased. Moreover, the selection of optimal therapy should greatly influence the threshold of interpretation of TMJ radiography.

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