Metacarpal cortical bone mass in patients with mandibular pain and dysfunction

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Sixty consecutive patients with mandibular pain and/or dysfunction were divided in three groups; one group with temporomandibular joint (TMJ) crepitation, another with tenderness on palpation of the TMJ and a reference group without any of these signs.

The TM joints of the patients were exposed radiographically in oblique lateral and transmaxillary projections. The hands were exposed in the dorsovolar projection. The metacarpal index of Barnett & Nordin (2)

$$\left(\frac{D-d}{D}\right)$$

was determined from the hand radiographs as well as the Exton-Smith (II) index

$$\left(\frac{D^2-d^2}{L\text{-}D}\right)$$

Radiographic abnormalities in the TMJ and hand joints were recorded and quantified in indices as well as clinical abnormalities in the masticatory system.

The index of Barnett & Nordin was significantly lower in the group of patients with palpatory tenderness of the TMJ than in the reference group. The Exton-Smith index was significantly and negatively correlated to the radiographic index of hand joint but not TMJ disease. A statistically significant positive correlation was found between the Exton-Smith index and the size of the TMJ condyle.

The results of the present study indicate that patients with palpatory tenderness of the TMJ, probably of inflammatory origin, have a smaller second metacarpal cortical bone mass than reference patients, as have patients with radiographic signs of hand joint disease.

Key-words: Temporomandibular joint syndrome; radiography; metacarpal index; osteoarthrosis; arthritis

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In the interpretation of radiographs of the temporomandibular joint (TMJ) the appearance of the cortical outlining of the joint surfaces is often considered. The cortical layer is thereby often interpreted as being either absent, eroded, normal or thickened. These signs as well as other radiographic signs of deviation in shape or disease of the TMJ, may be related to general cortical bone mass.

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It has been shown that patients with osteoarthrosis of the hip differ from normal control subjects with respect to cortical thickness and remodelling of the second metacarpal bone (26). These patients had an increased periosteal but unchanged endosteal apposition of bone in the second metacarpal, resulting in an increased bone mass. Similar findings have been reported by Foss & Byers (12) and Byers & Foss (5). The indices used to es-

timate general bone mass and to estimate skeletal remodelling activity in these studies were developed by Barnett & Nordin (2) and Exton-Smith et al (11). Both indices are obtained by measurement on hand radiographs of the external and internal diameters of the second metacarpal at the midpoint of the shaft. The index developed by Barnett & Nordin (2) is based on cortical thickness, while the index proposed by Exton-Smith et al. (11) is based on cortical area.

No information is available on the relationship between metacarpal cortical bone mass and osteoarthrosis or any other disease of the TMJ. The aim of the present study was therefore to provide answers to the following questions:

1. Do patients with clinical signs of osteoarthrosis or arthritis of the TMJ differ from other patients with mandibular pain and dysfunction with respect to metacarpal cortical bone mass?
2. Is there a correlation between radiographic signs of TMJ and hand joint disease and metacarpal cortical bone mass?
3. Is there a correlation between deviation in shape of the mandibular condyle (remodelling) and metacarpal cortical bone mass?

MATERIAL AND METHODS

Selection of patients

Sixty patients with mandibular pain and/or dysfunction were selected from a consecutive series referred to the Department of Stomatognathic Physiology of the University of Göteborg (16). Patients with diagnosed rheumatoid arthritis or other known systemic diseases involving joints or muscles have been excluded from the study. The patients were divided into three groups:

Group 1, consisting of the patients with TMJ crepitation audible with a stethoscope (n = 18);

Group 2, consisting of the patients with tenderness on palpation of the TMJ, but without TMJ crepitation (n = 17); and

Group 3, consisting of the patients not fulfilling any of the criteria above (n = 25).

Owing to technical difficulties and non-attendance, radiographs were missing for 8 of the patients in the original series, 2 of whom belonged to group 1, 2 to group 2 and 4 to group 3.

The age and sex distribution of the patients is given in Table 1. In groups 1 and 2 the mean age was higher (55 and 36 years, respectively) and women were more preponderant (83 and 76 %, respectively) than in group 3 (30 years and 60 %, respectively). The arithmetic mean of age for all patients was 45 years, and 72 % of them were women.

Radiographic methods

The hands of the patients were exposed in the dorsovolar projection. Kodak enveloped medical film was used. The exposure settings were 69mAs, 60 kVp and the target-film distance was 81 cm. The temporomandibular joints were exposed in oblique lateral and transmaxillary projections (18).

Metacarpal indices

The index of Barnett & Nordin (2) was determined from the radiographs using a sliding caliper. The ratio of the total cortical thickness (D-d) to the shaft diameter, D, was calculated

$$\left(\frac{D-d}{D}\right)$$

at the midpoint of the second metacarpal bone of both hands (Fig. 1). The cortical

Table 1. *Age and sex distribution of the patients in the various groups. Number of patients*

Sex	Patient groups	Age-groups (years) 16–24	25–49	50–88	Total
Women	Group 1	0	5	10	15
	Group 2	4	6	3	13
	Group 3	3	11	1	15
Men	Group 1	0	2	1	3
	Group 2	1	2	1	4
	Group 3	6	3	1	10
Total		14	29	17	60

area was calculated (D^2-d^2) and normalized for bone size

$$\left(\frac{D^2-d^2}{L-D}\right)$$

Exton-Smith index). The measurements were made to one tenth of a millimetre. The error of measurement was estimated by duplicate measurements made on the hand radiographs of 10 individuals, selected at random, 2 months later.

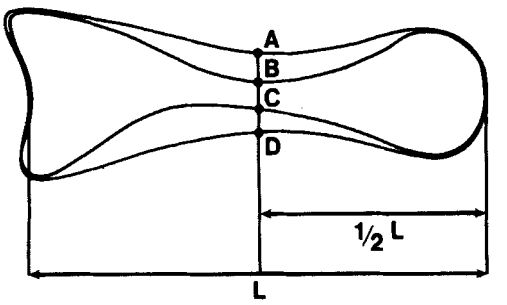

Fig. 1. Schematic drawing of the second metacarpal bone showing the measurements performed. L = length, D (= A – D) = external diameter and d (= B – C) = internal diameter.

Radiographic indices of joint disease

Indices of radiographic abnormalities in the TMJ and hand joints have been constructed and described previously (19). These indices are not intended to be specific for osteoarthrosis or any other joint disease but merely a quantification of the radiographic findings. The index of the TMJ included the following *five* radiographic signs: flattening of the lateral part of the condyle (frontal plane), flattening of the temporal eminence (sagittal plane), eroded cortical layer of the condyle (frontal plane), subcortical sclerosis of the condyle (frontal plane), reduced joint space (sagittal plane). The presence of each of these five signs contributed one unit to the score, which thus varied between 0 and 5 units. The radiographic index of *hand joints* (interphalangeal and metacarpophalangeal joints) was constructed in the same way and included the following *seven* radiographic signs: marginal osteophytes (increased amount of peripheral mineralized tissue), eroded cortical layer, thickened cortical layer, subcortical sclerosis, reduced joint space, obliterated joint space, subluxations. The index thus ranged from 0 to 7 units.

Clinical examination

The clinical examination of the masticatory system was performed with methods which have been described elsewhere (6, 20), used routinely at the Department. The clinical signs included in the clinical dysfunction index constructed by Helkimo (15) were recorded (mandibular

movement capacity, pain during mandibular movements, tenderness on palpation of the masticatory muscles and TMJ, TMJ sounds and deviation of the mandible during mouth opening) and this index was used as a measure of the severity of mandibular pain and dysfunction. The TMJ was also auscultated for crepitation and palpated for unilateral bony enlargement of the condyle (i.e. a difference in size between right and left condyles revealed by lateral palpation).

Statistical methods

The statistical significance of differences between sexes, age- and patient-groups was tested with Fisher's permutation test (25). Significance tests for partial correlations were performed with Pitman's test (4).

Sex and age were included as confounding variables in all the tests. The material was then divided into groups according to sex and age. Three age-groups were studied: 16–24, 25–49 and 50–88 years. The Fisher test variables were first calculated for each group separately and were then pooled. The p-value was calculated using the Edgeworth expansion. The levels of statistical significance are denoted by ** $p < 0.01$, * $0.01 \leqslant p < 0.05$, and N.S. not significant.

Pearson's product-moment correlation coefficient (r) was calculated to obtain an approximate estimate of the strength of the partial correlations (r_p), but *no significance tests* were based on this coefficient.

The error of measurement on the radiographs was estimated as the standard deviation of a single measurement and the coefficient of variation in per cent

$$\left(c = \frac{s \cdot 100}{\bar{x}}\right)$$

The standard deviation was calculated from the differences between the duplicate readings (d_i) according to the following formula:

$$s = \sqrt{\frac{\Sigma d_i^2}{2n}}$$

RESULTS

Error of measurement

The standard deviation of a single measurement was 0.26 mm for measurement of length (L), 0.09 mm for external diameter (D), and 0.18 mm for internal diameter (d). The coefficients of variation were 0.4 % (L), 1.0 % (D), and 5.2 % (d), respectively.

Right and left side

The values of both metacarpal indices were similar for the right and left metacarpal bone (Table 2).

Sex and age differences

The index of Barnett & Nordin

$$\left(\frac{D-d}{D}\right)$$

showed a statistically significant negative correlation to age ($p < 0.01$; Table 2). The Exton-Smith index

$$\left(\frac{D^2-d^2}{L-D}\right)$$

was significantly lower in women ($p < 0.01$).

Differences between groups

The index of Barnett & Nordin

$$\left(\frac{D-d}{D}\right)$$

Table 2. *Distribution of metacarpal indices in the different groups of patients and their correlation to sex and age. $\bar{x}$ = mean value, SD = standard deviation*

		Group 1 $\bar{x}$/SD Range	Group 2 $\bar{x}$/SD Range	Group 3 $\bar{x}$/SD Range	Test of difference 1–3	 2–3	Correlation to sex and age
$\frac{D-d}{d}$	Right	0.56/0.13 0.3–0.8	0.58/0.09 0.4–0.7	0.65/0.09 0.5–0.8	N.S.	*	Age**(r = -0.62)
	Left	0.55/0.12 0.4–0.7	0.58/0.07 0.5–0.8	0.65/0.11 0.5–0.8	N.S.	*	Age**(r = -0.64)
$\frac{D^2-d^2}{L-D}$	Right	0.98/0.21 0.7–1.5	1.08/0.22 0.8–1.7	1.07/0.19 0.7–1.6	N.S.	N.S.	Sex** Age (r = -0.10)
	Left	0.98/0.21 0.6–1.4	1.02/0.18 0.8–1.4	1.02/0.12 0.8–1.2	N.S.	N.S.	Sex** Age (r = -0.15)

was significantly lower in group 2 than in group 3 ($p < 0.05$) in both the right and left metacarpal bone (Table 2). The difference in index value between groups 1 and 3 is due to the age difference between the groups.

Correlations

The Exton-Smith index

$$\left(\frac{D^2-d^2}{L-D}\right)$$

was significantly and negatively correlated to the radiographic index of hand joint disease ($p < 0.05$; Fig. 2) with consideration taken to the small influence of age. The following single variables included in the radiographic index were significantly ($p < 0.05$) and negatively correlated to the Exton-Smith index: marginal osteophytes, thickened cortical layer, and reduced/obliterated joint space.

A statistically significant positive correlation was found between the Exton-Smith index and unilateral enlargement of the TMJ condyle ($p < 0.05$; Fig. 3) with consideration taken to the small influence of age as confounding factor.

Correlations between the metacarpal indices and crepitation of the TMJ as well as the clinical dysfunction index were not statistically significant when age was taken into consideration as a confounding factor. No correlation at all could be detected between the metacarpal indices and the radiographic index of TMJ disease.

DISCUSSION

The intra-observer error of measurements of the thickness of the radial cortex has been estimated previously (27) and was then judged to be acceptable (~ 8 %). In a later study (1) similar intra- as well as interobserver errors (8–11 %) were found for measurement of the meta-

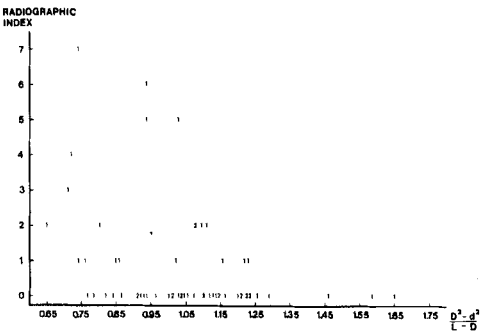

Fig. 2. Relationship between the Exton-Smith index $\left(\frac{D^2-d^2}{L-D}\right)$ of the second metacarpal bone and the radiographic index of hand joint diesease. Pearson's $r_p = -0.37$ when the influence of age is excluded and $r = -0.38$ before age is excluded.

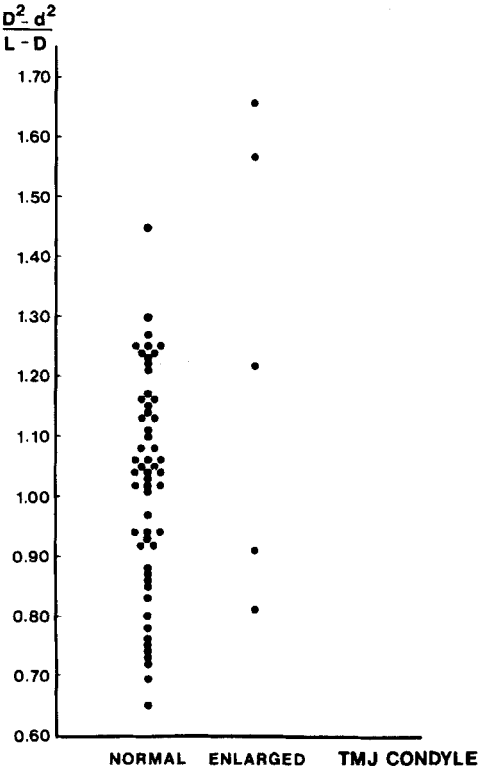

Fig. 3. Relationship between the Exton-Smith index $\left(\frac{D^2-d^2}{L-D}\right)$ and unilateral enlargement of the TMJ condyle. Pearson's $r_p = 0.32$ when the influence of age is excluded and $r = 0.29$ before age is excluded.

carpal cortical thickness. The error of measurement in the present study was similar to that reported by Dalén & Lamke (7), who found an intra-observer variability including refilming of 1.9% for outer diameter and 5.2% for inner diameter of the second metacarpal bone.

The observer variability in the interpretation of individual radiographic signs of disease in the temporomandibular and hand joints has been previously investigated and was found to be great (18, 21). The signs with the lowest variability were selected for use in the present study.

The values of the metacarpal indices were similar for the right and left bones, which is in agreement with previous reports (1, 13).

The Exton-Smith index

$$\left(\frac{D^2-d^2}{L-D}\right)$$

was significantly lower in women than in men, which is in agreement with findings on bone mineral content (7). No sex difference could be found with respect to the Barnett & Nordin index, which also corroborates the results of Dalén & Lamke (7).

The metacarpal index developed by Barnett & Nordin

$$\left(\frac{D-d}{D}\right)$$

decreased significantly with age in this group of patients, which is also in agreement with previous results (2, 7, 8, 28). Barnett & Nordin (2) proposed that the lower limit of normality for their metacarpal index should be 0.43 and that lower values indicate osteoporosis. When this limit is applied, 16% of the patients in group 1 and 2–3% of the patients in groups 2 and 3 were considered osteoporotic.

Reduction of cortical bone mass of the second metacarpal shaft has been reported to occur in chronic rheumatoid arthritis (3, 13) often in association with «irreversible» radiographic changes and soft tissue (muscles, skin) atrophy in the hands (23). Loss of bone mass has also been reported to occur at the site of local arthritis in a «frozen shoulder» (22). There are several factors which can contribute to the atrophy of bone and soft tissues, among them inflammation (arthritis, myositis, vasculitis), inactivity, age, sex, occupation, endocrine disturbances, calcium deficiency, corticosteroid treatment and neurogenic factors. Loss of function is an important factor for development of osteoporosis of the hand (10), which is often secondary to painful synovitis.

The lower value of the Barnett & Nordin index

$$\left(\frac{D-d}{D}\right)$$

in group 2 compared to group 3 may be due to a general inflammatory condition. Group 2 differs from the reference group with respect to palpatory tenderness of the TMJ, commonly interpreted as a sign of inflammation, and similar symptoms in other joints. This group of patients was also tested for subjective symptoms and clinical signs of joint disease in their hands (16, 17) and it was found that the patients in group 2 had a significantly higher frequency of stiffness and pain (42%) in their hands as well as difficulties in moving their fingers (42%) than the patients in group 3 (3 and 10% respectively). Clinically, the patients in group 2 had a significantly higher frequency of tenderness on palpation and pain on movement in the DIP II joints (26%) compared to those in group 3 (3%). The lower value of the metacarpal cortical thickness ratio in group 2 may therefore be explained by restricted hand function due to local pain and stiffness.

The positive correlation found between the Exton-Smith index and unila-

teral enlargement of the TMJ condyle indicates that the size of the TMJ condyle is positively correlated to general bone mass as reflected by the second metacarpal bone.

The negative correlation found between the Exton-Smith index and the radiographic index of hand joint disease is in agreement with previous findings in rheumatic patients (23) and can be explained by the influence on hand function and bone mass of the nearby damaged joints.

The patients with OA of the TMJ, as indicated by crepitation of the joint, did not differ from control patients as regards to metacarpal cortical bone mass when the influence of age was allowed for. It therefore appears that the development of OA in the TMJ is independent of general cortical bone mass as reflected by the metacarpal cortical indices, perhaps in contradiction to other joints (5, 12, 26). Neither could any correlation be found between metacarpal cortical indices and the radiographic index of TMJ disease, which is consistent with this conclusion.

The validity of metacarpal indices as methods of estimating general bone mass has been discussed extensively in previous papers. Studies in which the indices have been used have shown significant correlations between bone mass of the second metacarpal and other long bones as well as the lumbar part of the spine (9, 14, 24). Strong correlations have also been obtained between the indices and the amount of bone mineral found when biopsies have been analyzed (14). Dalén & Lamke (7), however, showed that the correlation between morphological variables of bone mass in general is low, but that *cortical* bone measurements have a tendency to correlate internally. They also showed that morphological variables and bone mineral content did not always correspond. Nordin (24) found that cortical area was the morphological variable most strongly correlated to bone mineral content in the second metacarpal, which favours the Exton-Smith index in this context. The view that the second metacarpal cortical bone is representative for cortical bone in general has thus gained considerable support.

The results of the present study indicate that patients with palpatory tenderness of the TMJ, probably of inflammatory origin, have a smaller second metacarpal cortical bone mass than reference patients, as have patients with radiographic signs of hand joint disease. It was also found that unilateral enlargement of the TMJ condyle was associated with increased cortical bone mass of the second metacarpal bone.

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