Dentomaxillofacial Radiology (2019) 48, 20180245

birpublications.org/dmfr

RESEARCH ARTICLE

CBCT characteristics and interpretation challenges of temporomandibular joint osteoarthritis in a hand osteoarthritis cohort

Margareth Kristensen Ottersen, Anna-Karin Abrahamsson, Tore Arne Larheim and Linda Zamoline Arvidsson

Department of Maxillofacial Radiology, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Oslo, Norway

Objectives: To characterise osteoarthritis (OA) in the temporomandibular joints (TMJs) by means of cone beam CT in a hand OA population, and identify interpretation challenges.
Methods: The TMJs of 54 individuals (mean age 71.3) recruited from the "The Oslo hand OA cohort", independently of TMJ-related symptoms, were examined with cone beam CT (ProMax MidCBCT). Images were analysed for bone change characteristics and each joint was diagnosed with either OA, no OA or as indeterminate for OA. The image analysis criteria developed for the Research Diagnostic Criteria for Temporomandibular Disorders were used. Frequencies of bone changes, joint diagnoses and severity grades (1–2) were calculated, as well as κ values for observer agreement.
Results: In the OA joints, the most frequent bone changes occurred in the condyle: flattening (79%), osteophyte (72%) and subcortical sclerosis (70%). The most frequent changes in the fossa/eminence were flattening (57%), erosion (49%) and subcortical sclerosis (47%). 53 (49%) of the 108 joints were diagnosed with TMJ OA (68 % Grade 2), 29 joints (27%) with no OA, and 26 joints (24%) were indeterminate for OA. Inter- and intraobserver agreement showed mean κ values of 0.67 and 0.62, respectively.
Conclusions: TMJ changes were common in elderly with hand OA and characterised by bone productive changes. The radiologic features indicated a late stage TMJ OA. Interpretation challenges related to subtle changes were identified and are reflected by the rather low observer agreement. The diagnosis of TMJ OA should be based on evident and clear abnormalities only.
Dentomaxillofacial Radiology (2019) **48**, 20180245. doi: 10.1259/dmfr.20180245

Cite this article as: Ottersen MK, Abrahamsson A-K, Larheim TA, Arvidsson LZ. CBCT characteristics and interpretation challenges of temporomandibular joint osteoarthritis in a hand osteoarthritis cohort. *Dentomaxillofac Radiol* 2019; **48**: 20180245.

Keywords: temporomandibular joint; diagnostic imaging; osteoarthritis; cone beam computed tomography

Introduction

Osteoarthritis (OA) is the most common joint disease,[1] hence frequently found in the temporomandibular joint (TMJ). It is a complex, gender- and age-related disease with inflammatory mediators released by cartilage, bone and synovium.[2] Severity of the osseous changes increases by age, also in the TMJ.[3] According to Ahmad et al[4] CT is considered the most reliable method to assess OA in the TMJ. Several studies have shown that cone beam CT (CBCT) with lower radiation exposure is similarly accurate, for review see Larheim et al.[5]

In patients with hand OA, an increased susceptibility to develop OA in other joints has been demonstrated.[6] From a cohort of such patients, we recently reported the

Correspondence to: Dr Margareth Kristensen Ottersen, E-mail: margak@odont.uio.no

Received 27 June 2018; revised 17 December 2018; accepted 19 December 2018

clinical TMJ characteristics in 54 individuals of whom 67% had TMJ OA as diagnosed by means of CBCT.[7] Few studies have explored the CBCT characteristics of TMJ OA in elderly individuals, and we are not aware of any TMJ study in patients with hand OA. Thus, the purpose of the present study was to describe the CBCT characteristics of the TMJs in individuals recruited from this cohort and also to identify interpretation challenges with the diagnostic criteria applied.

Methods and materials

Participants

The present study was performed as a result of a collaboration between the Department of Maxillofacial Radiology, Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Norway and the Department of Rheumatology, Diakonhjemmet Hospital, Oslo, Norway.

The participants were recruited from the Oslo hand OA cohort, which was established in 2001, consisting of patients with hand OA recruited from the outpatient rheumatology clinic at Diakonhjemmet Hospital. Details of the recruitment and drop-outs, both in Oslo Hand OA cohort and in the present study, have been presented elsewhere.[7–9] Patients included in the present study will be named "individuals" to emphasize that they were not recruited due to TMJ-related symptoms. The study was approved by the Regional Committee of Medical and Health Research (REC) of south-east Norway (2011/1411). Written informed consent was provided by all participants.

Imaging assessment

The CBCT examinations were performed at the Department of Maxillofacial Radiology from august 2013 until March 2014. The CBCT unit was a ProMax Mid 3D CBCT (Planmeca Oy, Helsinki, Finland). Field of view was 200 × 60 mm. Default settings were applied with a voltage of 90 kV and tube current of 10 mA. Spatial resolution on CBCT images was set to 200 µm. CBCT images were taken with teeth in occlusion and standardised head position. Reconstructed images were exported in "digital imaging and communications in medicine" format files. The images were analysed in Sectra PACS viewer IDS five version (Sectra, Linköping, Sweden) on an Eizo Flex Scan GS320 (20 inch, colour, 1536 × 2048, 32 bit) monitor. The images were viewed in axial, oblique sagittal and oblique coronal planes (perpendicular to and parallel with the long axis of the mandibular condyle) in the multiplanar reformatted view of the software. Observers were allowed to adjust the brightness and contrast settings for best display to mimic the routine diagnostic approach. All images were interpreted separately by three maxillofacial radiologists (MKO, LZA, TAL) with 3–30 years of experience of interpreting TMJ images.

Table 1 Osseous diagnosis for the TMJ based on CBCT-defined bone changes[a]

A	No OA	Normal relative size of the condylar head; and No subcortical sclerosis or articular surface flattening; and No deformation due to subcortical cyst, surface erosion, osteophyte or generalised sclerosis.
B	Indeterminate for OA	Normal relative size of the condylar head; and Subcortical sclerosis with/without articular surface flattening; or Articular surface flattening with/without subcortical sclerosis; and No deformation due to subcortical cyst, surface erosion, osteophyte or generalised sclerosis
C	OA	Deformation due to subcortical cyst, surface erosion, osteophyte or generalised sclerosis

CBCT, cone beam CT; OA, osteoarthritis; TMJ, temporomandibular joint.
[a]According to the comprehensive diagnostic criteria by Ahmad et al.[4]

The observers were calibrated before they interpreted all the 54 CBCT examinations independently, blinded to clinical information. The diagnostic criteria described by Ahmad et al[4] were used in the analysis of bone change characteristics, and each TMJ was given a diagnosis of OA, no OA or indeterminate for OA (Table 1).

The TMJ OA were also graded based on the system proposed by Ahmad and Schiffman[10]: Grade 1 when the joint displayed either a small osteophyte (<2 mm length), or a single small erosion (<2 mm in depth and width), or a single small subcortical cyst (<2 mm in depth and width); Grade 2 when the joint displayed a larger osteophyte (≥2 mm length), and/or a larger erosion (≥2 mm in depth and width), and/or a larger subcortical cyst (≥2 mm in depth and width), and/or two or more imaging signs of Grade 1.

A second image interpretation of 15 individuals was made after 16 weeks by the three observers for intraobserver agreement analysis. The CBCT examinations for the second interpretation were selected using a random number generator (RNG-Random Number Generator, Intemodino Group s.r.o., App Store).

Statistical analyses

IBM SPSS v. 25.0 (Statistical Package for Social Services, Chicago, IL) was used for statistical analyses. κ statistics analysis was performed to determine consistency within and between observers. For the reliability studies, OA ratings were dichotomised as either present (TMJ OA) or absent (no TMJ OA or indeterminate for TMJ OA). According to Fleiss et al[11] κ values of <0.40

Table 2 TMJ osseous diagnosis[a] based on CBCT-defined bone changes in 54 individuals recruited from a hand OA cohort

		Patients[7] *n = 54* *No. (%)*	*Joints* *n = 108* *No. (%)*
A	No OA	10 (18)	29 (27)
B	Indeterminate for OA	8 (15)	26 (24)
C	OA	36 (67)	53 (49)

CBCT, cone beam CT; OA, osteoarthritis; TMJ, temporomandibular joint.
[a]According to the comprehensive diagnostic criteria by Ahmad et al.[4]

are considered to be poor, values from 0.40 to 0.75 to be fair to good, and values >0.75 to be excellent. For interobserver reliability, the agreement was evaluated pairwise, and a mean of these values gave the final κ value. Any disagreement between the observers was discussed until consensus was met and each joint got a final imaging diagnosis.

Results

A total of 54 individuals were included in the present study (48 females and 6 males). The mean age was 71.3 years ± 5.2 (SD) (range, 61–83 years).

53 (49%) of the total series of 108 joints were found to have OA. The remaining 55 joints were either normal or interpreted as indeterminate for OA (Table 2).

In the 53 TMJs diagnosed with OA, articular surface flattening (79%), osteophyte (72%) and subcortical sclerosis (70%) were the most frequent changes in the condyle. The most frequent changes in the fossa/eminence were flattening (57%), followed by surface erosion (49%) and subcortical sclerosis (47%) (Table 3).

36 (68%) of the 53 OA joints were categorised as Grade 2, and the remaining 17 (32%) as Grade 1. Osteophyte ≥ 2 mm was found in 22 (61%) Grade 2 joints. All findings of cortical erosions and subcortical cysts in the OA joints were measured <2 mm in both depth and width, and the diagnoses of the remaining 39% of Grade 2 joints were based on the findings of two or more imaging signs of Grade 1.

The most frequent combination of bone changes in TMJ OA was articular surface flattening and osteophyte formation of the condyle, together with flattening of the fossa/eminence (Figure 1). Combinations of at least these three bone changes were seen in 28 (53%) of the 53 joints with OA. Another frequent combination was articular surface flattening and osteophyte in the condyle, together with surface erosion in the fossa/eminence (Figure 2). Combinations of at least these three bone changes were seen in 19 (36 %) of the 53 joints with OA.

In the 26 joints interpreted as indeterminate for OA, 14 had articular surface flattening, 7 had subcortical sclerosis, and 5 had a combination of both subcortical sclerosis and surface flattening.

Table 3 Frequencies of CBCT-defined bone changes[a] in TMJs with OA

Bone changes	*OA joints n = 53 No. (%)*
Condylar head	
Articular surface flattening	42 (79)
Osteophyte	38 (72)
Subcortical sclerosis	37 (70)
Surface erosion	21 (40)
Subcortical cyst	8 (15)
Deviation in form	4 (8)
Loose calcified body	3 (6)
Generalised sclerosis	2 (4)
Condylar hypoplasia	2 (4)
Condylar hyperplasia	0
Bony ankylosis	0
Fossa/eminence	
Articular surface flattening	30 (57)
Surface erosion	26 (49)
Subcortical sclerosis	25 (47)
Subcortical cyst	2 (4)

CBCT, cone beam CT; OA, osteoarthritis; TMJ, temporomandibular joint.
[a]According to the comprehensive diagnostic criteria by Ahmad et al.[4]

Inter- and intraobserver agreement for the imaging assessment showed mean κ values of 0.67 (range 0.61–0.74) and 0.62 (range 0.54–0.66), respectively. When excluding the registrations of the least experienced observer, the corresponding mean κ values were 0.61 and 0.65, respectively.

Discussion

This is the first report demonstrating the CBCT characteristics of TMJ OA in a study population of elderly with hand OA. Although the individuals were recruited regardless of TMJ-related symptoms, half of the joints proved to have OA. Typically, more than one imaging sign was present, and a combination of at least three signs was seen in more than half of the OA joints. Articular surface flattening, osteophytes and subcortical sclerosis in the condyle were the most frequent signs. Thus, the imaging features were mainly characterised by bone productive changes. Since surface flattening and subcortical sclerosis are both considered indeterminate for the diagnosis, osteophyte formation was clearly the most frequent of the radiologic signs decisive for OA. This feature was evident in more than two-thirds of the OA joints (Figure 1). Surface erosions occurred consistently as small cortical irregularities (<2 mm in depth and width) and not as punched-out erosions. Both surface erosions and subcortical cysts were always seen in combination with bone productive changes. We therefore consider the radiologic features to represent a late stage of TMJ OA in accordance with previous studies, as reviewed by Hussain et al.[12] They also discussed that

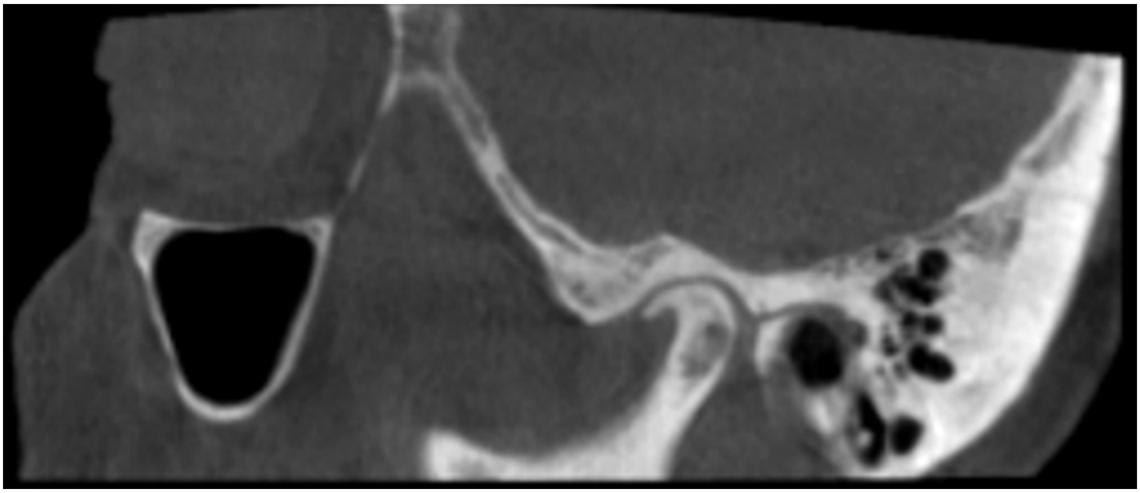

Figure 1 Female, 77 years. Oblique sagittal CBCT view shows deformed joint with condylar osteophyte and subcortical sclerosis in condyle and fossa, interpreted as osteoarthritis. CBCT, cone beam CT.

osteophytes are formed to stabilise the TMJ by repairing and broadening the joint surfaces, as shown in other joints.

The impression of a quiescent late stage of TMJ OA in the present study population was supported by clinical observations such as normal mouth opening capacity, and by the fact that only a minority had sought healthcare due to TMJ-related symptoms.[7] Clinical symptoms of TMJ OA seem to resolve after some time, except for crepitus,[13] which is consistent with the findings in the present study population.[7]

Considering the increased susceptibility of patients with hand OA to develop OA in other joints,[6] the frequency of TMJ OA in this population is expected to be high. Since no study in the general elderly population seems to be available for comparison, the figure of 67% is difficult to interpret. In a CT study of patients with generalised OA and symptomatic TMJs, 80% showed TMJ OA[14] although the mean age (63 years) was lower compared to our study group (71 years). In a population-based MRI study of a birth cohort (mean age 74.6 years) the frequency was 70%.[15] Due to differences in method and study population, the frequencies should be compared with caution. Another reason for this is the use of different diagnostic criteria. In both studies, the authors considered subcortical sclerosis as a sign decisive for OA,[14,15] in one of them also surface flattening.[15] According to Ahmad et al,[4] we did not consider subcortical sclerosis and surface flattening to be decisive for TMJ OA.

Even with the same diagnostic criteria[4] and the same imaging modality (CBCT), a substantial variation of TMJ OA frequencies, from 25.0 to 79.8% of joints, have been reported in asymptomatic individuals.[16,17] To some extent this can be explained by differences in study populations. The interpretation of image signs may also

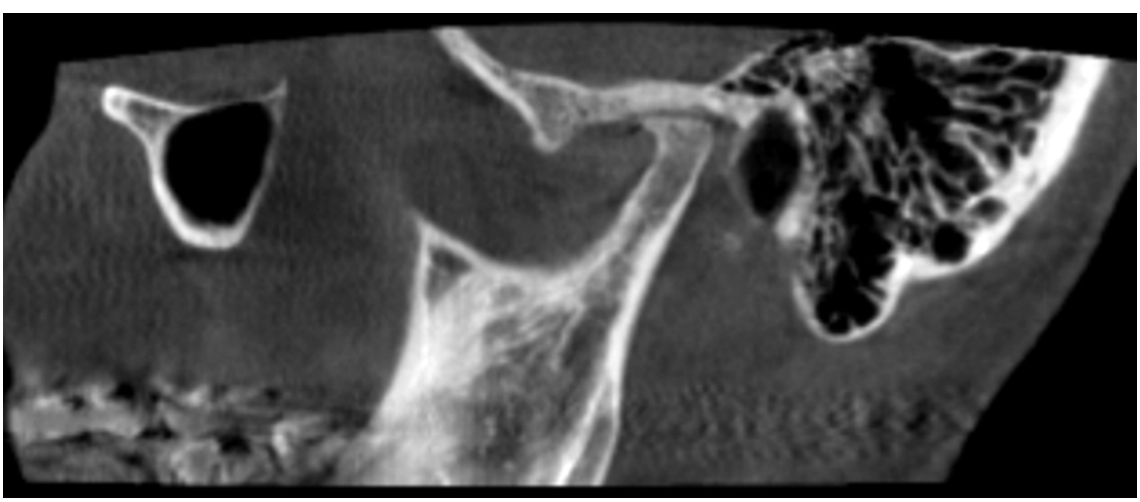

Figure 2 Female, 72 years. Oblique sagittal CBCT view shows deformed joint with surface flattening of condyle and fossa/ eminence, surface erosion and subcortical sclerosis in the fossa, interpreted as osteoarthritis. CBCT, cone beam CT.

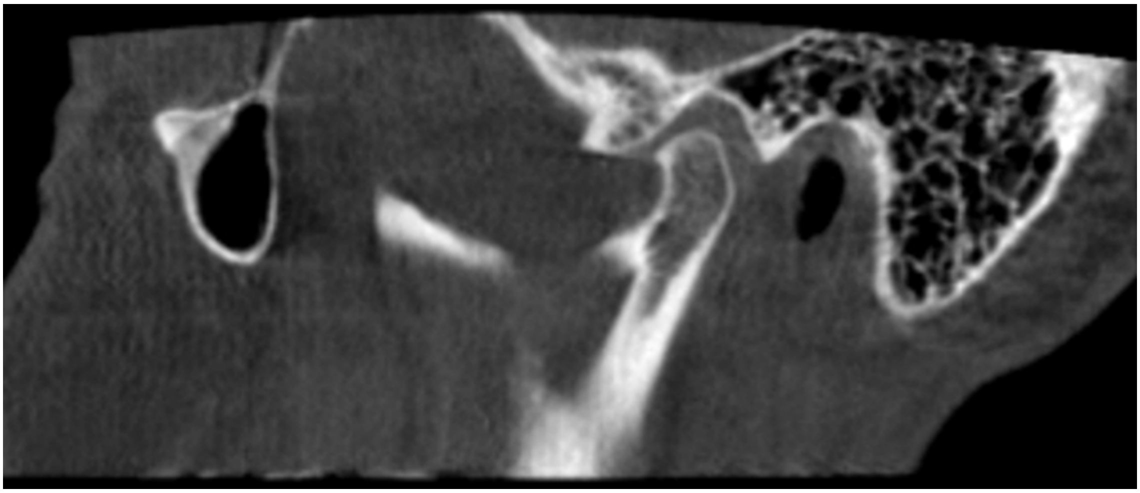

Figure 3 Female, 69 years. Oblique sagittal CBCT view shows small beaking of the anterior aspect of the condyle due to the close position of the cortical plates, interpreted as no osteoarthritis. CBCT, cone beam CT.

lead to different diagnostic results in different studies, but interpretation challenges are rarely discussed in TMJ diagnostic studies.

One specific challenge in the present study was the interpretation of a subtle beaking of the anterior aspect of the condyle *vs* a frank osteophyte (Figure 1). A flattening of the anterior slope and a pointed anterior tip of a condyle might be interpreted as an osteophyte. Assessing the presence of subcortical sclerosis/sclerotic border, which is decisive for an osteophyte according to the criteria, was the major challenge in those cases. However, in the anterior portion of the condyle, mild sclerosis can in some cases be almost impossible to differentiate from "impression of sclerosis", which may occur due to the close position of the cortical plates.[18] In our opinion, an exophytic angular formation, if very small (<1 mm) and observed as the only sign, should not be decisive for an OA diagnosis (Figure 3).Small osteophyte-like formations have been reported in asymptomatic individuals.[19,20]

Another specific challenge was the interpretation of sclerosis, which may vary considerably, from just a slightly thickened cortical plate, to a generalised sclerosis. Various degrees of sclerosis are also typical in other joints with OA.[21] We found it particularly challenging to differentiate between subcortical sclerosis, defined as "any increased thickness of the cortical plate", and generalised sclerosis, defined as "no clear trabecular orientation with no delineation between the cortical layer and the trabecular bone that extends throughout the condylar head". This differentiation is of great importance, because generalised sclerosis is decisive for OA, while subcortical sclerosis is not. We reported generalised sclerosis in only two joints. The very small number might be explained by our interpretation of the criterion. It is unclear to us how extensive a sclerosis needs to be to be classified as generalised, *i.e.* "extending throughout the condylar head".[4]

In the present study, a high number of joints were categorised as "indeterminate for OA". This is in accordance with other studies using the same criteria.[16,22] Uncertain diagnosis should be kept to a minimum in any diagnostic classification system. If only the joints with combined flattening and sclerosis had been included (Figure 4), the category "indeterminate for OA" would have dropped from 24% to about 5% in the present study population. Slight flattening could be interpreted as a normal variant. This finding is reported in one-third of TMJs in healthy adults, and is not considered a reliable indicator for OA in other joints.[23] Similarly, subcortical sclerosis, when occurring alone, could be a normal variant. However, the question is how pronounced the changes must be to be classified as disease. According to Ahmad and Schiffman,[10] flattening and sclerosis may progress to OA representing regressive remodelling, whereas non-progression would represent adaptive remodelling. Exploring flattening and sclerosis as precursors for OA development requires longitudinal follow-up of TMJs categorised as indeterminate.

Observer interpretation disagreement resulted in κ values lower than those obtained by Ahmad et al[4] although being fair to good according to Fleiss et al.[11] In the present study, there was a substantial variation in experience between the observers. Even when excluding the registrations of the least experienced observer the values were rather low. Subtle findings, challenging the differentiation between pathology and normal anatomy, were usually the cause of disagreement in interpretation. In a recent review, we emphasized that the diagnosis of OA should be based on evident, and not on subtle bone changes that may represent a normal anatomic variation or remodelling.[24] The experience from the present investigation fully support this view. Subtle bone changes are unreliable and can lead to overdiagnosis if classified as pathology.

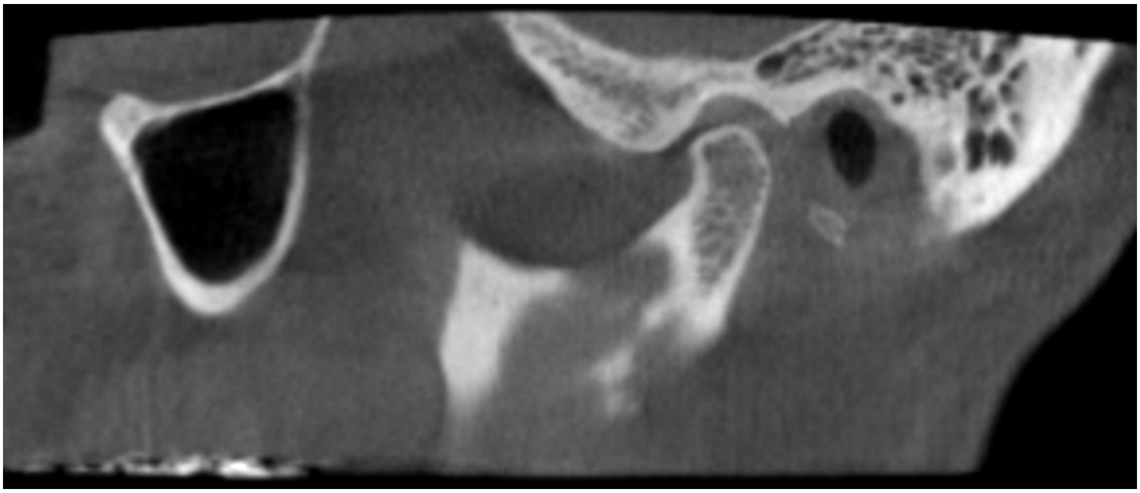

Figure 4 Female, 66. Oblique sagittal CBCT view shows condylar flattening and sclerosis in the fossa/ eminence area, interpreted as indeterminate for osteoarthritis. CBCT, cone beam CT.

The present study has some limitations. The sample size is relatively small. A larger sample size and a control group would have strengthened the reliability of the current study results. It also has to be emphasized that, to our knowledge, the grading system of OA in the TMJ proposed by Ahmad and Schiffman[10] has not been validated.

Conclusions

TMJ OA was common in elderly individuals with hand OA and characterised by bone productive changes, indicating a late stage of disease. Interpretation challenges related to subtle changes were identified and are reflected by the rather low observer agreement. The diagnosis of TMJ OA should be based on evident and clear abnormalities only.

Acknowledgment

We would like to thank the patients in the Oslo Hand OA Cohort for participating in the study. We are grateful to Dr Tore K. Kvien and Dr Ida K. Haugen at Diakonhjemmet Hospital, Oslo, for allowing us to study the TMJ OA in a sample of this cohort. We will also thank the staff at the Department of Maxillofacial Radiology, Faculty of Dentistry, University of Oslo.

Funding

This study was supported by research scholarship from the Faculty of Dentistry, University of Oslo. The source of funding had no involvement in the study design, collection, analysis and interpretation of data, in the writing of the manuscript, and in the decision to submit the manuscript for publication.

References

1. World Health Organization. *Background Paper 6.12*. Osteoarthritis: World Health Organization; 2013. http://www.who.int/medicines/areas/priority_medicines/BP6_12Osteo.pdf.
2. Berenbaum F. Osteoarthritis as an inflammatory disease (osteoarthritis is not osteoarthrosis!) *Osteoarthritis Cartilage* 2013; **21**: 16–21. doi: https://doi.org/10.1016/j.joca.2012.11.012
3. Alexiou K, Stamatakis H, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. *Dentomaxillofac Radiol* 2009; **38**: 141–7. doi: https://doi.org/10.1259/dmfr/59263880
4. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, et al. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 2009; **107**: 844–60. doi: https://doi.org/10.1016/j.tripleo.2009.02.023
5. Larheim TA, Abrahamsson AK, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. *Dentomaxillofac Radiol* 2015; **44**: 20140235. doi: https://doi.org/10.1259/dmfr.20140235
6. Hirsch R, Lethbridge-Cejku M, Scott WW, Reichle R, Plato CC, Tobin J, et al. Association of Hand and knee osteoarthritis: evidence for a polyarticular disease subset. *Ann Rheum Dis* 1996; **55**: 25–9. doi: https://doi.org/10.1136/ard.55.1.25
7. Abrahamsson AK, Kristensen M, Arvidsson LZ, Kvien TK, Larheim TA, Haugen IK. Frequency of temporomandibular joint osteoarthritis and related symptoms in a hand osteoarthritis cohort. *Osteoarthritis Cartilage* 2017; **25**: 654–7. doi: https://doi.org/10.1016/j.joca.2016.12.028
8. Slatkowsky-Christensen B, Mowinckel P, Loge JH, Kvien TK. Health-related quality of life in women with symptomatic hand osteoarthritis: a comparison with rheumatoid arthritis patients, healthy controls, and normative data. *Arthritis Rheum* 2007; **57**: 1404–9. doi: https://doi.org/10.1002/art.23079

9. Haugen IK, Slatkowsky-Christensen B, Bøyesen P, van der Heijde D, Kvien TK. Cross-sectional and longitudinal associations between radiographic features and measures of pain and physical function in hand osteoarthritis. *Osteoarthritis Cartilage* 2013; **21**: 1191–8. doi: https://doi.org/10.1016/j.joca.2013.04.004
10. Ahmad M, Schiffman EL, Disorders TJ, Pain O. Temporomandibular joint disorders and orofacial pain. *Dent Clin North Am* 2016; **60**: 105–24. doi: https://doi.org/10.1016/j.cden.2015.08.004
11. Fleiss JL, Levin B, Paik MC. *The Measurement of Interrater Agreement*. Statistical Methods for Rates and Proportions: John Wiley & Sons, Inc; 2004. pp. 598–626.
12. Hussain AM, Packota G, Major PW, Flores-Mir C. Role of different imaging modalities in assessment of temporomandibular joint erosions and osteophytes: a systematic review. *Dentomaxillofac Radiol* 2008; **37**: 63–71. doi: https://doi.org/10.1259/dmfr/16932758
13. Yadav S, Yang Y, Dutra EH, Robinson JL, Wadhwa S. Temporomandibular joint disorders in older adults. *J Am Geriatr Soc* 2018; **66**: 1213–7. doi: https://doi.org/10.1111/jgs.15354
14. Massilla Mani F, Sivasubramanian SS. A study of temporomandibular joint osteoarthritis using computed tomographic imaging. *Biomed J* 2016; **39**: 201–6. doi: https://doi.org/10.1016/j.bj.2016.06.003
15. Schmitter M, Essig M, Seneadza V, Balke Z, Schröder J, Rammelsberg P. Prevalence of clinical and radiographic signs of osteoarthrosis of the temporomandibular joint in an older persons community. *Dentomaxillofac Radiol* 2010; **39**: 231–4. doi: https://doi.org/10.1259/dmfr/16270943
16. Bakke M, Petersson A, Wiese M, Svanholt P, Sonnesen L. Bony deviations revealed by cone beam computed tomography of the temporomandibular joint in subjects without ongoing pain. *J Oral Facial Pain Headache* 2018; **28**: 331–7. doi: https://doi.org/10.11607/ofph.1255
17. Al-Ekrish AA, Al-Juhani HO, Alhaidari RI, Alfaleh WM. Comparative study of the prevalence of temporomandibular joint osteoarthritic changes in cone beam computed tomograms of patients with or without temporomandibular disorder. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2015; **120**: 78–85. doi: https://doi.org/10.1016/j.oooo.2015.04.008
18. Larheim TA, Kolbenstvedt A. High-resolution computed tomography of the osseous temporomandibular joint. Some normal and abnormal appearances. *Acta Radiol Diagn* 1984; **25**: 465–9.
19. Brooks SL, Westesson P-L, Eriksson L, Hansson LG, Barsotti JB. Prevalence of osseous changes in the temporomandibular joint of asymptomatic persons without internal derangement. *Oral Surgery, Oral Medicine, Oral Pathology* 1992; **73**: 118–22. doi: https://doi.org/10.1016/0030-4220(92)90168-P
20. Ribeiro RF, Tallents RH, Katzberg RW, Murphy WC, Moss ME, Magalhaes AC, et al. The prevalence of disc displacement in symptomatic and asymptomatic volunteers aged 6 to 25 years. *J Orofac Pain* 1997; **11**: 37–47.
21. Jacobson JA, Girish G, Jiang Y, Sabb BJ. Radiographic evaluation of arthritis: degenerative joint disease and variations. *Radiology* 2008; **248**: 737–47. doi: https://doi.org/10.1148/radiol.2483062112
22. Krisjane Z, Urtane I, Krumina G, Neimane L, Ragovska I. The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study. *Int J Oral Maxillofac Surg* 2012; **41**: 690–5. doi: https://doi.org/10.1016/j.ijom.2012.03.006
23. Kijowski R, Blankenbaker D, Stanton P, Fine J, De Smet A. Correlation between radiographic findings of osteoarthritis and arthroscopic findings of articular cartilage degeneration within the patellofemoral joint. *Skeletal Radiol* 2006; **35**: 895–902. doi: https://doi.org/10.1007/s00256-006-0111-7
24. Larheim TA, Hol C, Ottersen MK, Mork-Knutsen BB, Arvidsson LZ. The role of imaging in the diagnosis of temporomandibular joint pathology. *Oral Maxillofac Surg Clin North Am* 2018; **30**: 239–49. doi: https://doi.org/10.1016/j.coms.2018.04.001