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CBCT SPECIAL ISSUE: REVIEW ARTICLE

Temporomandibular joint diagnostics using CBCT

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The present review will give an update on temporomandibular joint (TMJ) imaging using CBCT. It will focus on diagnostic accuracy and the value of CBCT compared with other imaging modalities for the evaluation of TMJs in different categories of patients; osteoarthritis (OA), juvenile OA, rheumatoid arthritis and related joint diseases, juvenile idiopathic arthritis and other intra-articular conditions. Finally, sections on other aspects of CBCT research related to the TMJ, clinical decision-making and concluding remarks are added. CBCT has emerged as a cost- and dose-effective imaging modality for the diagnostic assessment of a variety of TMJ conditions. The imaging modality has been found to be superior to conventional radiographical examinations as well as MRI in assessment of the TMJ. However, it should be emphasized that the diagnostic information obtained is limited to the morphology of the osseous joint components, cortical bone integrity and subcortical bone destruction/production. For evaluation of soft-tissue abnormalities, MRI is mandatory. There is an obvious need for research on the impact of CBCT examinations on patient outcome.
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Introduction

CBCT examination of the temporomandibular joint (TMJ) was first reported only a couple of years after this dentomaxillofacial imaging modality was launched in the literature.[1,2] The diagnostic potential of CBCT *vs* conventional radiographic examinations was suggested in three cases of different conditions; intra-articular fractures, osteoarthritis (OA) and fibro-osseous ankylosis.[3] 3 years later, another case report indicated its value in the assessment of early and late OA, as well as hypoplasia of the TMJ.[4]

Available literature on CBCT has become extensive since then, including reviews for application to the TMJ.[5–8] The present overview will give an update on TMJ imaging using CBCT and its diagnostic value compared with other imaging modalities, with main sections on diagnostic accuracy and OA. The usefulness of CBCT in the diagnostic assessment of other TMJ conditions will be shortly reviewed. Finally, sections on clinical decision-making and concluding remarks are added.

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Diagnostic accuracy

A number of studies investigating the diagnostic accuracy of CBCT dedicated to the TMJ are available. As far as we know, the first accuracy study was published in 2005, demonstrating that CBCT provided accurate and reliable linear measurements of TMJ dimensions of dry human skulls.[9] The accuracy of CBCT in the assessment of TMJ dimensions was confirmed in a more recent study, concluding that the measurements of the joint spaces were very similar to the actual joint spaces.[10]

In 2006, it was shown that CBCT had a sensitivity of 0.80 for detecting erosions/osteophytes in an autopsy material with macroscopic observations as the gold standard.[11] In the same study, CBCT was compared with multislice or multidetector CT, hereafter called CT, and although the latter had a slightly inferior sensitivity (0.70), no significant differences were found between the two modalities. In a larger series of dry human skulls comparing CBCT with conventional (spiral) tomography in 2007, a significantly lower sensitivity was found for depicting cortical defects and osteophytes, but no significant differences between the modalities were observed.[12] Another dry skull study in the same year showed that CBCT provided superior reliability and greater accuracy than conventional (linear) tomography and panoramic radiography in depicting condylar cortical erosions.[13]

A more recent study of a dry human skull material substantiated the observation of Honda et al[11] with no significant differences between CBCT and CT for detecting surface osseous changes.[14] However, the sensitivities were found to be lower and thus in accordance with Hintze et al.[12]

The fact that CBCT has a diagnostic accuracy comparable with CT[11,14] was confirmed when assessing condylar fractures in an experimental study on sheep.[15]

The sensitivity of CBCT for assessing bone defects is dependent on the size of the defects, as demonstrated by Marques et al[16] and confirmed by Patel et al[17] in their investigations of simulated condylar lesions. Extremely small defects, that is, <2 mm, proved to be difficult to detect,[17] although the sensitivity for detecting condylar osseous defects overall was fairly high: 72.9–87.5%. These measurements corroborated those reported by Marques et al,[16] but they substantially exceeded those reported by Hintze et al,[12] who investigated morphological changes such as condylar flattening and osteophytes. It is thus suggested that erosion of the condylar surface may be easier to detect from CBCT images than other morphologic changes.[17]

The diagnostic accuracy of erosive changes in the TMJ has been shown to be influenced by the imaging protocol in some studies[17,18] but not in others.[19,20] Dry human skulls were scanned with large view and standard view protocols by Zhang et al,[19] who found no significant difference between the examinations for the presence or absence of defects on the surface of the condyles. Both scanning protocols were reliable, with areas under the receiver operating characteristic curves being 0.739 and 0.720, respectively. Since the large view protocol had an effective radiation dose of only about one-sixth of the standard view protocol, the large view protocol was recommended for the assessment of TMJ conditions.[19]

In another study by the same authors using the same *in vitro* material, no significant differences were found, neither with normal nor high resolution.[20] However, they also concluded that the accuracy of detecting condylar defects highly depends on the CBCT unit used for examination. Comparing different fields of view, 12, 9 and 6 inches with voxel sizes of 0.4, 0.3 and 0.2 mm, respectively, the highest diagnostic efficacy for depicting condylar erosions was found with the smallest field of view.[18] In another study comparing CBCT scans with different voxel sizes (0.4 and 0.2 mm) for assessing simulated defects in fresh pig mandibular condyles, the sensitivity improved significantly for small (but not for large) defects with the increase of scanning resolution.[17] Approximately one out of three small defects (both diameter and depth <2 mm) might be missed from diagnosis when using 0.4-mm voxel size CBCT scans. Using a higher scan resolution (0.2-mm voxel size), the defects, regardless of size, were detected with >80% sensitivity.[17]

Also in this study, it was emphasized, supporting the study by Zhang et al,[20] that the data obtained with a particular CBCT scanner cannot automatically be applied to other CBCT scanners.

An interesting study compared conventional tomography, CT and CBCT with micro-CT and microscopic observations and concluded that CBCT most accurately depicted erosive changes of the bone cortex of the mandibular condyle. The high detectability of CBCT images on bone morphology of mandibular condyles was confirmed.[21]

In summary, CBCT in general has an acceptable accuracy for diagnosing osseous TMJ abnormalities with fairly high sensitivity, although small abnormalities might be missed. However, there are differences between different CBCT scanners and imaging protocols. In most studies, high specificity is reported. The diagnostic accuracy of CBCT seems to be comparable with CT for TMJ diagnostics.

Observer variation has been studied by several authors and in general seems to be acceptable. The observer agreement may be higher with smaller fields of view, and observers are also influenced by the size of bone defects. The smaller the defect, the more difficult its identification will be, with a lower percentage of observer agreement.

Osteoarthritis

The most common joint disease that may occur in any joint, including the TMJ, is OA. Earlier it was primarily considered a non-inflammatory disease,[22] but newer research on OA in general has demonstrated that this is an inflammatory condition involving all components of the joint.[23–25] Therefore, in the present review, we use the term OA in accordance with its use in medical literature, in a comprehensive, interdisciplinary textbook on temporomandibular disorders (TMDs)[26] and in a comprehensive article on image analysis related to research diagnostic criteria/TMD.[27] It should be mentioned that degenerative joint disease, osteoarthrosis and OA all are terms applied in the newly revised diagnostic criteria/TMD.[28,29]

Other imaging modalities have long been used for osseous evaluation of the TMJ, as reviewed by Larheim.[30] CT was found to be superior to hypocycloidal tomography for evaluating bone details in patients with rheumatic TMJ disease.[31] A systematic review, however, concluded that CT did not add any significant information to what was obtained with conventional tomography regarding erosions and osteophytes.[32] CT has also been compared with MRI for the assessment of cortical bone abnormalities in an autopsy study, concluding that CT was the superior modality.[33] This was substantiated in a clinical study comparing CBCT and MRI.[34] From these comparison studies and the accuracy studies in the previous section, it is clear that CBCT and CT are highly comparable regarding evaluation of the cortical bone. Thus, CBCT or CT is the method of choice, depending on the availability, for the assessment of cortical bone details of the TMJ because of the multiplanar reformation capabilities and high spatial resolution. This was also the conclusion made by Ahmad et al[27] in their comprehensive investigation of image criteria for TMJ OA, comparing CT, MRI and panoramic radiography. Moreover, they found that interobserver agreement of calibrated observers was close to excellent for CT and only fair for MRI using kappa statistics. With comparable accuracy and observer agreement the dose- and cost-effective modality, *i.e.* CBCT, should be preferred. However, CBCT is more sensitive to patient motion than CT, making the diagnostic assessment of small cortical abnormalities uncertain (Figure 1).

CT signs of TMJ OA were reported early in the 1980s,[35] and CT criteria for the diagnosis were suggested by Koyama et al.[36] Comprehensive and well-defined image criteria for OA were given by Ahmad et al[27]; *osteophyte*: marginal hypertrophy with sclerotic borders and exophytic angular formation of osseous tissue arising from the surface; *subcortical sclerosis*: any increased thickness of cortical plate in load-bearing areas relative to adjacent non load-bearing areas; *subcortical cyst*: a cavity below the articular surface that deviates from normal marrow pattern; *surface erosion*: loss of continuity of articular cortex; *articular surface flattening*: a loss of the rounded contour of the surface; and *generalized sclerosis*: no clear trabecular orientation with no delineation between the cortical layer and the trabecular bone that extends throughout the condylar head. Although these definitions are made for CT images, they are equally valuable for CBCT images.

No attempts were made to grade the extent of OA by Ahmad et al.[27] Another challenge is the differentiation between morphological variations of normalcy and small pathological changes such as between subtle "beaking" of the anterior aspect of the condyle and small osteophyte (Figure 2).

For other joints in the body, the image appearance of OA is characterized by joint space narrowing and bone proliferation, that is, osteophyte formation and bone sclerosis, as well as subchondral cysts. Erosions are not typical[37] but may be found, such as in knee OA.[38,39]

OA in the TMJ is also characterized by bone proliferation, but erosion is a feature as well,[36,40–42] as illustrated in Figure 3. If bone destruction is prominent with little

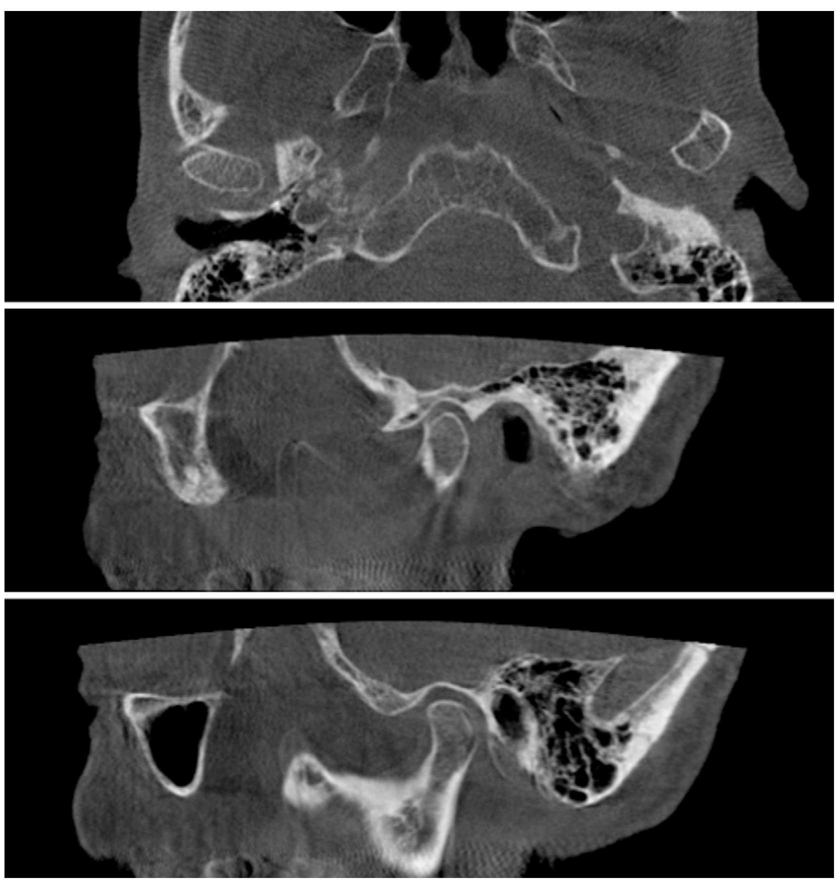

Figure 1 CBCT of normal temporomandibular joint with motion artefact simulating osteophyte and remodeling (double contour) (female, 75 years).

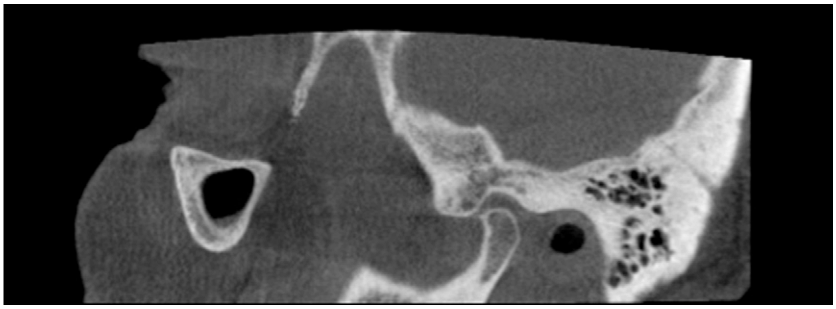

Figure 2 CBCT of beaking of anterior aspect of condyle—remodeling or small osteophyte? (female, 61 years).

or no bone proliferation, the diagnosis will be erosive OA.[43] Such a condition can hardly be distinguished from rheumatoid arthritis (RA) or another inflammatory arthritis.

Joints with articular surfaces that were smooth in outline and with some flattening and/or sclerosis were interpreted as indeterminate for OA by Ahmad et al.[27] The present authors have experience with CT of healthy volunteers demonstrating areas of idiopathic sclerosis that actually can be quite obvious.[43] Thus, sclerosis should be interpreted with caution if it is not occurring on articulating surfaces or together with other signs indicating pathology. Joints with a condylar shape that clearly deviate from the rounded "normal" appearance but with a smooth cortical outline without evidence of osteophyte, sclerosis, subchondral cyst or erosion and with a rather even thickness of the cortical plate, may present a diagnostic challenge. Preferably, they should be interpreted as remodelled or deformed, particularly in young patients. Such a deformed joint may be the result of previous trauma or, as reported by Arvidsson et al,[44] juvenile idiopathic arthritis (JIA) (Figure 4).

Several investigations on CBCT-assessed OA in the TMJ are available. The first large series of patients (mean age, 48 years) appeared in 2009 and demonstrated that both the frequency and severity of OA was related to age.[45] This is well-accepted knowledge from OA research. The most common radiographic findings were flattening, erosion and osteophyte, followed by sclerosis. In another study, sclerosis and erosion were most frequently observed, followed by flattening.[46] In that study of 220 patients aged 11–78 years (mean, 29 years), only 1 kind of condylar change was observed in 27% (119 of 440 joints), 2 kinds in 15% and 3 kinds in 12%. Only a few joints had more than three kinds of condylar change. The most frequently observed change (68% of the joints) was posterior position of the condyle in fossa. The author concluded that with more widespread use of CBCT, more specific or detailed guidelines for OA are needed.[46]

In a series of 319 patients aged 10–89 years, 227 (71%) had bone changes consistent with OA.[47] The prevalence increased with age (except in the oldest age group with few patients) and females had a greater pre-disposition, in accordance with the general view on OA.

One study investigated the relationship between pain and other clinical signs and symptoms, and CBCT assessed OA and found poor correlation.[48] This is also in accordance with the generally accepted view. On the other hand, the clinical dysfunction index proposed by Helkimo[49] was highly correlated with CBCT-assessed TMJ OA but not with joint space changes.[50]

A case report of osteonecrosis of the mandibular condyle demonstrated in a follow-up that a primary subchondral osseous breakdown of the condyle developed into secondary articular surface collapse and OA.[51] This supports the view that osteonecrosis in the bone marrow can be a precursor of TMJ OA, similar to other joints.[52]

TMJ OA has also been investigated in asymptomatic patients with different dentofacial deformities showing that those with skeletal jaw discrepancies (in particular Class II patients) more frequently demonstrated OA than those without jaw discrepancies.[53]

In patients with OA, investigations using three-dimensional (3D) shape analysis have been performed. Quantification of 3D surface models of mandibular condyles in patients with TMJ OA and in asymptomatic

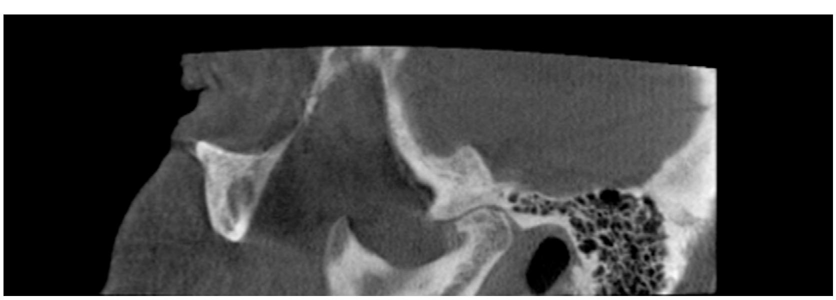

Figure 3 CBCT of osteoarthritis: osteophyte, sclerosis, flat articular surfaces, erosion and possible subchondral cyst (female, 68 years).

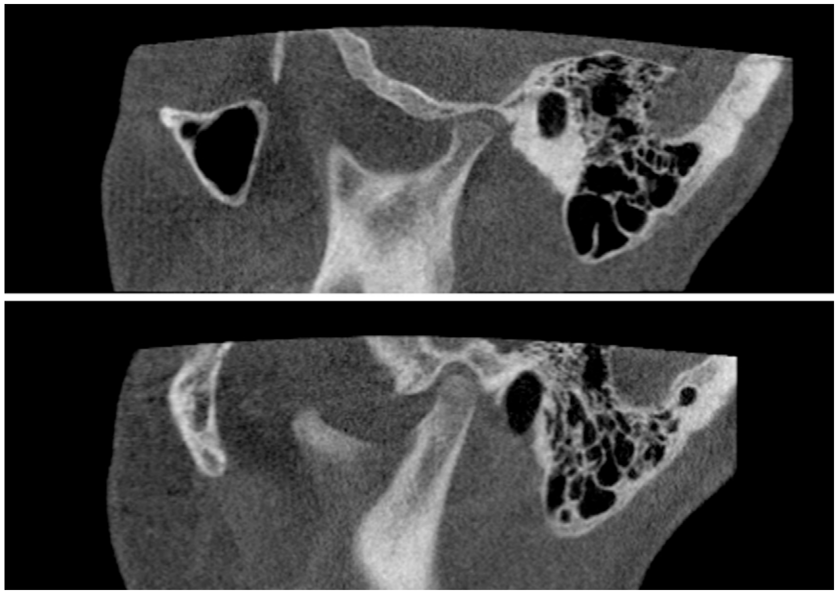

Figure 4 CBCT of juvenile idiopathic arthritis (female, 13 years): deformed (remodelled) right joint: rather flat fossa/eminence and condyle, without cortical erosion (upper) and normal left joint for comparison (lower).

subjects revealed significant differences.[54] It was even suggested that the extent of resorptive changes paralleled pain severity and duration. In another study of the same group, it was found that 3D shape analysis measurements of data simulated 3- and 6-mm defects on the surface of 3D models of condyles had an acceptable accuracy. Thus, 3D shape analysis could be applied in a longitudinal clinical study of TMJ OA in patients undergoing jaw surgery.[55]

Two studies have investigated the thickness of the roof of the glenoid fossa by CBCT in symptomatic patients with TMD, one with and the other without TMJ OA. The study without OA showed that the thickness did not correlate with condylar morphology, gender and age of the patients.[56] In the other study, the thickness did correlate with the presence of OA.[57]

Juvenile osteoarthritis

Although OA traditionally affects adults and elderly people, the TMJ may be also affected in adolescents and children (Figure 5). As mentioned by Nickerson and Boering[58], the condition was referred to as arthrosis deformans juvenilis by Boering in 1966. He found condylar abnormalities and mandibular growth disturbances in patients below 20 years of age without any suspicion of sequel from trauma. Various terminology has been applied to the paediatric age group similar to in adults; degenerative arthritis, degenerative joint disease, osteoarthrosis and OA.[59–61] In our opinion, juvenile OA (JOA) would be an appropriate term today, and this term is consistently used in the present text. The condition might potentially have an effect on mandibular growth and lead to facial deformity.[60,62,63]

Although radiographic studies are sparse, different imaging modalities have been applied to assess JOA: plain films,[59] conventional tomography[60] and MRI.[62,63] However, CT studies have rarely been carried out,[64] and only a few CBCT studies on JOA are available. After an early case report,[65] two larger studies have been published.[61,66] Cho and Jung[61] studied JOA in 282 children and adolescents aged 10–18 years and found that the prevalence was higher in the 181 symptomatic (26.8%) than in the 101 asymptomatic (9.9%) patients. In the other study of 386 patients with TMD aged 10–19 years and 339 asymptomatic pre-orthodontic patients with

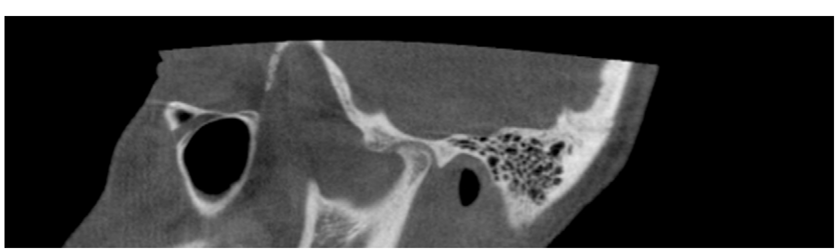

Figure 5 CBCT of juvenile osteoarthritis: deformed (remodelled) joint: osteophyte, sclerosis and cortical erosions (female, 13 years).

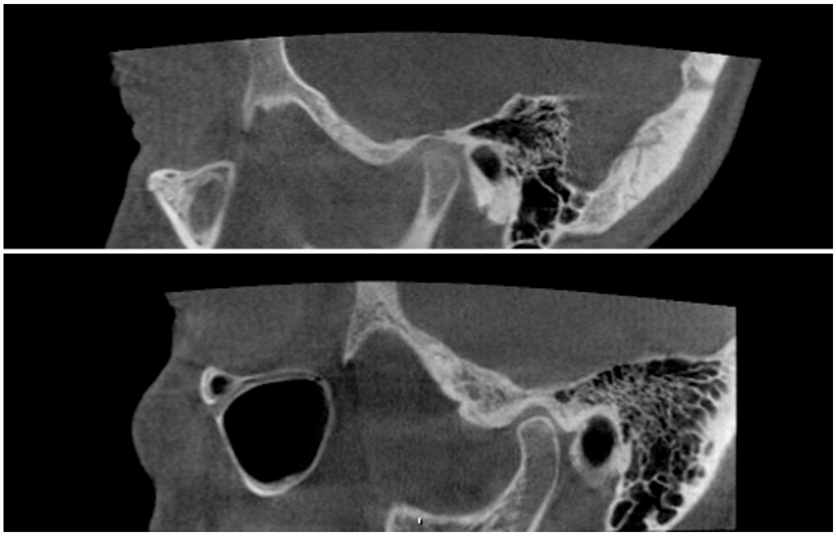

Figure 6 CBCT of normal temporomandibular joint (?): non-compact, non-homogeneous cortical surface of condyle (upper), making diagnostic assessment uncertain (female, 13 years). Normal compact and homogeneous cortical outline of condyle (lower) for comparison (female, 69 years).

malocclusions as controls, Wang et al[66] confirmed the high occurrence of JOA, which was significantly higher in the TMD group (40.7%) than in the control group (12.1%). In both studies, the occurrence of juvenile TMJ OA was higher in females than in males in the patient groups, but there were no differences between the genders in the control groups.

In another CBCT study of young asymptomatic post-orthodontic subjects aged 12–20 years, Ikeda and Kawamura[67] investigated the position of the condyle in the fossa and found a correlation to the position of the disc on MRI.

The condylar position and its clinical significance have been and still are a controversial subject that has attracted much attention. Many variables will influence the condylar position when CBCT is used for the TMJ examination and one should be careful to use the joint space as a diagnostic criterion, at least as the only criterion. Even in healthy children, the TMJ space is frequently asymmetric.[68]

In young individuals, the evaluation of the cortical bone is a greater challenge than in adults because the cortical bone will not necessarily be continuous and compact. In a CBCT study, it was concluded that the cortical bone begins to form around the periphery of the condyle during adolescence: 12–14 years.[69] A continuous, homogeneous and compact cortical bone layer of the articular surface is established in young adults by the age of 21–22 years, indicating full development of the mandibular condyle.

When examining young patients, keeping a low dose is preferable. CBCT can be applied with very low exposure, and images obtained with only 2 mA can be acceptable for certain diagnostic tasks (Figure 4). However, more noisy images combined with the lack of a continuous and compact cortical layer can make the assessment of articular surfaces uncertain (Figure 6).

Bone changes in the TMJ can indicate disease (OA) and/or a remodelling process. The boundary between these conditions can be difficult to determine, especially in growing individuals where the TMJ is undergoing morphological changes. Subtle JOA may be neglected, missed or even over diagnosed.

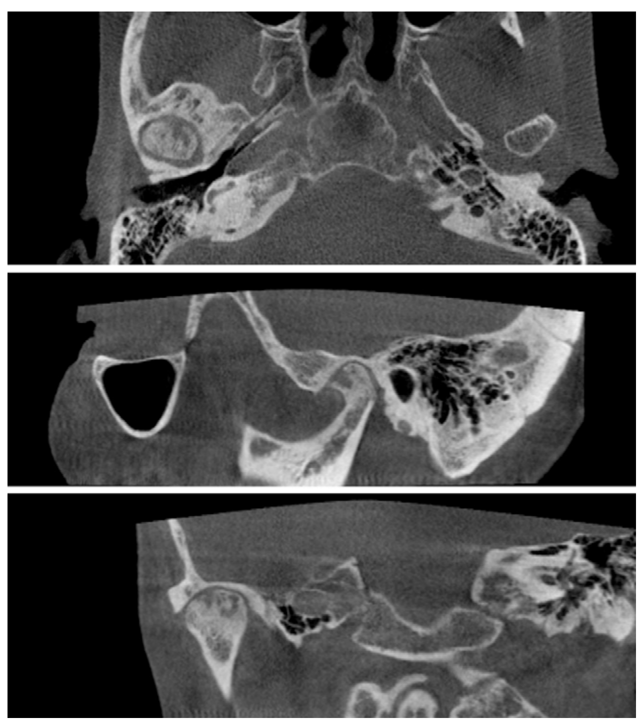

Figure 7 CBCT of rheumatoid arthritis: punched-out destruction with sclerosis (female, 59 years).

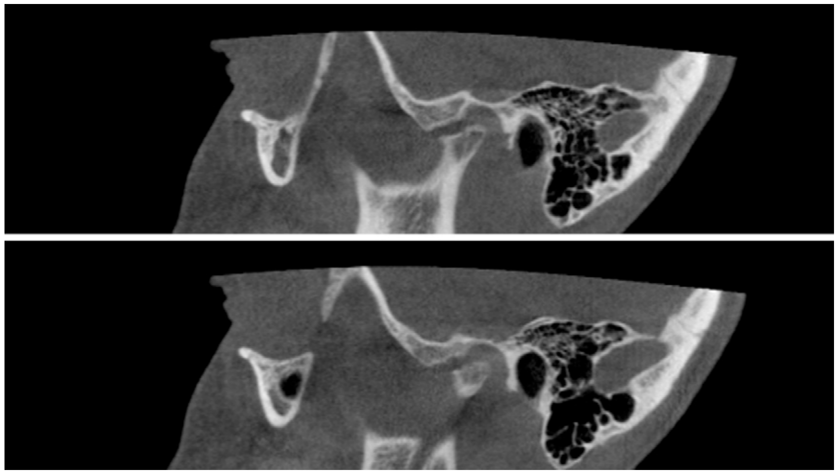

Figure 8 CBCT of juvenile idiopathic arthritis: deformed (remodelled) joint with surface erosions: flattened condyle with enlarged anteroposterior dimension and double contour. Articular eminence also flattened (female, 16 years).

Rheumatoid arthritis and related joint diseases

For joints in general, the hallmark of inflammation in bone as assessed from plain images and CT, is the cortical erosion (destruction).[70] Thus, erosions without bone proliferation indicate inflammatory arthritis, that is, RA, which is the most frequent rheumatic disease. Multiple erosions with bone proliferation may indicate ankylosing spondylitis or psoriatic arthritis, or other seronegative spondylarthropathies.[70] In the TMJ, it is not possible to differentiate between rheumatic diseases based on imaging, although the bone production seems to be more pronounced in ankylosing spondylitis; most of our TMJ ankylosis cases are in this disease group.

Typical findings in rheumatic patients with active TMJ arthritis are punched-out bone destructions (erosions), which may become quite severe (Figure 7). Both the condyle and the fossa/eminence can be involved. Osteoarthritic signs may accompany the destruction. In long-standing disease, flattening and bone-productive changes (sclerosis, osteophyte) may be more evident and the cortical erosions less pronounced. In such cases, the differentiation between OA and inflammatory arthritis with secondary OA may be impossible with CBCT used as the only imaging modality. It is the experience of the present authors that the destruction/deformation may be more pronounced in patients with a rheumatic disease.

Little research on CBCT and RA is available. Hajati et al[71] found that a majority of patients with early RA showed radiographic signs of bone destructions in the TMJ, and that plasma levels of glutamate were associated with the extent of these changes.

Juvenile idiopathic arthritis

Rheumatic disease may also occur in childhood, and JIA is the most frequent inflammatory musculoskeletal disease in patients younger than 16 years of age. TMJ affection may lead to typical facial growth deformities.[72,73] Most large studies of children with JIA indicate that nearly half of the children will have radiographical TMJ abnormalities, although MRI studies with fewer patients have shown much higher frequencies.[74] The joints are characterized by deformation and may show a highly variable morphology.[44] Flattening of the condyle and fossa/eminence and widening of the fossa as well as the condyle anteroposteriorly

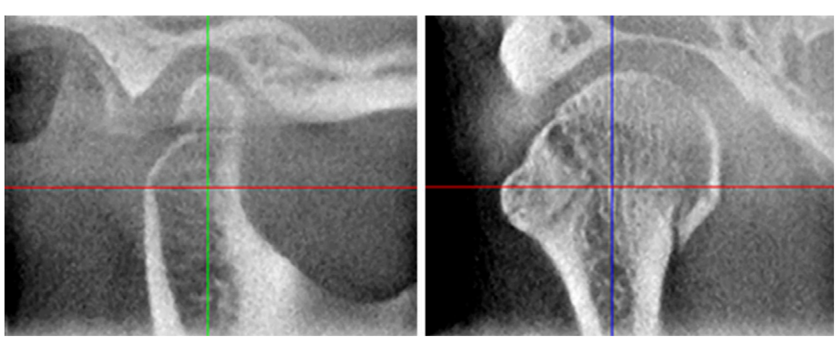

Figure 9 CBCT of intra-articular fractures. Reproduced from Larheim and Westesson[91] with permission from Springer.

Figure 10 CBCT of developmental anomaly, probably hemifacial microsomia (male, 8 years). Abnormal condyle morphology and condyle location, lack of fossa/eminence development and enlarged coronoid process (upper, middle). For comparison, normal contralateral joint (lower).

are typical findings (Figure 8). Without bone erosions, the deformations may be considered growth disturbances of the joint (Figure 4) or a result of previous erosions with subsequent remodelling/"healing".[44] Erosions may be present in active periods of the disease but should not be confused with non-homogeneous and non-compact cortex of the condyle seen in healthy growing children.[69] It is well known that symptoms and clinical signs of TMJ involvement may be subtle, making imaging an important diagnostic tool.[75–77]

Some CBCT studies of patients with JIA are available. A clinical evaluation according to the research diagnostic/TMD criteria[78] revealed only a few of the patients with JIA with TMJ bone abnormalities on CBCT.[79] CBCT was used to measure condylar volume or 3D asymmetry in patients with JIA.[80,81] It was also applied to patients with unilateral TMJ involvement undergoing splint therapy to reduce the mandibular asymmetry.[82] A grading system for TMJ JIA has recently been suggested, using a combination of CBCT and MRI findings.[83]

Other intra-articular disorders

CBCT was applied in a series of 34 cases of osteochondroma of the mandibular condyle,[84] and in a case report,[85] both studies emphasized the value of 3D reconstructions when viewing expansive lesions. The imaging modality has also been applied to a series of 27 cases with facial asymmetry and condylar hyperplasia.[86] In addition, reports of cases have been published, such as synovial chondromatosis,[87,88] fibrous ankylosis in RA[89] and metastasis of a bronchial carcinoma.[90] Similar rare conditions have been illustrated in previously mentioned review articles,[5,6] which also showed trauma and developmental cases. Condylar fractures can be nicely demonstrated with CBCT (Figure 9) and so can developmental anomalies (Figure 10). In patients with facial deformities, both the TMJ and the facial skeleton abnormalities can be visualized with CBCT scanning, depending on the field of view.

Miscellaneous

Several investigations using 3D analysis of the mandibular condyle are available. The volume and surface of condyles from young adult subjects without pain or TMD have been reported as values of normal TMJs for future 3D comparative studies.[92] The reliability of regional 3D registration and superimposition methods for the assessment of mandibular condyle morphology, across subjects and longitudinally, has been found to be acceptable.[93] The authors claim that subtle bony differences in 3D condylar morphology can be quantified. The method was applied to assess changes in condylar 3D morphology in patients who underwent maxillomandibular advancement with and without simultaneous disc repositioning. Those with disc repositioning showed evident condylar bone apposition, in contrast to those with maxillomandibular advancement without disc repositioning.[94]

The normal standards for position of the mandibular condyle in the fossa has also been investigated. The condylar position was assessed in asymptomatic subjects both in oblique sagittal images[95] and in oblique coronal and axial images,[96] providing norms for 3D assessment in healthy individuals.

Pneumatization of the temporal bone may be a diagnostic challenge for the assessment of cortical erosions in the articular eminence if they reach the articular surface, and CBCT is the superior method to depict such anatomic variations.[97]

CBCT has been applied in the evaluation of bifid mandibular condyles,[98,99] coronoid hyperplasia[100] and articular eminence morphology[101–103] and to assess condylar remodelling accompanying splint therapy.[104]

The superior semi-circular canal of the vestibulum system was investigated in patients with TMJ symptoms suggesting a possible relationship between a specific morphological pattern; the dehiscence of its roof and symptoms.[105] The maxillofacial radiologist should be aware of this anatomic structure.

A method based on the registration of single-plane fluoroscopy images and 3D low-radiation CBCT data has also been proposed to quantify 3D mandibular motion (TMJ and chewing function).[106]

CBCT has also been found useful as an image-guided technique for safe puncturing of the superior TMJ space.[107] This procedure proved effective for pain mitigation and improved mouth opening during the early post-operative period after pumping manipulation treatment.[108]

Clinical decision-making

Although the literature on TMJ diagnostics using CBCT has become rather extensive, the current available data seem to be limited to the first two levels in the six-stage framework to assess the efficacy of imaging methods as defined by Fryback and Thornbury:[109] technical efficacy and diagnostic accuracy efficacy. Little attention has been paid to the next two levels, diagnostic thinking efficacy and therapeutic efficacy. This is particularly important in the evaluation of patients with TMD, being the largest group of patients undergoing TMJ imaging procedures.

To the best of our knowledge only one study has focused on the value of CBCT examinations in clinical decision-making; primary diagnosis and management of patients with TMD. The clinical decision changed in more than half of the patients when it was based on physical, panoramic and CBCT examinations compared with a decision based on physical and panoramic examinations only.[110] Thus, the usefulness of CBCT in patient management was clearly demonstrated.

Concluding remarks

In a relatively short period of time, CBCT has emerged as a cost- and dose-effective alternative to CT for examination of the TMJs, although it may be more sensitive to motion artefacts. The imaging modality is superior to conventional radiographic methods, as well as MRI, in the assessment of osseous TMJ abnormalities. However, it should be emphasized that the diagnostic information obtained is limited to the morphology of the osseous joint components, cortical bone integrity and subcortical osseous abnormalities. For the assessment of inflammatory activity and soft-tissue abnormalities such as internal derangement in patients with TMD, MRI is the method of choice. There is a lack of knowledge about the impact of CBCT examinations on patient outcome and thus an obvious need for research in this area.

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