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TECHNICAL REPORT

Radiographic examination of the temporomandibular joint using cone beam computed tomography

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Cone beam CT (CBCT) is a new technique for maxillofacial imaging. We describe a reconstruction technique for radiographic examination of the temporomandibular joint (TMJ) using CBCT, and we further present four cases where the technique was employed. The technique provides a complete radiographic investigation of the bony components of the TMJ. The reconstructed images are of high diagnostic quality. The examination time is shorter and the patient dose is lower than that with conventional CT. It may therefore be considered as the imaging technique of choice when investigation of bony changes of the TMJ is the task at hand.
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Introduction

Although the use of computed tomography (CT) as a diagnostic tool has been an indispensable routine in medicine for many years, its application in dentistry has taken slower steps. This was mainly due to the rather high cost of the equipment, the large space required for its operation and the high dose of radiation involved. The use of CT results in significantly higher absorbed doses compared with panoramic radiography and linear tomography. It has therefore been of great concern whether the superiority of CT outweighs the biological risks for the patient;[1–3] nevertheless, the number of CT examinations in dentistry has rapidly increased in recent years. CT scans are now widely used for the examination of pathological conditions and trauma in the maxillofacial region, in presurgical implant treatment planning and the assessment of the temporomandibular joint.[4–7] One of the reasons for this is the development of new techniques, such as spiral CT and cone beam CT (CBCT). These techniques allow the use of a shorter scanning time whilst the radiation dose is up to six times lower compared with conventional CT scans.[8–10]

CBCT, also known as volumetric CT (VCT), uses a cone-shaped X-ray beam instead of the collimated fan beam used with spiral CT. The tube-detectors system performs a 360° rotation around the head of the patient using a constant beam angle. This rotation produces the initial data, the so called raw data, which are presented as a lateral tomogram. The raw data are used for primary reconstruction. The options for the thickness of the layers to be reconstructed are 0.3 mm, 1.0 mm, and 3.0 mm, and the reconstruction angles are determined by the clinician. The primary images can be used for further secondary reconstructions in all planes and for three-dimensional (3D) reconstructions.

In a recent report, CBCT images of four cases were presented.[11] However, there are no reports on the techniques that can be used for reconstruction of the raw data. In this report we describe the reconstruction technique used routinely in our clinic for radiographic examination of the temporomandibular joint (TMJ) using CBCT, and we further present four cases where the technique was employed.

The reconstruction is oriented according to the individual angle of the condyle to ensure imaging of the true condyle position in the fossa. It has been shown that images of improved diagnostic quality can be obtained when the reconstructed images are parallel or perpendicular to the long axis of the condyle.[12–14]

Reconstruction technique

The reconstruction technique introduced in this report results in obtaining lateral and coronal CBCT images as well as 3D reconstructions of the TMJ (Figure 1).

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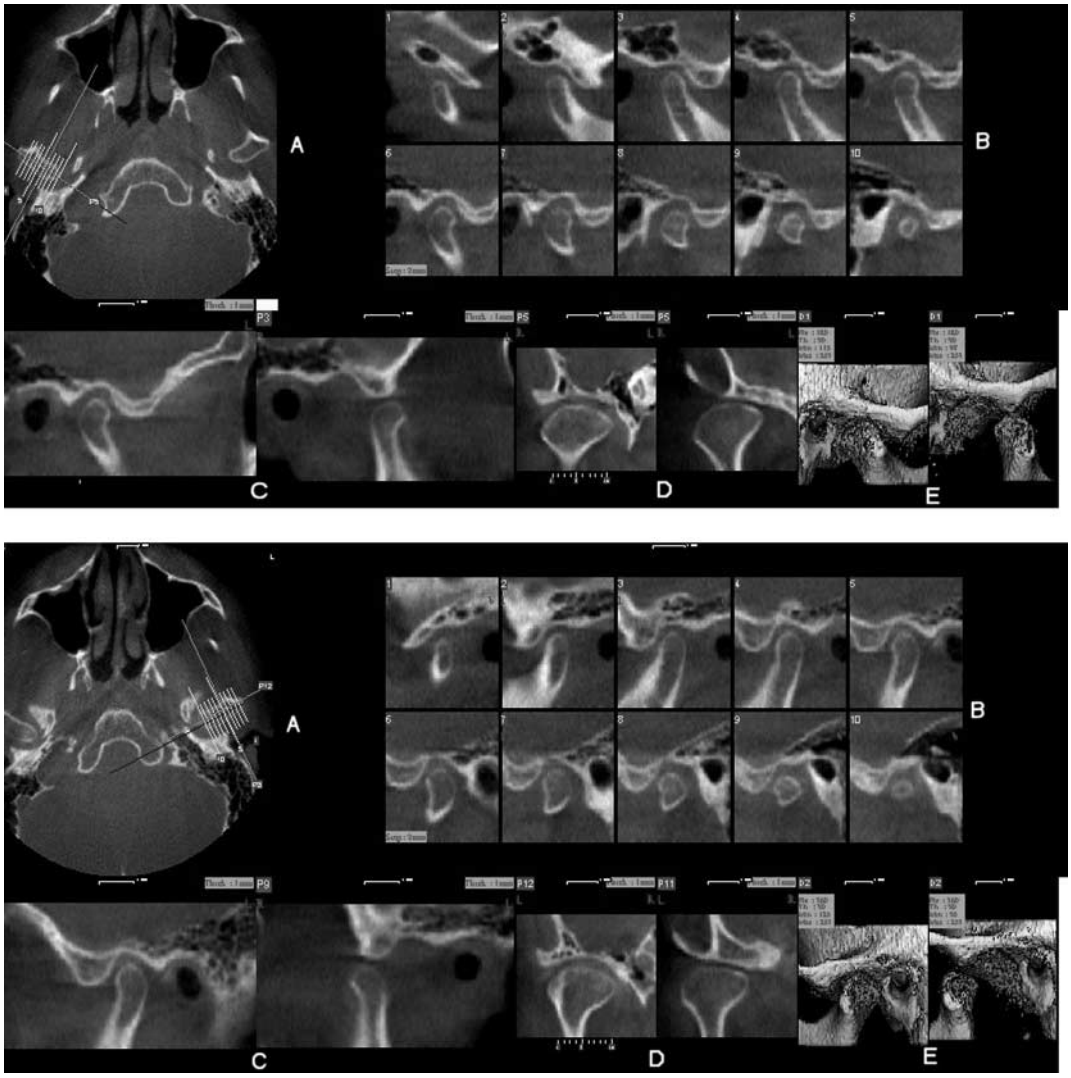

Figure 1 Film layout of a typical examination of the right and left temporomandibular joint. (a) Axial image, (b) lateral images perpendicular to the long axis of the condyle (closed mouth), (c) central lateral images (closed and open mouth), (d) coronal views parallel to the long axis of the condyle (closed and open mouth) and (e) three-dimensional reconstructions (closed and open mouth)

The technique is used with a CBCT scanner (NewTom Model QR-DVT 9000, Verona, Italy) operating with a maximum output of 110 kV and 10 mA, with 0.7 mm Al-equivalent filtration and a standard 14° cone beam angle. The patient is placed in a supine position with the head within the circular gantry housing the X-ray tube and the detectors. Accurate positioning of the head is facilitated by the use of two light-beam markers. The vertical positioning light must be aligned with the mid-sagittal line of the patient, which helps keep the head of the patient centred with respect to the rotational axis. The lateral positioning light is centred at the level of the condyles, indicating the optimized centre of the reconstruction area. The X-ray tube–detectors system performs a 360° rotation around the head of the patient. Scanning time is 76 s and the output is automatically adjusted during the 360° rotation according to tissue density, the so called "smart beam technology".

If the range and type of movement of the condyle needs to be assessed, a second scanning of the patient takes place. The scanning procedure is the same only with the patient's mouth open. A bite block can be used to keep the mouth wide open.

When acquisition of the second raw data is completed, the patient may leave the examination room and the clinician is able to perform the primary reconstruction. The area of interest, in this case the TMJ, is defined and the software automatically generates a series of axial slices of 1 mm thickness (Figure 2).

One of the axial views is used as a reference view for secondary reconstruction. To orient the reconstruction according to the individual angle of the condyle, a line is traced that corresponds to the long axis of the examined condyle. This line also defines the most distal and medial point on the condyle that the secondary reconstruction will cover (Figure 2b). The software then generates lateral slices perpendicular to the long axis of the condyle. The lateral views are reformatted images perpendicular to the plane of the axial views. Depending on the size of the

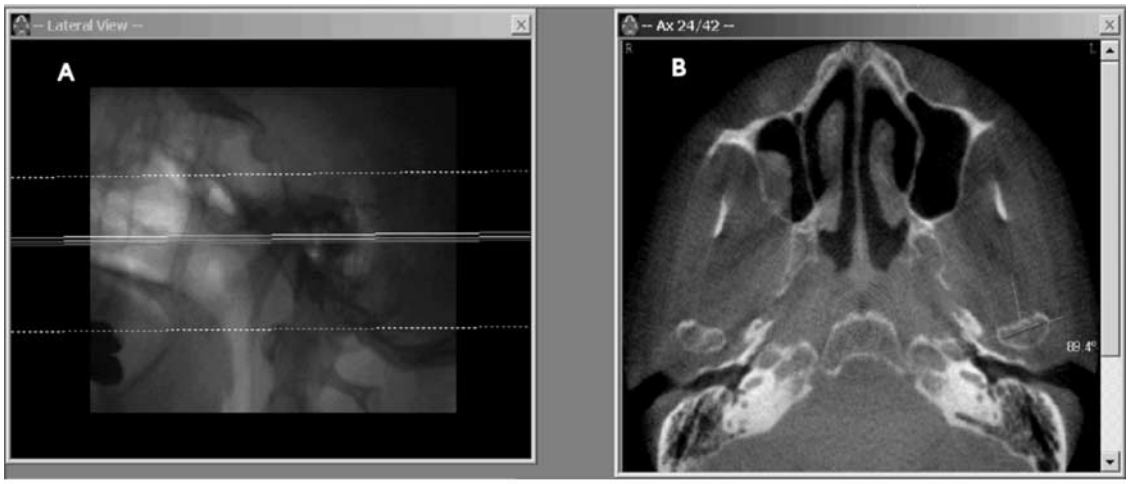

Figure 2 (a) The area of interest (*e.g.* temporomandibular joint) is defined on the raw data. (b) Axial image resulting from the primary reconstruction. The user traces a line that corresponds to the long axis of the examined condyle, defining simultaneously the most distal and medial point that the secondary reconstruction will cover

condyle, eight to ten lateral views can be obtained, spaced 2 mm apart, thus covering the defined region of interest from the lateral to the medial pole (Figure 1b).

In addition, since the centre of the condyle is defined during the previous steps, the lateral slice that corresponds to this central point is used as a reference lateral view, revealing the true position of the condyle in the fossa (Figure 1c).

The third step of the technique involves reconstruction of images parallel to the long axis of the condyle, leading to the acquisition of coronal slices of 2 mm thickness (Figures 3 and 1d). The software also provides the option for 3D reconstruction (Figure 1e).

In the open-mouth position the same procedure described above is performed. Central lateral and coronal views are generated as well as 3D reconstruction images of the condyle, which is normally positioned in this case slightly over the tubercle, often resulting in better visualization of its body (Figures 1c–e).

Case reports

Case 1

A 28-year-old female was referred complaining of headaches, clicking during mouth opening and painful

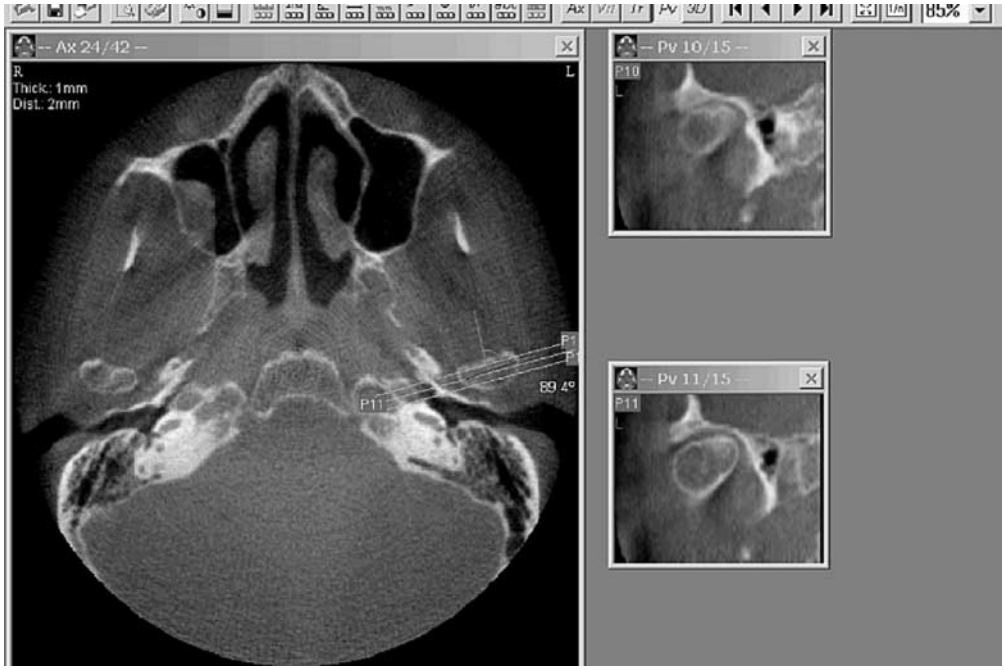

Figure 3 Reconstruction of axial slices parallel to the long axis of the condyle; production of coronal slices of 2 mm thickness

muscles on palpation. The lateral views revealed a normal radiographic appearance of the articular surfaces, a centre condyle position in the fossa as well as normal joint space (Figure 4). The final diagnosis was myofascial dysfunction.

Case 2
A 48-year-old female presented with TMJ pain and crepitus. The reconstructed lateral and coronal images revealed signs of early degenerative arthritis, namely condyle flattening, erosions of the cortical bone as well as early osteophyte formation (Figure 5).

Case 3
A 72-year-old female presented with symptoms in the TMJ region: pain at rest and on motion, limitation of mouth opening and crepitus on motion. The reconstructed images (closed and open mouth) showed evidence of severe arthritic changes (Figure 6). On closed-mouth lateral centre view, condylar head resorption was observed, as

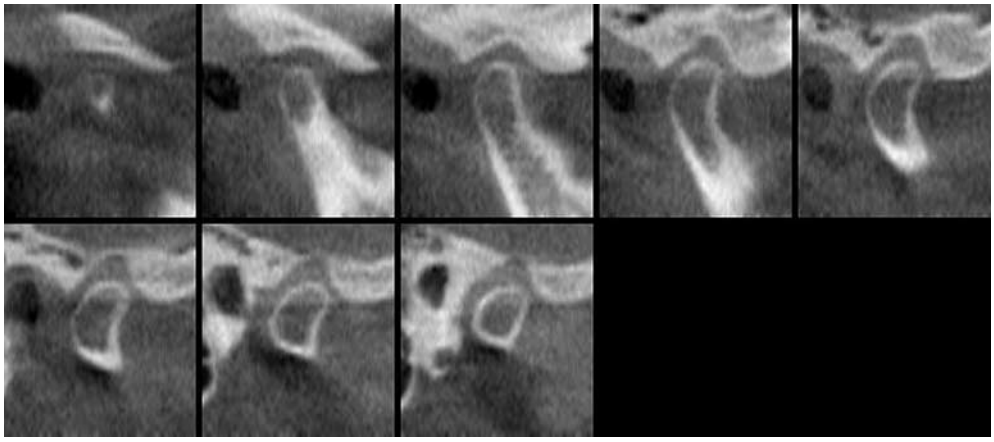

Figure 4 Closed-mouth reconstructed lateral images of a normal right temporomandibular joint

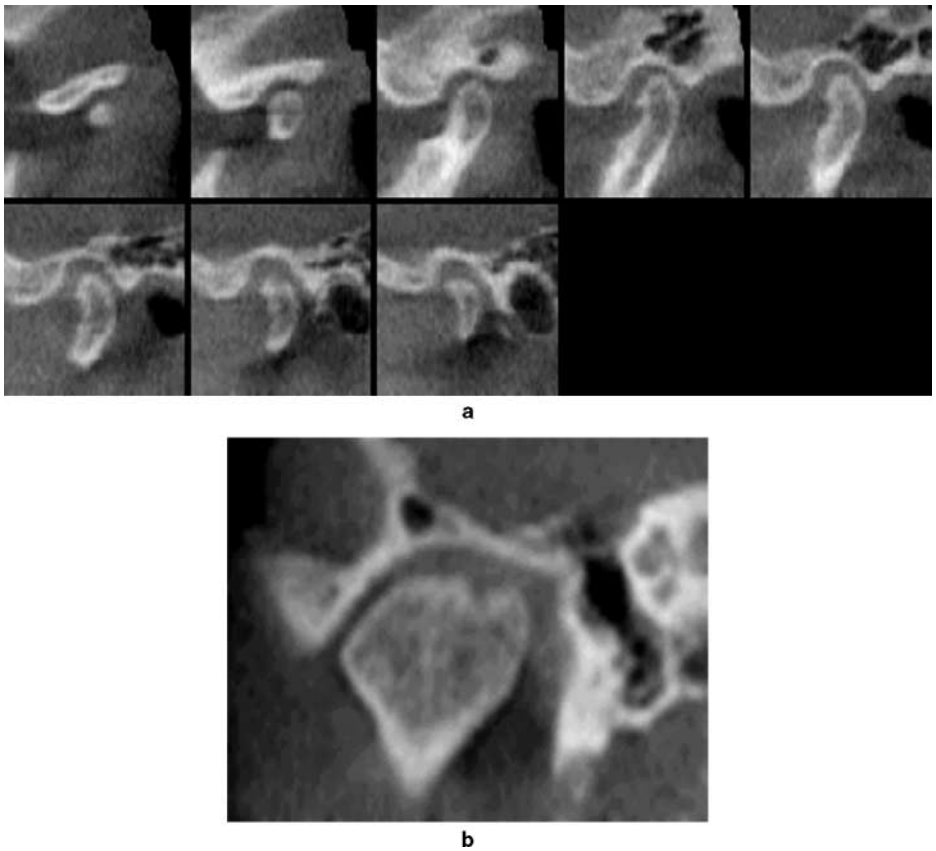

Figure 5 Early arthritis. (a) Closed-mouth reconstructed lateral images of the left temporomandibular joint show flattening of the condyle and osteophyte formation on the anterior surface. (b) The coronal reconstructed image shows loss of cortical bone on the superior surface and erosion

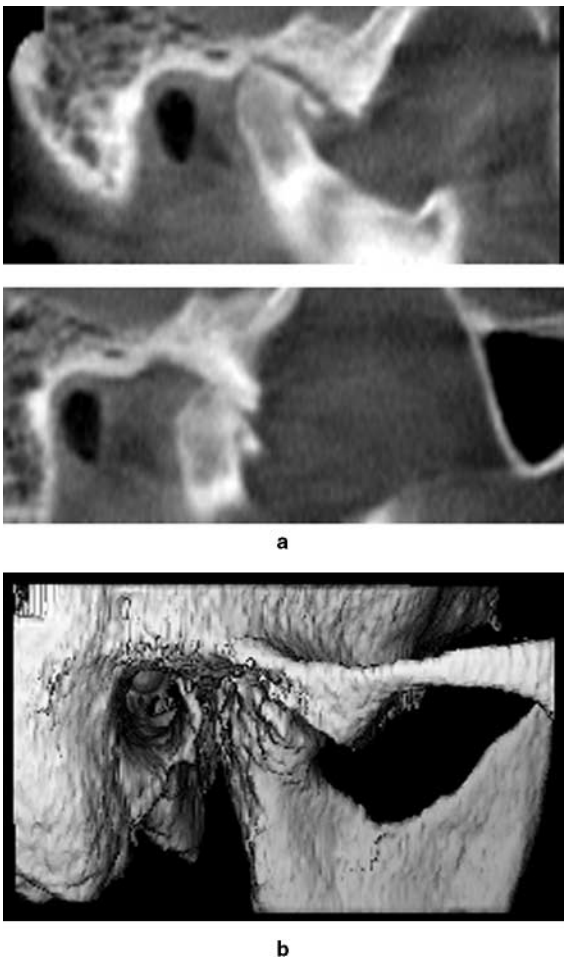

Figure 6 Severe arthritis. (a) Central lateral reconstructed image of the right temporomandibular joint (closed and open mouth) showing severe erosion, bone sclerosis, osteophyte formation and reduced joint space. (b) Three-dimensional reconstruction showing contact between the condyle and glenoid fossa

well as bone sclerosis, osteophyte formation and significant joint space reduction (Figure 6a). On open-mouth lateral view, limitation of the anterior motion of the condyle and bony contact of the condyle to the glenoid fossa was observed (Figures 6b,c).

Case 4

A 29-year-old female was referred to the clinic with deviation of the midline and facial asymmetry. Both the lateral and coronal images showed a smaller and not well formed right condyle (Figure 7a) compared with the normal left condyle (Figure 7b). This condition was characterized as hypoplasia of the right mandibular condyle.

Discussion

The TMJ is a rather difficult area to investigate radiographically. A number of imaging techniques have been developed over the years; however, there is still no single technique that provides accurate imaging of all the components of the complex anatomy of the joint. Modern imaging modalities, such as MRI and CT, are now being used more frequently for radiographic examination of the TMJ.

MRI is considered as one of the most useful investigations since it provides images of both soft tissue and bony components. However, the contraindications for certain types of patients and a few other disadvantages of MRI, such as long scanning time and restricted availability of the equipment, should be taken into consideration.

On the other hand, CT provides images of the bony components only. However, this can be sufficient for the final diagnosis in a number of pathological conditions. Pathological changes such as formation of osteophytes, erosion, fractures, ankylosis, developmental abnormalities, as well as the position of the condyle in the fossa in open- and closed-mouth conditions can be detected on CT images. A main disadvantage of the CT examination still remains the high radiation dose involved.

CBCT is a new technique producing reconstructed images of high diagnostic quality using lower radiation doses than normal CT. According to the manufacturer, owing to the use of the cone-shaped X-ray beam and the "smart beam technology", the absorbed dose from a CBCT scan is approximately equivalent to two to five panoramic exposures; however, this claim needs further investigation.

Additionally, the CBCT scanning time of 76 s is shorter than the time required for a conventional CT examination. This time is also shorter compared with conventional tomography. For instance, an exposure time of 56 s is required to take just four lateral tomograms of a single TMJ using conventional spiral tomography.

The technique described in this paper provides images that are obtained in planes parallel or perpendicular to the long axis of the condyle instead of the true anatomic coronal and sagittal planes. This results in high quality images of the bony components on all planes. Developmental and pathological changes can be detected using the lateral views. Furthermore, the central lateral view defines the true position of the condyle in the fossa, which often reveals possible dislocation of the disc in the joint.

Additional information on the condition of the surface of the condyle head can be obtained by the coronal views, as seen in Case 2. Pathological changes that are potentially concealed in the lateral images may be revealed in the coronal views owing to their orientation being perpendicular to the lateral ones. The coronal views of the condyle obtained with conventional techniques, *e.g*. linear tomography or reverse Towne's, are of low image quality. Therefore, they were hardly included in the routine TMJ radiographic examination since they increased radiation risk for the patient without achieving significant diagnostic benefit. On the other hand, the CBCT coronal views are of high image quality and are obtained within a few seconds without any additional irradiation of the patient.

Finally, a 3D reconstruction gives a general overview of the TMJ, sometimes valuable in cases with severe morphological abnormalities or for surgical planning.

Examining the joint with open mouth can be helpful in diagnosing internal derangement in the joint.

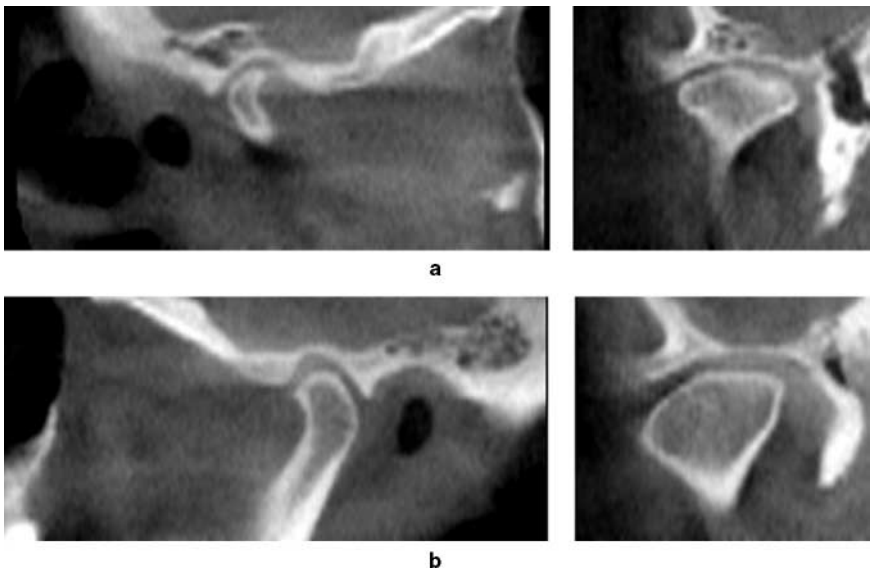

Figure 7 Closed-mouth central lateral and coronal views of (a) the right and (b) the left temporomandibular joint show hypoplasia of the right condyle

The central lateral view gives information regarding the extent of translation of the condyle in the fossa. Furthermore, the coronal view in the open-mouth situation often leads to a clearer view of the condyle, since it translates slightly over the tubercle giving an unobstructed view of the condyle head. It should always be taken into consideration, however, that a second scanning with open mouth doubles the radiation dose for the patient; it should thus be performed only in cases where the additional diagnostic information outweighs the increased risk.

The presented technique provides a complete radiographic investigation of the bony components of the TMJ. The reconstructed images are of high diagnostic quality, the examination time is shorter, and patient dose is lower than that with conventional CT. It may therefore be considered as the imaging technique of choice when investigation of bony changes of the TMJ is the task at hand.

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