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Cone Beam Computed Tomography Imaging in the Evaluation of the Temporomandibular Joint

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ABSTRACT A radiological examination is an essential part of the diagnosis and management of temporomandibular joint disease. Accurate evaluation of the TMJ has been difficult due to the superimposition of other structure in conventional radiographs. Cone beam computed tomography provides precise imaging of TMJ anatomy without superimposition and distortion. The CBCT's preciseness enables practitioners to better identify problems, as well for other strategies. Common conditions of the TMJ in which CBCT plays a role are discussed.

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Although the use of computed tomography, CT, as a diagnostic tool has been an indispensable in medicine for many years, its application in dentistry has been more limited. 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 in terms of imaging outweighs the biological risks for the patient.[1-3] Nevertheless, the number of CT examinations in dentistry has rapidly increased in recent years, particularly for examination of pathological conditions and trauma in the maxillofacial region.[4-7]

Cone beam computed tomography, CBCT, for dental and maxillofacial diagnostic osseous tasks has been rapidly developed as an alternative to conventional CT for assessment of the temporomandibular joint, TMJ, and presurgical implant treatment planning. CBCT results in images of CT-like quality, yet is made with less-expensive equipment and components, shorter patient examination time, and much lower radiation dose than required for conventional CT.[8-12] In addition, the CBCT scanning procedure and the image reconstruction software are user friendly.

Due to the increasing use of the CBCT, the aim of this paper is to assess the utility of CBCT for diagnosis of TMJ disease.

TMJ Imaging

Studies have shown that clinical assessment of TMJ disorders is often inconsistent with joint imaging studies.[13,14] Additionally, TMJ problems involve both hard and soft-tissue and the astute

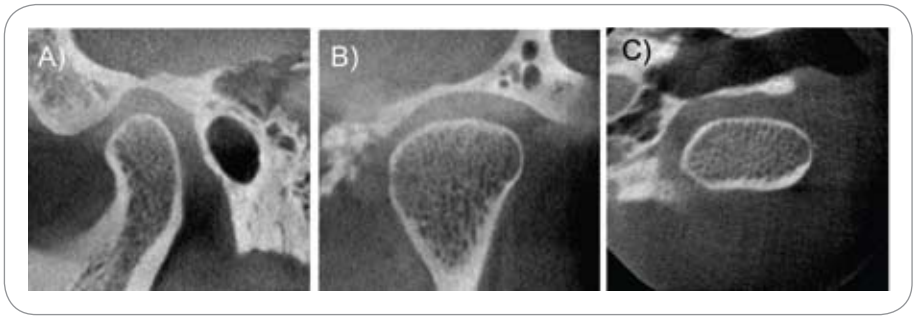

FIGURE 1. Normal TMJ in the closed position seen on corrected lateral **(A)**, coronal **(B)**, and axial **(C)** CBCT sections.

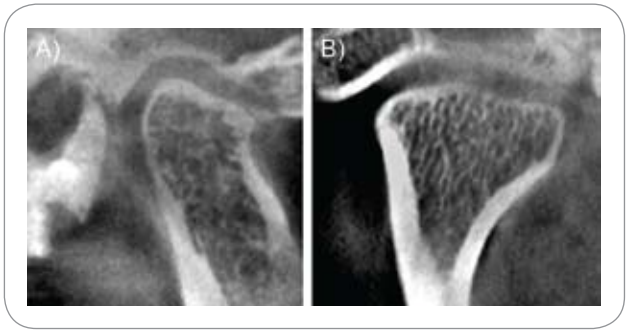

FIGURE 2. Bone remodeling on lateral **(A)** and coronal **(B)** CBCT sections showing flattening and cortical thickening of the antero-superior surface of the condylar head and glenoid fossa.

clinician needs to base the decision to order imaging on the type of tissue to be imaged. The TMJ imaging protocol begins with hard-tissue imaging to evaluate the bony contours, the positional relationship of the condyle and fossa, and the range of motion. In many cases, a radiographic examination is a decisive factor for the differential and final diagnoses of several pathological conditions of the TMJ.[15-17]

Prior to CT and CBCT, no single imaging technique was readily available for accurate, easily interpreted representations of all osseous aspects of the TMJ complex and associated structures. While panoramic radiography has frequently been used as a simple, low-cost method to evaluate the bony structures of the TMJ, it suffers serious limitations. In this technique, the lateral slope and central portions of the condyle are visualized because of the oblique orientation of the beam with respect to the condyle long axis. However, findings are usually limited to fractures, obvious erosions, sclerosis, and osteophytes of the condyle.[18] Further, the depiction of the articular eminence and fossa is not adequate for diagnosis of other than advanced changes of shape and structure because of superimposition by the base of the skull and zygomatic arch.

For a more detailed evaluation of the TMJ, conventional plane projections such as the panoramic, modified TMJ-specific panoramic, transcranial, and, to a lesser extent, Townes and submentovertex, SMV, can be used to provide an appreciation of TMJ anatomy. Conventional tomography avoids anatomy superimposition and unpredictable magnification, and has been used as a method of choice for bony TMJ examination.[19-23] However, when compared with microscopy, tomography underestimates small bone abnormalities and thus the diagnostic accuracy is limited.[24]

CT proved valuable for the evaluation of bony TMJ details in early 1980s and is superior to hypocycloidal tomography, although not by all investigators.[19,20,25] In patients with expansive masses, ankylosis, arthritides, osteoarthritis or fractures, CT is superior to both conventional tomography and magnetic resonance imaging, MRI, for the assessment of bony TMJ components.[26,27] MRI has the added advantage over CT scans to depict soft tissues such as the disc, ligaments, and muscles, and may be more useful than CTs when the patient presents with internal derangement or joint dysfunction.[28,29] Tasaki and Westesson found a 95 percent accuracy of diagnosis in sagittal and a 93 percent accuracy in coronal MRI of fresh autopsy specimens.[30] The use of an MRI has been the preferred imaging modality for the overall assessment of the TMJ.[31]

The introduction of the CBCT technology specifically designed for use in dentistry has opened up new opportunities in TMJ imaging. CBCT has been recognized as a reliable method for the examination of the osseous components of the TMJ. This technique is easy to perform, is reproducible, and delivers a relatively low dose to the patient.[32-34]

CBCT provides images that can be reconstructed 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 in all planes. Because the patients are positioned in a relatively natural head position, the TMJ positional relationships can be more accurately evaluated than in a CT examination where the patient is supine. The images generated via CBCT are not distorted and provide good bone density evaluation (**FIGURE 1**).

Application of CBCT in the Management of TMJ Disorders

Patients with TMJ disorders constitute a heterogeneous group. Many have symptoms that are not directly related to the joints proper. Although the clinical assessment of the TMJ provides limited information with respect to its status, imaging should only be performed if a thorough physical examination indicates the need for more information.

The goals of TMJ imaging are to evaluate the integrity of the structures when disorders are suspected, to confirm

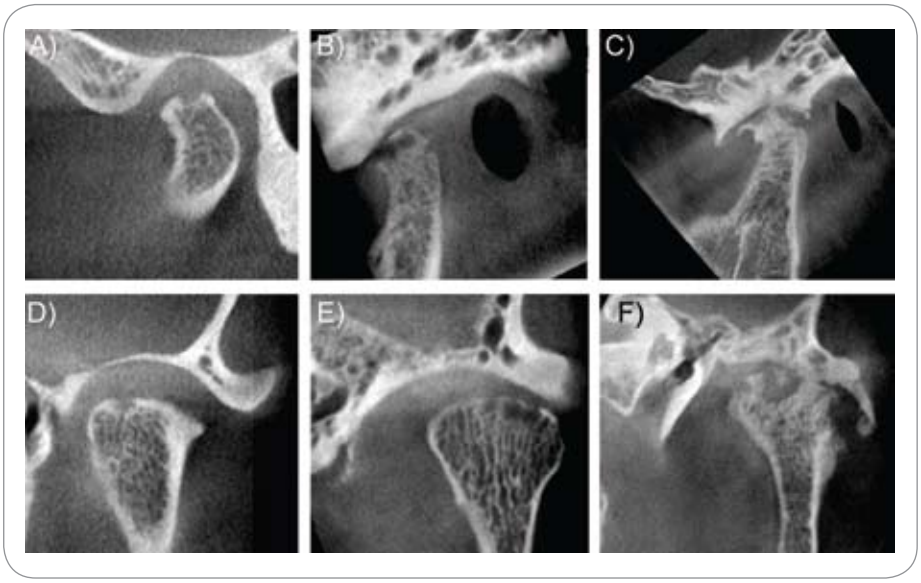

FIGURE 3. Progressive osteoarthritic changes depicted on lateral **(A, B, C)** and coronal **(D, E, F)** CBCT sections. Mild erosion of the condylar head and normal glenoid fossa **(A, D)**, moderate erosion, bone sclerosis, and reduced joint space with lateral position of the condylar head within the glenoid fossa on the coronal section **(B, E)**, and severe erosion, bone sclerosis, osteophyte formation, periosteal bone reaction, and significantly reduced joint space **(C, F)**.

the extent and stage the progression of disorders, and to evaluate the effects of treatment. Below are common conditions of the TMJ in which imaging plays a diagnostic or confirmatory role.

Remodeling

Remodeling is a physiologic process that aims to adapt the structure of TMJ to the mechanical forces applied to the joint. Excessive forces may cause alteration of the shape of the condyle and articular eminence.[35,36] This adaptive response may result in a flattening of curved joint surfaces, increased bone density (sclerosis), and absence of destruction or degeneration of articular soft-tissue. TMJ remodeling occurs throughout one's adult life and is considered abnormal only if accompanied by clinical signs and symptoms of pain or dysfunction, or if the degree of remodeling seen radiographically is judged to be severe. CBCT findings may include flattening, the cortical thickening of articulating surfaces, and subchondral sclerosis (**FIGURE 2**). These changes may affect the condyle, temporomandibular components, or both.

Osteoarthritis

Degenerative arthritis or osteoarthritis is an age-related disorder, and the most common pathological condition of the TMJ. Osteoarthritic bony changes include irregular cortical outlines, erosions, osteophyte formation, subchondral cyst formation, resorption of the condylar head, and reduced joint space[37-45] (**FIGURE 3**). These changes are most commonly seen on the condyle but may also involve the mandibular fossa or articular eminence. A joint with osteoarthritic changes may also demonstrate flattening or sclerosis.

CBCT is a valuable imaging technique for the diagnosis of degenerative changes of the TMJ.[33,34] Honda et al. evaluated the comparative diagnostic reliability of CBCT and helical CT (HCT) in detecting osseous abnormalities (erosions and osteophytes) of the TMJ condyle.[34] They determined that the spatial resolution of CBCT is superior to that of HCT. They emphasized that because of its high image quality, decreased cost, and radiation dose, CBCT is a viable diagnostic alternative to HCT for detecting erosions and osteophytes in the TMJ. CBCT images provide superior reliability and greater accuracy than corrected-angle linear tomography and TMJ panoramic projections in the detection of condylar cortical erosion.[46]

Inflammatory Arthritis

A general classification of arthritis divides the diseases into inflammatory, degenerative, infectious, metabolic, and traumatic categories. The inflammatory arthritides are a heterogeneous group of systemic disorders that manifests as synovial membrane inflammation in several joints.[47,48] The group includes rheumatoid arthritis, juvenile idiopathic arthritis, psoriatic arthritis, ankylosing spondylitis, and Reiter syndrome. When an inflammatory disorder of the TMJ is suspected, CBCT is recommended for evaluation of subtle abnormalities. Both joints should be imaged for comparison. Cortical erosions most often involve the articular eminence and the anterior aspect of the condylar head. CBCT images also show subchondral sclerosis, flattening of articulating surfaces, subchondral cysts, and osteophyte formation. The radiographic appearance of inflammatory arthritis is not specific but can be very similar to osteoarthritis. However, the degree of joint destruction is more advanced. When CBCT findings demonstrate severe arthritic changes of the TMJ that cannot be supported by clinical findings or patient's age, the possibility of inflammatory arthritis should be entertained. Correlation with patient symptomatology with other joints, as well as blood tests, might be necessary to further evaluate the patient. Clinical findings include palpable pain in the TMJ, crepitation, and bite changes with developing contralateral and anterior open bite and limited opening.

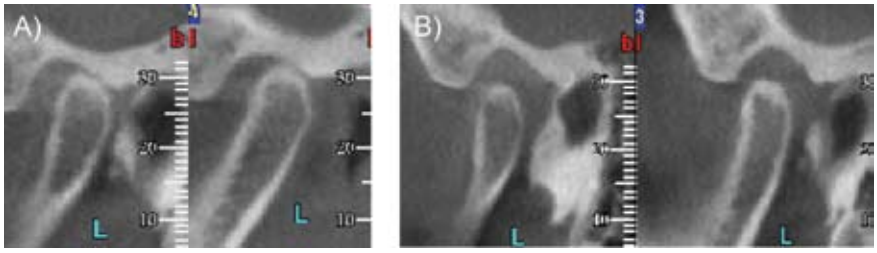

FIGURE 4. Retruded position of the condylar head in closed-mouth position **(A)** and limited translatory movement of the condyle upon opening **(B)** suggest disk displacement.

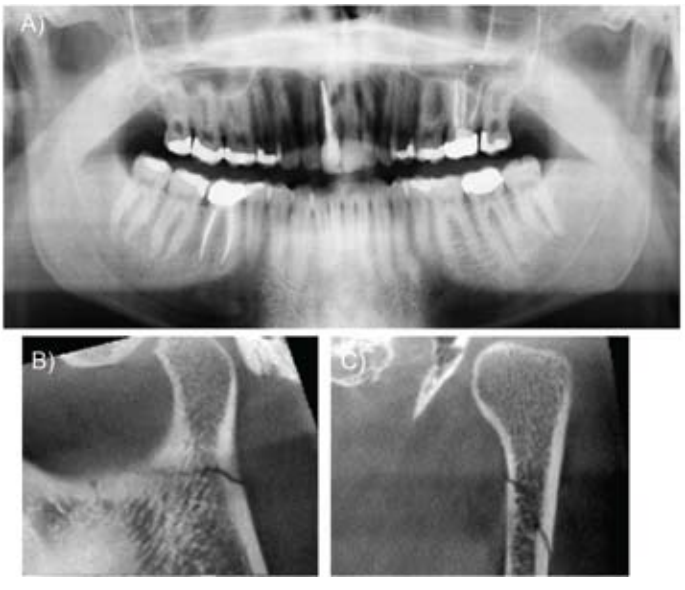

FIGURE 5. Condylar neck fracture cannot be seen on the panoramic radiograph **(A)**. However, lateral **(B)** and coronal **(C)** CBCT sections demonstrate a complete, oblique, minimally displaced fracture of the left condylar neck.

Internal Derangement

Internal derangement of the TMJ is defined as an abnormal positional relationship of the disc relative to the mandibular condyle and articular eminence. Clinically, the derangement may be indicated by clicking in the affected joint or by a restricted opening. Clicking in the TMJ associated with the internal derangement is usually due to the disc displacement being reduced during the opening movement, but a derangement that does not reduce and is associated with restricted opening is characterized as close-locked. The disc cannot be visualized with CBCT. However, disc displacement can reposition the condyle from its central position within the glenoid fossa to a posterior position in the fossa, suggesting an internal derangement. Furthermore, in the case of disc displacement without reduction, the condyle may be restricted in the opening movement.[49,50]

The concentric, posterior, or lateral localization of the condyle within the joint space in closed position should be evaluated on the CBCT images. Furthermore, the translatory movement of the condyle upon opening in relation to the articular eminence should be assessed (**FIGURE 4**). Deviations from the norm can raise suspicions for internal derangement. If clinically indicated, MRI is the method of choice to provide definitive diagnostic information for the TMJ soft-tissue components.

Fracture

Fractures of the TMJ usually occur at the condylar neck and often are accompanied by condylar head dislocation. They can be classified according to location (intracapsular, extracapsular, or subcondylar), type (nondisplaced, displaced, or dislocated), or direction of the fracture (vertical, horizontal, or sagittal).[51,52]

CBCT is useful in the evaluation of TMJ trauma and offers superior anatomic visualization compared to plain radiographs without superimposition of anatomic structures.[52,53] Also, cortical outline irregularity and condylar medial displacement can be assessed on CBCT (**FIGURE 5**). An MRI should be considered in cases of capsular tear and hemarthrosis, where detailed soft-tissue evaluation is needed.

In cases of facial trauma and limited opening, fractures of the zygomatic arch also should be considered. In such cases, the coronoid process may impinge on the fractured zygoma, limiting jaw opening. The limitation and imaging for this would be similar to what is discussed below for coronoid hyperplasia.

Ankylosis

Ankylosis is a fibrous or bony union between joint components and can be caused by trauma, rheumatoid arthritis, or infection. Conventional images may reveal little useful information other than a limited amount of condylar translation.[54] A CBCT examination is recommended, if ankylosis is clinically suspected, as it provides superior visualization of the osseous components. In fibrous ankylosis, the articulating surfaces are usually irregular because of erosions and joint space is narrow. In bony ankylosis, no joint space, at least in parts of the joint, is visible. Secondary degenerative changes are common (**FIGURE 6**). Patients have no or severely limited condylar translation movement in opened-mouth views.

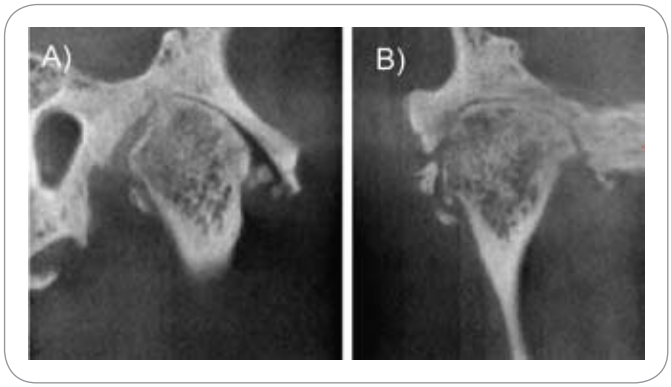

FIGURE 6. Osseous ankylosis on lateral **(A)** and coronal **(B)** CBCT sections showing irregular articular surface, narrow joint space, and continuity of the condyle head with the glenoid fossa at the middle aspect of the condyle. Additionally, small bony fragments, probably representing detached osteophytes, are seen within the joint space.

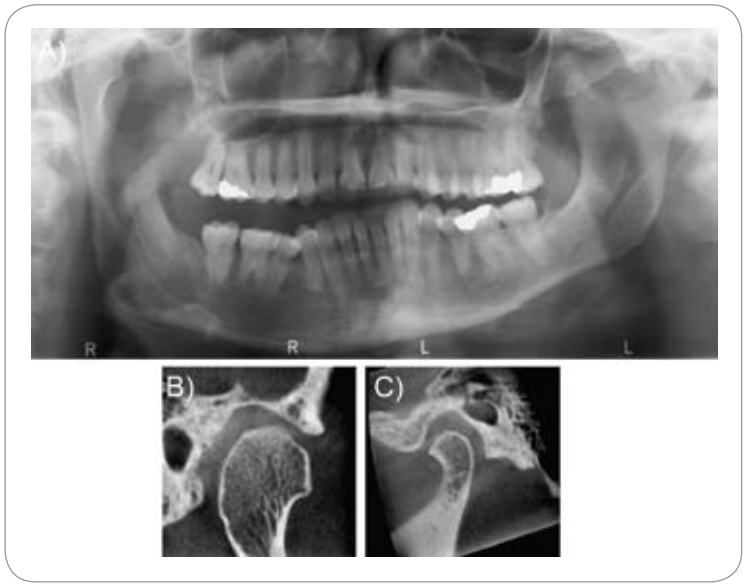

FIGURE 7. Right condylar hyperplasia seen on panoramic **(A)** and lateral **(B)** CBCT sections. Lateral section of the normal left condyle **(C)** is shown for comparison.

Developmental Abnormalities of the TMJ

When clinical examination reveals a facial asymmetry, especially progressive asymmetry, a developmental disorder such as condylar aplasia, hypoplasia, or hyperplasia (**FIGURE 7**) should be suspected. A CBCT offers optimal evaluation of the extent of deformity.[55] Radiographic features include hyperplastic or hypoplastic condyle (unilateral or bilateral), joint remodeling (flattened, deformed), and bifid or split condyle. Because disk derangement may cause a facial asymmetry in young patients, a MRI may be appropriate in some cases.[54]

Coronoid Hyperplasia

Coronoid process hyperplasia may be developmental or acquired, resulting in elongation of the coronoid process. Usually the patient is asymptomatic until the hyperplastic coronoid process impinges on the medial surface of the zygomatic arch or the posterior surface of the maxilla during opening, restricting condylar translation. The elongated coronoid process and its relation to the zygomatic arch and posterior aspect of the maxilla can be clearly visualized on CBCT scans. It is important that CBCT scans are taken in the closed and open position, such that the exact contact point of the coronoid process with the zygomatic arch or maxilla are revealed.

Synovial Chondromatosis

Synovial chondromatosis is a benign tumor-like disorder of the joint characterized by chondrometaplasia of the synovial membrane, in which cartilaginous nodules form and may become pedunculated and/or detach from the synovial membrane, becoming loose bodies within the joint space.[56-58] Clinical symptoms often are characterized by joint swelling, pain, and joint dysfunction. CBCT findings of synovial chondromatosis include the presence of multiple, calcified, loose bodies in the joint space, widening of the joint space, irregular, or sclerotic glenoid fossa. These calcifications follow the condyle movement in an open position. The condyle may appear normal or may exhibit osseous changes similar to those in osteoarthritis (**FIGURE 8**).

Benign Tumors

Benign lesions affecting the TMJ include osteomas, osteochondromas, Langerhans histiocytosis, and osteoblastomas. Osteochondroma, the most common benign TMJ tumor is most commonly seen in the second or third decade of life. It is a slow-growing, exophytic lesion that arises from the cortex of bone and is capped with cartilage. Condylar osteochondroma can result in facial asymmetry, malocclusion, cross-bite on the contralateral side and lateral open bite on the affected side, open deviation, hypomobility, pain, and clicking. Osteochondroma of the mandibular condyle may arise on different sites around the condyle and present diverse shapes on panoramic radiographs.[59] CBCT imaging shows enlarged condyle with irregular outline and altered trabecular pattern, or an abnormal, pedunculated mass attached to the condyle. The tumor may erode adjacent osseous structures (**FIGURE 9**).

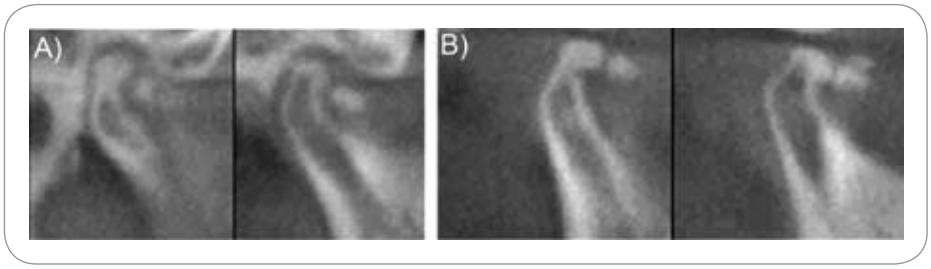

FIGURE 8. Synovial chondromatosis on lateral CBCT sections in closed **(A)** and open **(B)** position showing calcifications within the joint space that follow the condylar movement.

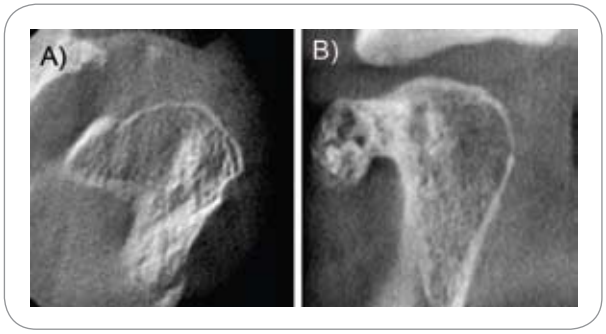

FIGURE 9. Osteochondroma on axial **(A)** and lateral **(B)** CBCT sections showing an exophytic lesion located on the anterior surface of the condylar head. These images show the continuity of the normal condylar trabeculation with the tumor.

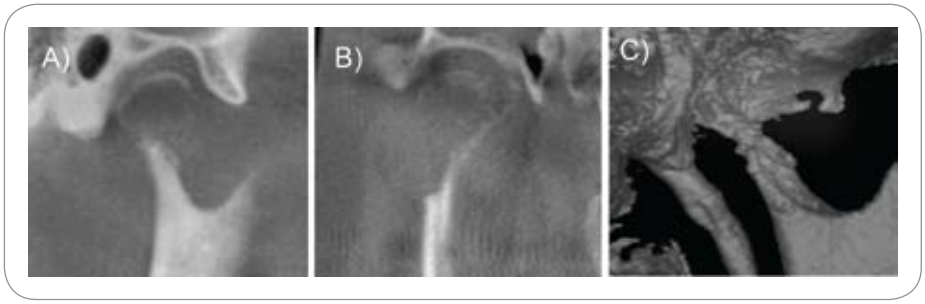

FIGURE 10. Metastatic breast carcinoma on lateral **(A)** and coronal **(B)** sections, and 3-D reconstructions **(C)**showing ill-defined, radiolucent, destructive lesion of the condylar head.

Malignancies

Malignancy of the TMJ is rare. The most common malignant lesion that affect the TMJ is metastasis from a distant site.[60-62] However, primary condylar malignancy, such as osteosarcoma or chondrosarcoma, or extension of local disease have also been reported.[62,63] Malignancies of the TMJ are notable for their atypical and misleading clinical presentation that usually mimics more common disorders, such as osteoarthritis. Patients often have symptoms of TMJ dysfunction such as pain, limited mandibular opening, mandibular deviation, unilateral facial swelling, and external auditory canal obstruction. When these patients do not respond to appropriate therapy, the clinician should recognize that the initial diagnosis might be incorrect.

CBCT can offer great advantages in the diagnosis of TMJ malignancy. Typically, malignant tumors show variable degrees of bone destruction with minimal expansion and erosive, ill-defined, irregular margins (**FIGURE 10**). If a malignancy is suspected on a CBCT, advanced imaging such as an MRI or CT with contrast is recommended for evaluation of local expansion of the lesion in the soft tissues, as well as for evaluation of the regional lymph nodes. In case of metastatic disease, a complete work-up with nuclear scan, whole body CT, and PET scanning might be appropriate.

Conclusions

CBCT has significantly increased the diagnostic abilities of the clinician at a lowered cost to the patient and lower radiation dosage compared with CT. CBCT images provide greater detail of the extent of damage to the articular surfaces from trauma, inflammatory disease, or degenerative processes. CBCT has become the imaging of choice for presurgical evaluation in surgery, for dental implants, and is replacing older imaging modalities for evaluation of TMJ disease. Although CBCT does not image soft-tissue, such as disc position relative to the condyle and fossa, appropriate clinical evaluation can usually determine if a disc displacement is a factor that needs to be treated. Most TMJ disc dislocations self-reduce and are painless. Those derangements that are painful or do not reduce are in a minority and require further imaging as part of the assessment. ■■■■

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