REVIEW
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Imaging of Temporomandibular Joint Disorders

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Abstract

The temporal bone and mandible, an articular disc, a number of ligaments, and numerous related muscles make up the temporomandibular joint (TMJ) which is a unique joint that not only permits sliding motion of the surfaces in one plane but also is the only joint where both the joints work together to create the bicondylar articulation. The American Academy of Orofacial Pain defines TMDs (temporomandibular joint disorders) as an umbrella term that covers a set of musculoskeletal and neuromuscular conditions involving the masticatory musculature, the TMJ, and/or their associated structures with several etiologies ranging from inflammation to degenerative diseases causing muscle spasm and fatigue. Since TMDs (temporomandibular joint disorders) involve muscular, skeletal, and disc components, the imaging modalities used for diagnosis should be inclusive of these components. For the sake of understanding the imaging of the joint can be categorized into modalities to visualize soft and hard tissues. Due to the involvement of both soft tissue and osseous components in TMJ disorders, it is important to carefully evaluate patients and choose the best investigative modality, as they are becoming more prevalent. The present narrative review focuses on the different imaging modalities used in temporomandibular joint disorders.

Keywords: Cone beam computed tomography, magnetic resonance imaging, electromyography for the masseter and temporalis, joint vibration analysis

INTRODUCTION

The temporomandibular joint (TMJ) comprises the temporal bone and mandible, articular disc, several ligaments, and numerous associated muscles. The TMJ is a compound joint classified based on its functional use and anatomical nature.[1] It is a unique joint that permits sliding motion of the surfaces in one plane and also the right and left TMJs work together to create the bi-condylar articulation.[2]

Mandibular movements can be intricate, requiring different combinations of muscle actions as well as rotation and translation in each TMJ. The muscles that function to close the jaw, bringing about these movements, are the masseter, temporal, and lateral or external pterygoid.[1,2] The mandible can open, protrude, retrude, and move laterally under voluntary control. The disc-condyle complex spins on the same side of excursion and translates to the opposite side. The muscles that open the jaw are the medial or internal pterygoid, geniohyoid, mylohyoid, and digastric.[2-4] The superior retrodiscal lamina stretches with each TMJ movement, causing the articular disc in the head or condyle to migrate backward. The elevation of the mandible in the vertical direction is principally accomplished by a joint bilateral contraction of the masseter, temporal, and medial pterygoid muscles. To return to its resting position, the disc–condyle complex in the TMJ glides up and back along the eminence.[3,4] Together with the superior lateral pterygoid, the elevator muscles support the disc-condyle complex and aid in the anterior rotation of the articular disc.

Movement of the mandible to the left or right sides involves the contraction of the lower portion of the lateral pterygoid muscle on the opposite side, aided by the posterior and medial fibers of the temporalis muscle on the same side.

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The importance of occlusion cannot be neglected in TMJ biomechanics. Due to the dynamic actions of muscles, it appears that the masticatory system has a compensatory mechanism that can also adjust to additional occlusal characteristics, such as cross-bite relationships on the swing side and interferences on the working side. The ability to adjust functionally differs and may be influenced by a number of variables, including age, the resistance of the joint, the presence or absence of systemic disorders, to name a few. Since the load-bearing components are placed on the lateral portion of the joint, these alterations are more frequently observed there, marking the onset of temporomandibular disorders (TMDs).[3]

The American Academy of Orofacial Pain (AAOP) defines TMDs as an umbrella term that covers a set of musculoskeletal and neuromuscular conditions involving the masticatory musculature, the temporomandibular joint (TMJ), and/or their associated structures.

The etiologies can be multifactorial, ranging from traumatic, inflammatory, and congenital in nature, degenerative TMJ, skeletal disorders, and psychological factors that cause stress and increase muscular activity, resulting in fatigue and spasms.[5-7] It is also characterized by deficient wound healing and fibrosis caused by continuous and irreversible injuries. The signs and symptoms most commonly associated with TMD are pain in the temporomandibular joint, pain during jaw movements or limitation in movement, facial pain, spasm and muscle pain on palpation, crepitation or popping, pain or ringing in the ear, neck pain, and headache. Temporomandibular disorders impact not only oral health but also general health, thus posing serious threats at both the individual and community level.[5-7]

The most often used diagnostic categorization systems are the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD).[5,7] and the classification of the American Academy of Orofacial Pain (AAOP). These classifications comprehensively provide inclusion for muscle-related, disc-related, and joint per se related conditions systematically to address the condition overall.[5,7]

Muscle pain includes myalgia and myositis, which is characterized by pain and tenderness in any of the masticatory muscles for the last 30 days, with limitation of mandibular movements.[5-7] Spasm of masticatory muscles is characterized by a sudden, involuntary, reversible tonic contraction of a muscle affecting any of the masticatory muscles. Acute malocclusion may be present too. Hypertrophy of one or more muscles, especially masseter or temporalis, is a common observation in TMDs due to overuse and secondary to chronic tensing of muscles.[6]

IMAGING METHODS FOR TEMPOROMANDIBULAR DISORDERS

Since TMDs involve muscular, skeletal, and disc components, the imaging modalities used for diagnosis should be inclusive

Table 1. Various Imaging Modalities for TMD Assessment

Hard Tissue Imaging	Soft Tissue Imaging
• Conventional radiograph • Orthopantogram • Computed tomography • Cone beam computed tomography	• Ultrasonography • Magnetic resonance imaging • Electromyography • Joint vibration analysis • Thermography

of these components. Moreover, the dynamic nature also necessitates the inclusion of investigations to involve the kinematics and biomechanics of the joint. For the sake of understanding, the imaging of the joint can be categorized into modalities to visualize soft and hard tissues.

The different imaging modalities commonly employed are outlined in Table 1.

HARD TISSUE IMAGING

Conventional Radiography

This, also known as "plain" radiography, is the oldest form of medical imaging. The various techniques include transcranial, transpharyngeal, and transorbital and submento-vertex view.[8-10]

Transcranial[7,11,12] or modified Stenver's view is employed to view the condylar head, articular fossa, and the joint space. Transpharyngeal[1,9,12] or Parma helps view the condylar neck and head. Transorbital or Zimmer's view helps visualize the condylar neck and head. Submento-vertex helps viewing the condylar head in the axial plane. A combination of these radiographs may have to be employed for complete viewing of joints.

Panoramic Radiography/ Orthopantogram (OPG)

Panoramic radiographs, considered to be a screening projection, provide a complete image of the mandible and maxilla. They give an overview of the jaws and teeth, allowing evaluation of mandibular symmetry, the maxillary sinuses, and the dentition[10,12,13] (Figure 1). This view helps in delineating conditions that present with pain perceived in the joint but originate from other structures, like maxillary sinuses.[10,11]

Figure 1. Orthopantogram showing both maxilla, mandible, and temporomandibular joint (marked in red).

Although it presents a complete image, owing to the superimposition of structures, it is difficult to differentiate structures of the joint and the surrounding bony structures and thus remains a choice for screening purposes only.

Computed Tomography (CT)

CT is useful to evaluate the bony elements of the TMJ as well as the adjacent soft tissues. It is ideal for assesing fractures, degenerative changes, erosions, infection, invasion by tumor, congenital anomalies, and evaluation of osseous ankylosis etc. is effectively possible.[13,14] The advantages of CT over conventional tomography lie in the fact that there is no superimposition of structures outside the area of interest, improved contrast resolution & the images can be viewed in various planes.

This is particularly valuable for TMJ imaging, since in addition to the TMJs, the remainder of the jaws as well as the skull base can be evaluated.[13-16] The disadvantage of using CT lies with required high exposure and hence the radiation dose is increased to the patient.

Cone Beam Computed Tomography (CBCT)

In recent years CBCT has emerged as an important sectional imaging option next only to CT. Being very similar to CT in image acquisition, it is a modality with less radiation exposure to patients. The diagnostic potential of CBCT versus conventional radiographic examinations was highlighted in 3 conditions: intra-articular fractures, osteoarthritis (OA), and fibro-osseous ankylosis.[15,16] Fine detailing of erosions of the condylar surface is easier to identify on CBCT[17] (Figure 2).

Disadvantages of CBCT include lower image contrast and higher image noise than in CT. Although it provides soft tissue detailing to some extent, it may not be reliable for complete treatment intervention.[10,13,15]

Soft Tissue Imaging

The evaluation of soft tissue components is equally important as that of hard tissues in TMDs; the position of the disk and its soft tissue structure is crucial to evaluate and assess the proper treatment protocol.[11,12]

Conventional radiographic techniques do not demonstrate the disk or disk position; hence function and integrity cannot be evaluated.[8,9] Soft tissue imaging is indicated when symptoms are unresponsive to conservative treatment, when significant TMJ pain and dysfunction are present, or when the clinical findings are suggestive of disk displacement.[11,12]

Ultrasonography of Joint

Ultrasonography (USG) is a less expensive and easily performed imaging modality used to evaluate the TMJ.[13,18] This is a simple way to look for the presence of a joint effusion and to evaluate the cartilage as well as disk displacements. It is used for image-guided injections for both diagnostic and therapeutic purposes.[13,18] The articular eminence and mandibular condyle present as hypoechoic with a hyperechoic cortex. The surrounding capsule, pterygoid muscle, and retrodiscal tissues are isoechoic, although the disc itself can be hyperechoic, hypoechoic, or isoechoic. Ultrasonography allows a dynamic and direct investigation of the surrounding structures (muscles, tendons, and ligaments), which is essential for an exhaustive understanding of the pathophysiological aspects of TMD.[10,13,15,17] One of the difficulties of USG is the lack of clear images, especially in the open-mouth position, due to the overlying osseous structures. Additionally, the medial part of the disc cannot be visualized.[14,18]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) allows for near-cinematic dynamic imaging studies without the use of ionizing radiation.[10,13,15,19] Magnetic resonance imaging of the TMJ is regarded as the imaging gold standard for the evaluation of

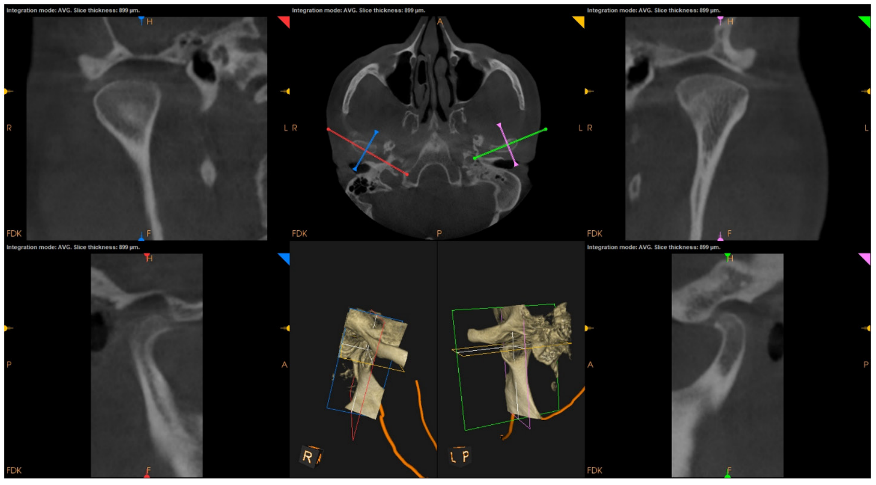

Figure 2. CBCT images showing coronal axial, sagittal, and 3D reconstructed views of the TM joint.

TMJ.[13,14] Magnetic resonance imaging should be part of the standard evaluation when an internal structural joint abnormality is suspected as it provides high resolution and great tissue contrast. This allows for a detailed evaluation of the anatomy as well as the biomechanics of the joint through open and closed mouth imaging. As a non-invasive imaging modality, it allows for the evaluation of the disc in a static position, along with imaging of the surrounding muscles and detecting joint effusions. In a healthy mouth, the disc remains atop the mandibular condyle while the condyle moves anteriorly to articulate with the articular eminence. It should be within 10° of vertical where the posterior band meets the intermediate-signal-intensity bilaminar zone. On both T1-weighted and fluid-sensitive sequences, the disc has a medium to low signal intensity. It shouldn't medially or laterally overhang the mandibular condyle on the coronal view. For all imaging sequences, the bilaminar zone has an intermediate signal intensity compared to the muscle.[14,19] The MRI findings can help to indicate several notable alterations in the disc–condyle complex[20]: disc displacement, disc deformity with associated perforation, osteoarthrosis, and abnormalities in the retrodiscal region.[20]

- The best way to diagnose mediolateral disc displacement is through coronal oblique imaging. Disc is typically observed as symmetric crescentic hypo-intense material on the imaging slice just anterior to the condyle and above the condylar head.[21,22] A disproportionately large amount of disc material will be present on either side of the condyle in cases with medial disc displacement (Figure 3).
- Degeneration of the joint leads to disc deformity and perforation, which causes the disc to lose its biconcave aspect and shorten in the anteroposterior dimension. With STIR (Short tau inversion recovery) imaging, marrow edema can be seen as well.[14,19]
- In the presence of osteoarthrosis, articular prominence and osteophyte production can be noted. A decrease in marrow signal on proton-density and STIR imaging that is consistent with sclerosis, as well as the development of sub-chondral cysts, are additional alterations. Elderly patients with advanced osteoarthrosis are typically asymptomatic.[19,21,22]
- Fibrotic alterations, a decrease in T2 signal, a pseudo disc sign, and thickening of the posterior meniscal attachment are likely signs of more chronic pathology. Rupture of the retrodiscal soft tissues was also cited by various studies as a marker of degeneration.[19,21,23]

The important disadvantages of MRI include being expensive and time-consuming, restricted use in patients with claustrophobia, the possibility of missing a portion of the condyle having a pseudocyst, and bone conditions and soft tissue calcifications with inflammatory diseases or tumors may be missed in this imaging modality.

Electromyography

Electromyography records the muscle activity during resting and contraction phases.[17] Electromyography recording in an asymptomatic subject in the intercuspal position will likely to be uniform between the 2 sides of the temporalis and masseter muscles.[24] In a resting state of the muscle, the activity is found to be at its lowest, whereas in TMDs, resting activities are found to be higher than normal.[25,26] Matos et al[25] have employed the EMG in conjunction with MRI and other biometric technology options, particularly to ascertain the decompression effect of occlusal orthotics on the TMJ. It is an indirect representation of muscle fibers under biomechanical loading of the TMJ during maximal clenching.[25-28] Electromyography helps in measuring the electrical activity of the masticatory muscles and the jaws' 3-dimensional location in relation to their maximal clenching. Electromyography of TMDs exhibits the following symptoms: (1) a modest rise in basal tone; (2) a noticeably decreased ability for clenching; and (3) an apparent paradoxical suppression of the dysfunctional side

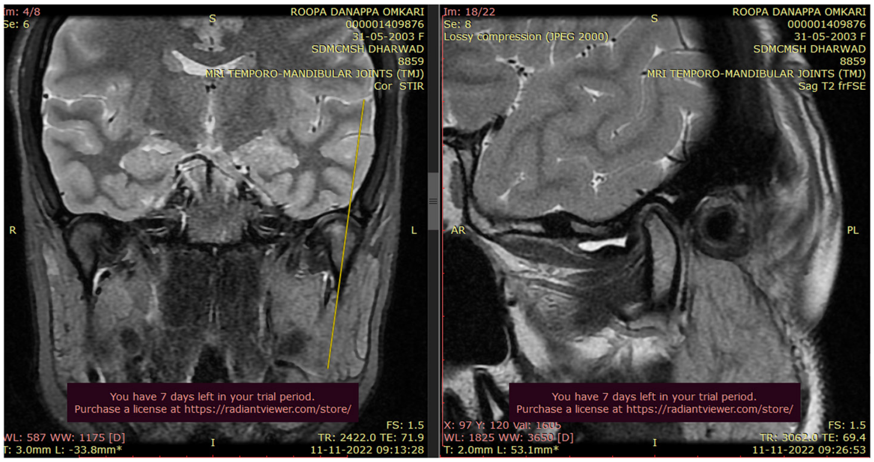

Figure 3. MRI showing disc–condylar complex in sagittal and coronal plane.

Essent Dent 2024; 3(3): 114-120

during movement of the mandible towards that side[25-28] (Figure 4).

Joint Vibration Analysis

The TM joint commonly emits a variety of sounds, which are audible when the joint is experiencing an internal derangement. When a disc is partially or fully displaced, partially or entirely decreased, or folds over on itself, it generates noises during movements. Joint vibration analysis stands as one of the non-invasive, reliable functional diagnostic tools gaining steady popularity for the functional diagnosis of TMDs.[29-32] Joint vibration analysis, a computer-based tool based on motion and friction principles, provides a low-cost solution regarding the dynamic information of the joints (Figure 5). It records all the vibrations of the underlying tissue during function, produces a visual representation of the vibration, and analyzes its intensity.[29-32] Since JVA has the potential to provide the functional and dynamic position of the disc, it can serve as an excellent screening tool in identifying functional pathologies of the TM joint.[29-32]

Thermography

Infrared scanning is a painless diagnostic tool, free of chemical contrast, with the ability to scan the microcirculatory

Figure 4. 4-Channel electromyography showing temporalis masseteric electrodes and EMG amplifier.

Figure 5. Joint vibration analysis.

activity of the skin. It offers no hazard to pregnant women, children, or elderly and can be used to evaluate TMDs involving dysautonomia, painful muscular dysfunction, and the myofascial trigger points. The findings of infrared are consistent with muscle pain on palpation, as it acts as a link to moderate subjectivity and objectivity.[33-35]

As it provides no direct contact to the face, it can be employed to diagnose trigger points by hot spots.[33] The hot spot refers to myofascial pain trigger areas tender on clinical examination.[33,34] The painful areas are hypo-radiant compared to other areas. Infrared diagnosis is the only way of imaging recognized for early and correct diagnosis of the site of pain.[33-35]

CONCLUSION

Due to the increase in the number of patients with TMDs reporting, clinicians should be well aware of available techniques for appropriate treatment planning. As this structure includes both soft tissue and osseous components, a careful evaluation of patients and selection of the appropriate investigative modality turn out to be crucial. Amongst the various investigations discussed, MRI stands to be the gold standard for diagnosing TMJ disc position, whereas CBCT

Table 2. Various Investigations to be Undertaken to Diagnose TMD

Imaging Modalities	Uses and Indication
• Conventional radiograph	• Positive findings on transcranial radiographs include degenerative joint disease, which is typically most noticeable in the lateral third of the condylar head
• Orthopantogram	• For imaging the TMJs, a panoramic radiograph is frequently utilized in conjunction with other hard tissue imaging methods as a "screening" projection. • Mandibular symmetry, the maxillary sinuses, and the dentition.
• Computed tomography	• Osseous detail of the TMJs • Osseous ankylosis, neoplasms, heterotopic bone growth, and other abnormalities in and around the joints
• Cone beam computed tomography	• Intra-articular fractures, osteoarthritis (OA), and fibro-osseous ankylosis
• Ultrasonography	• Image-guided injections for both diagnostic and therapeutic purposes. • Retrodiscal tissues and muscles and tendons and other soft tissue structures
• Magnetic resonance imaging	• Gold standard for imaging of the joint • Use in imaging of disc position with or without displacement and effusion, and dynamic measurements of muscle, especially Lateral Pterygoid muscle.
• Electromyography	• To find the electrical activity of masticatory muscle and to assess the symmetry and synergy of muscle in arthrogenous TMD
• Joint vibration analysis	• For assessment of vibrations in joints, which can help us diagnose the direction of disc displacement in conjunction with MRI
• Thermography	• Evaluate certain TMJD involving dysautonomia, painful muscular dysfunction, and the myofascial trigger points.

plays a role in identifying the bony or degenerative changes in the condyle and changes in the surrounding structures. Choosing the appropriate investigation depends on subjective clinical presentation and summary (Table 2). Many studies have emphasized the fact that using a biometric based approach in the evaluation of TMDs makes the treatment approach more systematic. Understanding the TMJ anatomy, biomechanics, and the imaging manifestations of diseases is important to accurately recognize and manage these various pathologies.

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