EC DENTAL SCIENCE
Review Article

The New Emerging Imaging Modalities for Diagnosis of Temporomandibular Joint Osteoarthritis (TMJ-OA)

Shital Nikam*, Mahendra Patait, Sayali Rajendra Pagare*, Kedar Saraf, Anuja Ghule, Maithili Kshirsagar and Priya Wakchaure

Department of Oral Medicine and Radiology, SMBT Dental College and Hospital, Ghulewadi, Sangamner, Maharashtra, India

***Corresponding Author:** Shital Nikam, Associate Professor, Department of Oral Medicine and Radiology, SMBT Dental College and Hospital, Ghulewadi, Sangamner, Maharashtra, India and Sayali Rajendra Pagare, Post Graduate Student, Department of Oral Medicine and Radiology, SMBT Dental College and Hospital, Ghulewadi, Sangamner, Maharashtra, India.

Received: March 20, 2024; **Published:** April 03, 2024

Abstract

The glenoid fossa, articular eminence, and mandibular condyle of the temporal bone form the complex synovial articulation known as the temporomandibular joint (TMJ). The superior and inferior compartments of the joint are separated by an intraarticular disc. The disease known as temporomandibular joint dysfunction encompasses the TMJ, the masticatory muscle, and related tissues. Displacement of the disc, TMJ joint noise. Degenerative joint diseases and congenital malformations may have an impact on the condition. Osteoarthritis is a degenerative joint disease marked by degradation of the articular tissue and concurrent remodeling of the subchondral bone underneath. Cone beam computed tomography (CBCT), which permits three-dimensional imaging of bony components of the skull, including the mandible and the TMJ, is a newly developed imaging tool in the process of diagnosing TMD. Aside from CBCT, other imaging techniques that can be used to diagnose osteoarthritis of the temporomandibular joint include MRI, ultrasonography, and bone scintigraphy. The posterior disk attachment of the TMJ and other soft tissue alterations are further explained by MR imaging. The objectives of ultrasonography include early diagnosis, differential diagnosis, patient evaluation, and monitoring of temporomandibular joint illness.

Due of its great sensitivity, bone scintigraphy has been utilized to diagnose temporomandibular joint osteoarthritis (TMJ-OA) in its early stages.

Keywords: *Temporomandibular Joint Osteoarthritis (TMJ-OA); Cone Beam Computed Tomography; Magnetic Resonance Imaging; Ultrasonography; Bone Scintigraphy*

Introduction

Osteoarthritis

Osteoarthritis is a prevalent form of joint disease. Osteoarthritis normally progresses slowly. Mechanical, inflammatory, and metabolic variables all contribute to synovial joint deterioration in osteoarthritis. Osteoarthritis is the most frequent type of joint disease. Osteoarthritis normally progresses slowly. Mechanical, inflammatory, and metabolic variables all contribute to synovial joint deterioration in osteoarthritis [1].

The most intricate movement in the human body is carried out by the temporomandibular joint (TMJ), a synovial joint. Osteoarthritis is a degenerative, progressive disorder identified by synovitis, subchondral bone remodeling, and degeneration of the cartilage. TMJ osteoarthritis is the most prevalent (TMJ-OA) cases, however, have a complicated and mixed origin or are unknown. TMJ-OA is a common subtype of temporomandibular disorders (TMDs). Secondary TMJ-OA is caused by disc dislocation, trauma, functional stress, and developmental problems [2].

TMJ internal derangements are prevalent, affecting anywhere from 4% to 28% of the adult population. The frequency is approximately 8:1 higher in women; the causes responsible for this predominance are unknown. TMJ issues are caused by trauma, bruxism, stress, and occlusal irregularities. Clinical indications and symptoms of TMJ internal derangement are not consistently reliable for determining the exact amount of the derangement [3].

The temporomandibular joint's (TMJ) two main functions, mastication and speech, have been of significant significance to dentists, orthodontists, clinicians, and radiologists. This interest stems from factors related to structure, function, adaptability, symptomatology, illness, and imaging. The term "ginglymoarthrodial joint" refers to a hinge joint that only permits backward and forward motion in one plane, whereas "arthrodia" refers to a joint that also permits gliding motion of the surfaces. Similar to knee articulation, the right and left TMJ produce a bicondylar articulation and an ellipsoid variation of synovial joints [4].

When it comes to jaw dysfunctions, the meniscus is especially important. It is located between the condyle and the glenoid fossa and, along with its different attachments and synovial fluid, occupies the area between them [5].

Cone beam computed tomography imaging showing changes in temporomandibular joint osteoarthritis

Cone-beam computed tomography (CBCT) is used to diagnose the bony structures of the temporomandibular joint. It measures the breadth of the articular space, the head of the condyle, and the form of the joint surfaces. Unless the articular disc calcifies with really severe degenerative changes, it is not evident on a CBCT scan. Only by evaluating the condylar head's location in the articular fossa can one determine indirectly the location of the articular disc in the temporomandibular joint [1].

The following traits are evaluated on CBCT in connection to the modifications in patients with temporomandibular joint osteoarthritis as shown in figure 1.

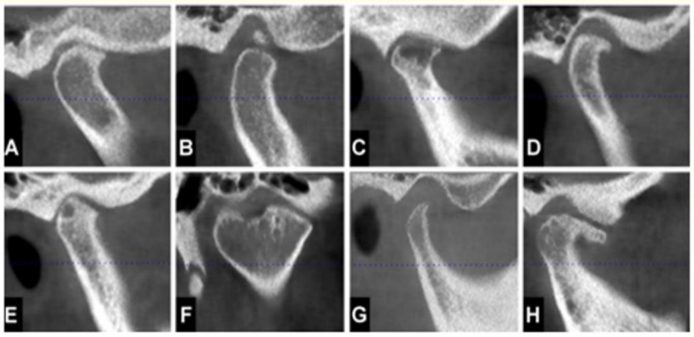

Figure 1: *Examples of the CBCT images of osseous changes in the temporomandibular joints (TMJ-OA) [6].*

A - Condylar flattening, subcortical sclerosis and joint space narrowing.

B - Loose calcified body.

C - Erosion in the condylar head and the sclerosis of the articular fossa.

D - Osteophyte formation of the condyle.

E - Subchondral cyst and the flattening of articular surfaces.

F - Bifid condyle.

G - Condylar hypoplasia: Condylar hypoplasia is characterized by normal condylar morphology but decreased size in all dimensions; condylar hyperplasia is characterized by increased size in all dimensions; and articular surface flattening (loss of the rounded contour of the surface) [7].

H - Osteophyte formation of the condyle, the sclerosis of the articular fossa and the flattening of the articular eminence.

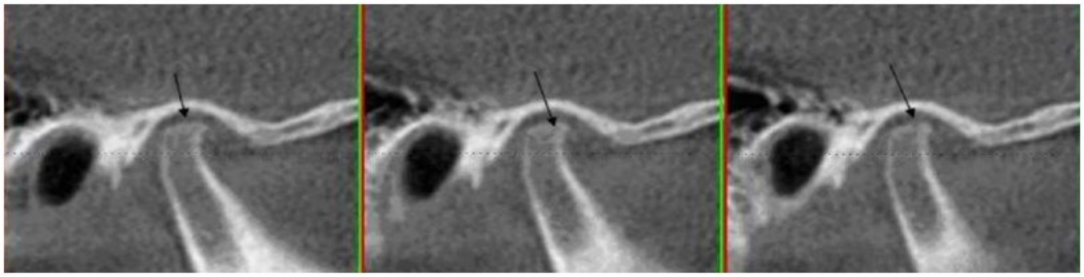

Figure 2: *Articular surface flattening and slight erosive changes of mandibular condyle [7].*

Pain during mandibular function may be caused by degenerative changes on the articular surface of the joint, which is subjected to increased loading during mandibular function, whereas joint pain during palpation may be caused by pathological changes in the lateral and posterior parts of the condyle [8].

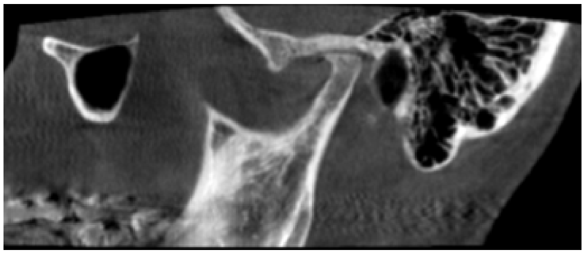

Figure 3: *Showing articular surface flattening [9].*

Figure 4: *Deformation of mandibular condyle, presenting subchondral sclerosis and osteophyte formation [7].*

Subcortical sclerosis (any increase in cortical plate thickness in load-bearing areas compared to neighboring nonload-bearing areas) [7].

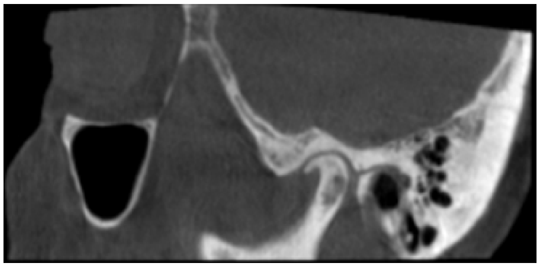

Figure 5: *In the oblique sagittal section view of the CBCT, osteoarthritis is shown as a deformed joint with a condylar osteophyte and subcortical sclerosis in the condyle and fossa on CBCT [9].*

The most common combination of bone alterations in TMJ OA was articular surface flattening, condyle osteophyte development, and fossa/eminence flattening [9].

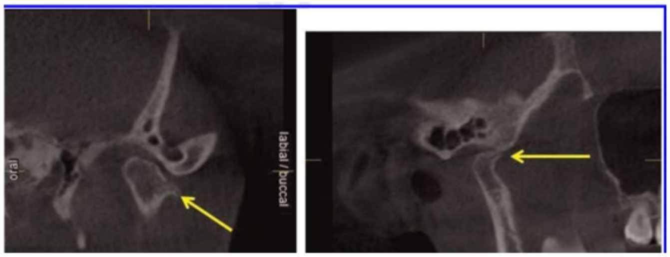

Figure 6: *Osteophyte shown on CBCT [10].*

Flattening: loss of an even convexity or concavity of the joint outlines, osteophyte: local outgrowth of bone arising from a mineralized joint surface [10].

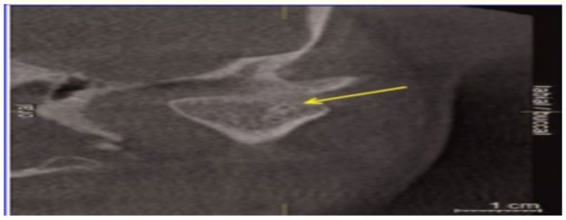

Figure 7: *Sub-cortical cyst shown on CBCT [10].*

A spherical radiolucent region that may be deep within trabecular bone or just below the cortical plate is known as an Ely's cyst (sub cortical cyst) [10].

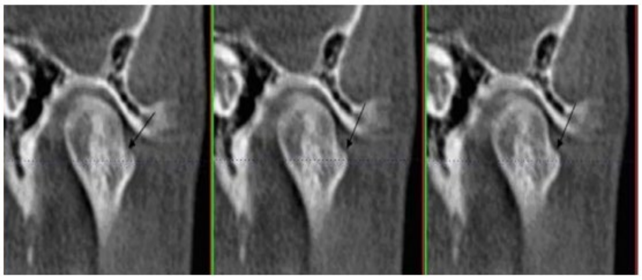

Figure 8: *Deviation in form of mandibular condyle [7].*

Deviation in form (a departure from normal shape that is not attributable to flattening) [7].

[All these features can be appreciated for temporomandibular joint osteoarthritis [TMJ-OA] on CBCT imaging].

Magnetic resonance imaging

In 1984, magnetic resonance imaging of the temporomandibular joint was first employed. Because prior methods were invasive and/or lacked the capacity to show: the disc, bilaminar region, surrounding muscles, and other soft tissues of the TMJ, the advantages of magnetic resonance over other radiological modalities were obvious early. As a result, MRI was the primary modality of TMJ diagnosis in the 1990s. MRI indications are determined by diagnostic criteria that have been confirmed through clinical diagnosis. The use of MRI allows for the differentiation of TMJ structures with complicated anatomical aspects. Furthermore, MRI scans of soft tissues, particularly those of the disc, clearly indicate variations. The Importance of MRI in diagnosis is found in fact that the most common TMJ derangements, such as disc opacities and osteoarthritis, are readily visible. MRI is a sophisticated and costly diagnostic technology, with strict clinical indications for its usage [14].

The following traits are evaluated on MRI in connection to the abnormalities in patients with temporomandibular joint osteoarthritis and are as follows.

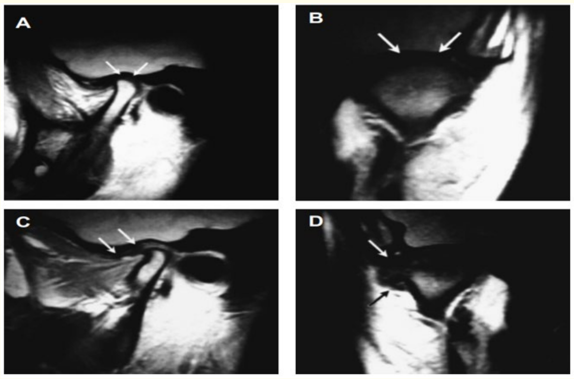

Figure 9A-9D: *A-B: Left TMJ that does not have internal derangement or osteoarthrosis.*

A. Sagittal MRI shows posterior band of the disk (arrows) superior to condyle.

B. Coronal MRI shows disk superior to condyle (arrows).

C-D: Right TMJ with OA and anterolateral disk displacement without reduction.

C. Sagittal MRI shows disk (arrows) anterior to condyle, which is flattened and deformed.

D. Coronal MRI showing lateral disk displacement [11].

These days, doctors routinely ask for magnetic resonance imaging (MRI) to look at the TMJ structures in TMD patients. This is a non-invasive method for identifying bone structures, changes in bone marrow, disc position, and joint fluid effusion. The clinical signs and symptoms of TMD have been found to be highly associated to MR imaging of OA and DD. This is a non-invasive technique for determining disc position, joint fluid, bone marrow alterations, and bone structures [12].

MR imaging is now the gold standard for identifying disk injuries, which can present as intrinsic disk lesions (e.g. changes in shape and signal intensity) or disk displacement [12].

Effusion of joints

A considerable volume of articular fluid is usually classified as joint effusion. The occurrence of joint effusion in asymptomatic patients is an unusual sign, and only modest volumes of fluid are found in these cases [13].

Joint effusion in large volumes has been associated to TMJ discomfort and disk displacement, and it represents an early alteration that can precede osteoarthritic changes. T2-weighted sequences are good for displaying joint effusion, which shows on MR imaging as regions of hyperintensity. Anterior band joint effusion is a typical finding [13].

A "arthrographic effect" is seen when there is a significant concentration of fluid, in which the fluid enhances the form of the disk in the upper and lower joint spaces. MR imaging can also help distinguish between joint effusion and synovial growth. Some scientists feel that gadolinium-enhanced MR imaging of the TMJ is beneficial. can distinguish between proliferating synovium that increases and joint effusion that does not. If rheumatoid inflammatory joint disease with joint effusion is suspected, this approach may be useful [13].

Figure 10: *Joint effusion.*

This phenomenon is best seen on T2-weighted images [13].

Retrodiscal layer rupture

The bilaminar zone is an anatomic area composed of Superior and inferior retrodiscal layers, as well as vasculonervous systems. The lower retrodiscal layer comprises the inferior retrodiscal layer is composed of collagen fibers, whereas the superior retrodiscal layer is composed of elastic fibers. These retrodiscal layers are made from of are crucial in proper disk displacement. MR imaging advancements now enable for precise representation of these structures and associated disease alterations. Superior retrodiscal layer fiber rupture can cause considerable disk instability [13].

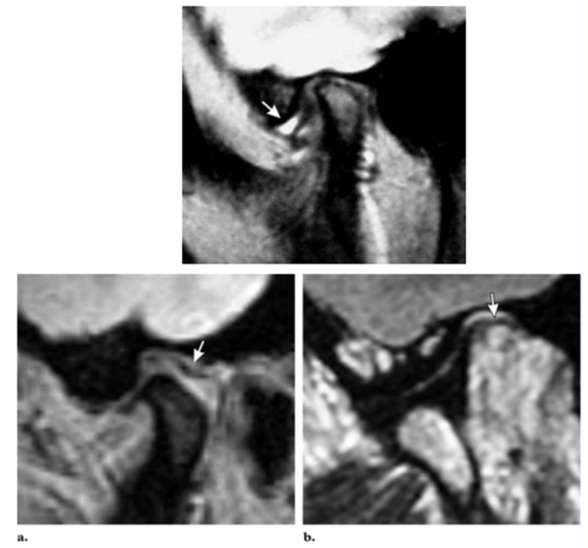

Figure 11: *This figure shows a retrodiscal tissue which is normal.*

A: The retrodiscal layers (arrow) are clearly visible in the sagittal oblique gradient-echo T2-weighted MR picture (closed mouth posture). These structures are vital in normal disk movement and are plainly seen with MR imaging.

B: Sagittal oblique spin-echo proton-density-weighted MR image (open-mouth position) shows the superior retrodiscal layer (arrow) between the posterior band and the mandibular fossa [13].

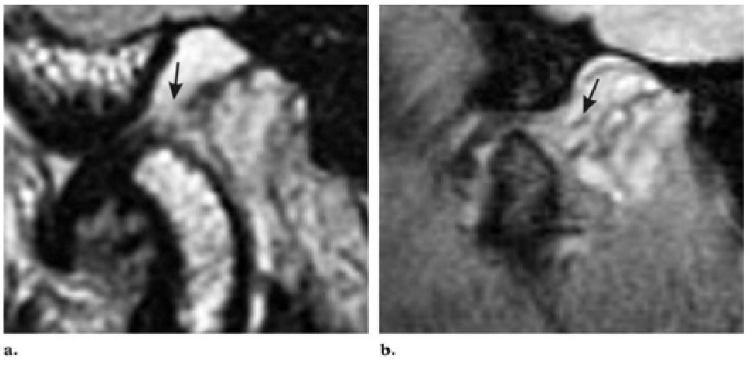

Figure 12: *This figure shows retrodiscal tissue which is abnormal.*

(a) Sagittal oblique spin-echo proton-density-weighted MR image (open-mouth position) obtained in a patient with internal derangement without reduction shows rupture of the fibers of the superior retrodiscal layer (arrow), resulting in loss of union with the posterior band.

(b) Sagittal oblique gradient-echo T2-weighted MR image (closed-mouth position) obtained in a different patient again depicts rupture of the fibers of the superior retrodiscal layer (arrow) [13].

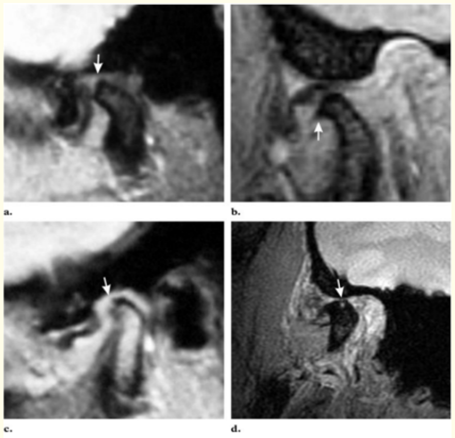

Figure 13: *Changes in osteoarthritis in four separate patients.*

A: Condylar flattening.

B: An osteophyte (arrow) is clearly visible.

C: Condylar erosion (arrow) is visible.

D: Demonstrates a condylar osteophyte, flattening, sclerosis, and erosion (arrow), all of which are signs of osteoarthritic changes [13].

Ultrasonography

TMD is best identified early, diagnosed differently, evaluated, and monitored by ultrasonography (USG). In addition, we would like to look at the United States' involvement in the diagnosis and assessment of illnesses. When carried out by a highly experienced specialist, USG is a sensitive and precise TMD screening method, with the exception of medially displaced discs.

operator. If the TMJ examination reveals any irregularities, An MRI should be performed for the patient. Despite a normal screening USG, if a component of medial disc displacement is discovered, an MRI should be performed. Only joint effusion was satisfactorily appraised by a majority of writers among the TMJ abnormalities (disk displacement, joint effusion, bone deformity). USG imaging can improve sensitivity and specificity after a baseline MRI. The use of ultrasound (USG) has the potential to be a beneficial a different imaging strategy for identifying TMJ issues, particularly the presence of intraarticular effusion (high accuracy). improved method uniformity, as well as standard criteria, are required. TMJ USG imaging can detect a variety of pathological abnormalities and can be used as a diagnostic tool [15].

A brief preliminary diagnostic process used to rule out various clinical hypotheses. Positive findings in the USG, on the other hand, should be validated by MRI. It's unknown whether USG can detect lateral and posterior displacements. In terms of detecting bone structures, the USG performs admirably. The accuracy of USG in determining the disc is shown in a normal position and disc-condyle connection problems are present. The comparison of disc displacement with and without reduction is less useful when using USG. Patients with TMD can have their disk displacement and joint effusion checked in the USG. USG is a reliable diagnostic method for identifying disc movement in general. The synovial structures, the articular disk, erosions, cystic lesions, flattening of the articular condyle, and destructive alterations to the joint are all examples of destructive arthritic changes. Condylar inflammation cannot yet be distinguished by TMJ USG results [15].

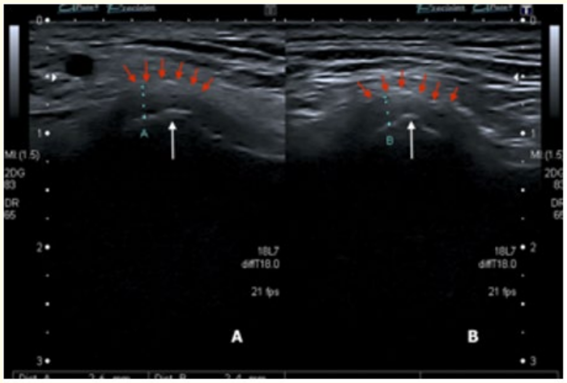

Figure 14: *Protocol for ultrasound synovitis is described as thicker synovia, joint effusion, and active synovial inflammation [16].*

Ultrasound imaging photos show that the condyle's surface is hyperechoic, or highly reflective of sound waves, and appears white. The muscles (lateral pterygoid and masseter) and connective tissues (joint capsule, retrodiscal tissue) in the ultrasound imaging pictures appear heterogeneously gray and are isoechoic (intermediate reflection of sound waves). But the joint capsule's border creates a white line since it reflects the USG waves very well. That sounds hyperbolic. These anatomic gaps are imaginary and typically unnoticeable unless effusion occurs because the opposing surfaces are in contact [15].

Figure 15: *Conventional USG transducer positions are parallel to the Frankfort horizontal plane (a plane connecting the highest point of the opening of the external auditory canal with the lowest point on the lower margin of the orbit) in closed-mouth [15].*

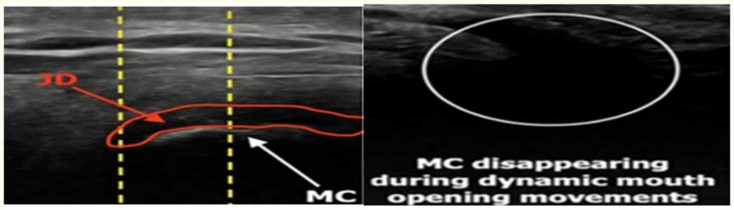

Figure 16: *The normal ultrasound appearance of the articular disk in the sagittal plane is an inverted hypoechoic C- shaped structure, outlined by the red circle [15].*

Figure 17: *Red arrows show the articular capsule [15].*

USG has been widely employed to detect effusion in many musculoskeletal areas; it is accurate at depicting the presence of intraarticular inflammatory fluids in larger joints [16].

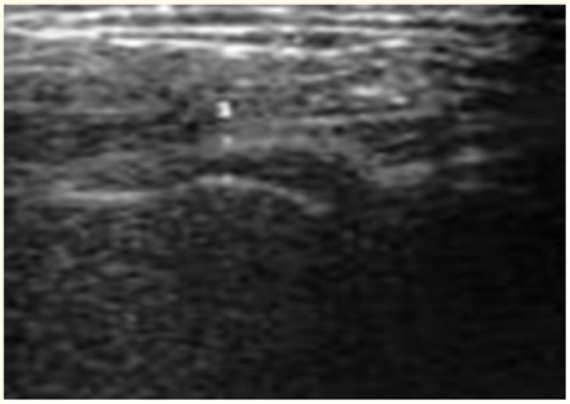

Figure 18: *The presence of joint effusion can be detected indirectly by measuring the distance between the two articular surfaces [16].*

Bone scintigraphy

Ultrasound imaging photos show that the condyle's surface is hyperechoic, or highly reflective of sound waves, and appears white. The muscles (lateral pterygoid and masseter) and connective tissues (joint capsule, retrodiscal tissue) in the ultrasound imaging pictures appear heterogeneously gray and are isoechoic (intermediate reflection of sound waves). But the joint capsule's border creates a white line since it reflects the USG waves very well. That sounds hyperbolic. These anatomic gaps are imaginary and typically unnoticeable unless effusion occurs because the opposing surfaces are in contact.

However, uptake of the bone tracer could be influenced by other factors, including infection, trauma, tumour, and the remodelling process after orthodontic treatment or temporomandibular disorder (TMD) treatment, hence the specificity of bone scintigraphy is relatively low compared to that of other modalities such as MRI and CT [17].

The radioisotope technetium 99m hydroxymethylene diphosphonate (740 MBq) was delivered intravenously into the subjects. Four hours later, static bone scintigraphy images, including lateral side views of the right and left regions of the cranium, were obtained using a dual-head gamma camera with a low-energy and high-resolution collimator [17].

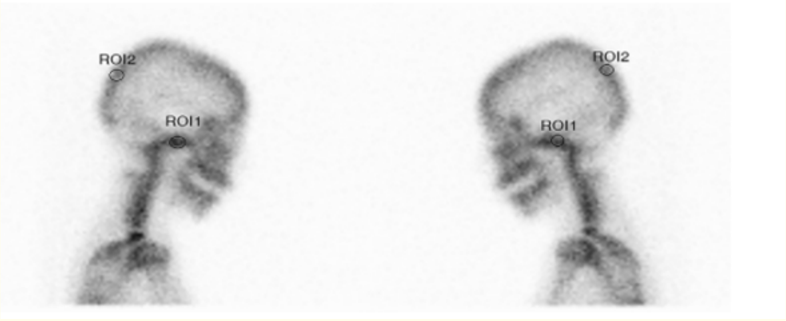

Figure 19: *Bone scintigraphy quantitative analysis using regions of interest (ROI). ROI1 was placed on both sides of the temporomandibular joints (TMJs). ROI2 was placed over the parietal bone area [17].*

Image analysis qualitative analysis: Visual analysis was used by experienced nuclear medicine practitioners to assess the uptake level of 99Tcm-HDP by the TMJ. The TMJ uptake results were compared to the contralateral joint's uptake. The change in the appearance of the mandibular condyle detected by orthopantomography and panoramic TMJ radiography was classified by a dentist as one of the following: no change, sclerosis, erosion, deformity, flattening, or osteophyte [18].

Quantitative analysis: A square area of the region of interest (13613 pixels) was designated for this purpose. TMJ 99Tcm-HDP uptake level was quantified, and counts in both the TMJ and parietal bones were assessed. The parietal bone was used as a baseline measurement to calculate the uptake ratio for the right and left TMJ areas, and the asymmetry index of the normal joint (contralateral to the TMJ) was calculated using the following formulas:11 N TMJ uptake ratio 5 (TMJ counts minus background counts)/background counts. 5 TMJ uptake ratio of the involved joint/TMJ uptake ratio of the non-involved joint N Asymmetrical index for the affected TMJ joint [18].

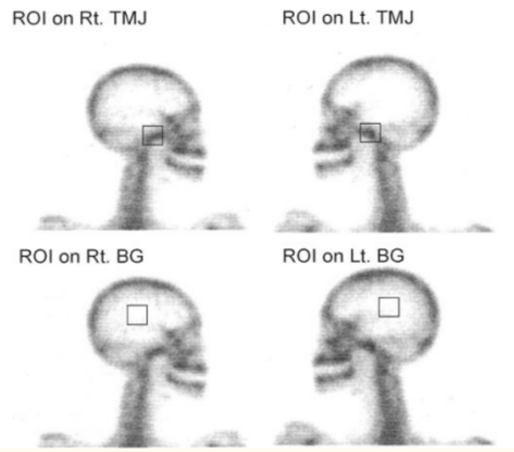

Figure 20: *On the right (Rt) and left (Lt) lateral skull images, 13613 pixel-square ROIs were located at the bilateral temporomandibular joints (TMJ) and parietal skull areas [18].*

Planar bone scintigraphy

The investigation made use of a SPECT/CT scanner configured with low-energy, high-resolution collimators. Regional planar pictures encompassing anterior, posterior, right lateral, and left lateral views were collected 3 - 4 hours after intravenous injection of 99mTc hydroxymethylene diphosphonate (dosage, 1295 MBq). Using planar bone scintigraphy pictures, two nuclear medicine physicians visually examined the 99mTc hydroxymethylene diphosphonate absorption in individual TMJs [19].

Figure 21: *TMJ uptake is visually graded in planar bone scintigraphy pictures. (a) Standard (grade 1). (b) Moderately to severely abnormal (grade 2). Severe abnormality (grade 3) [19].*

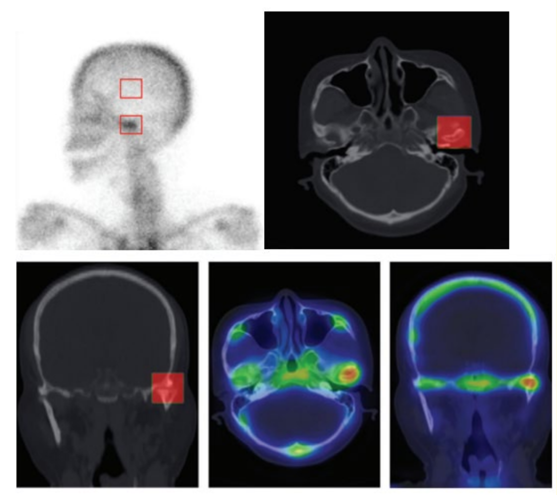

Figure 22: *Different imaging techniques used for bone scintigraphy [19].*

Conclusion

CBCT - a widely used method that results in images of CT like quality obtained using less expensive equipment and components, shorter patient examination time and a much lower radiation dose than required for conventional CT and it is mostly used to assess the bony changes in TMJ-OA.

Since MRI can precisely identify both the acute and chronic arthritic sequelae, it is presently considered the gold standard imaging modality for the examination of TMJ-OA, surpassing even ultrasonography in this regard.

Planar bone scintigraphy

The investigation made use of a SPECT/CT scanner configured with low-energy, high-resolution collimators. Regional planar pictures encompassing anterior, posterior, right lateral, and left lateral views were collected 3 - 4 hours after intravenous injection of 99mTc hydroxymethylene diphosphonate (dosage, 1295 MBq). Using planar bone scintigraphy pictures, two nuclear medicine physicians visually examined the 99mTc hydroxymethylene diphosphonate absorption in individual TMJs [19].

Figure 21: *TMJ uptake is visually graded in planar bone scintigraphy pictures. (a) Standard (grade 1). (b) Moderately to severely abnormal (grade 2). Severe abnormality (grade 3) [19].*

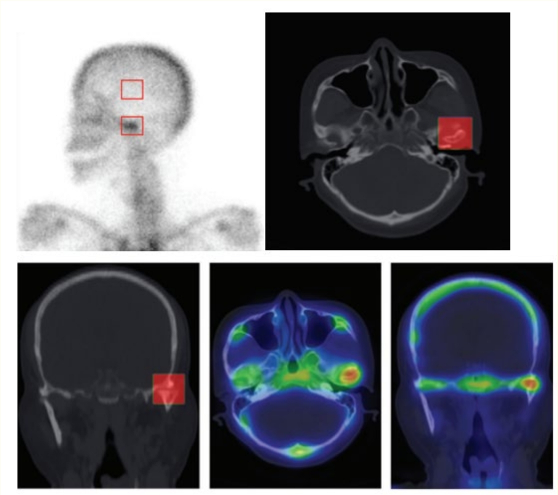

Figure 22: *Different imaging techniques used for bone scintigraphy [19].*

Conclusion

CBCT - a widely used method that results in images of CT like quality obtained using less expensive equipment and components, shorter patient examination time and a much lower radiation dose than required for conventional CT and it is mostly used to assess the bony changes in TMJ-OA.

Since MRI can precisely identify both the acute and chronic arthritic sequelae, it is presently considered the gold standard imaging modality for the examination of TMJ-OA, surpassing even ultrasonography in this regard.

Due to its many benefits over magnetic resonance imaging (MRI), including its cheap cost, wide availability, and real-time rapid evaluation capabilities-the last two of which are particularly beneficial for patients with claustrophobia and the pediatric population-ultrasonography can be recommended as a helpful examination method in the assessment of TMJ-OA.

Bone scintigraphy- because to its great sensitivity, has been utilized for the detection of TMJ OA in its early stages.

Conflict of Interest

There is no conflict of interest.

Bibliography

1. Derwich Marcin., *et al*. "Interdisciplinary approach to the temporomandibular joint osteoarthritis—review of the literature". *Medicina* 56.5 (2020): 225.
2. Wang XDd., *et al*. "Current understanding of pathogenesis and treatment of TMJ osteoarthritis". *Journal of Dental Research* 94.5 (2015): 666-673.
3. Katzberg Richard Wier. "Temporomandibular joint imaging". *Radiology* 170.2 (1989): 297-307.
4. Alomar X., *et al*. "Anatomy of the temporomandibular joint". *Seminars in Ultrasound, CT and MRI* 28.3 (2007): 170-183.
5. Werner Jochen A., *et al*. "Functional anatomy of the temporomandibular joint: A morphologic study on human autopsy material". *Anatomy and Embryology* 183.1 (1991): 89-95.
6. Koç Nagihan. "Evaluation of osteoarthritic changes in the temporomandibular joint and their correlations with age: A retrospective CBCT study". *Dental and Medical Problems* 57.1 (2020): 67-72.
7. Krisjane Z., *et al*. "The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study". *International Journal of Oral and Maxillofacial Surgery* 41.6 (2012): 690-695.
8. Kiliç S., *et al*. "Temporomandibular joint osteoarthritis: cone beam computed tomography findings, clinical features, and correlations". *International Journal of Oral and Maxillofacial Surgery* 44.10 (2015): 1268-1274.
9. Ottersen Margareth Kristensen., *et al*. "CBCT characteristics and interpretation challenges of temporomandibular joint osteoarthritis in a hand osteoarthritis cohort". *Dentomaxillofacial Radiology* 48.4 (2019): 20180245.
10. Talaat Wael., *et al*. "CBCT analysis of bony changes associated with temporomandibular disorders". *CRANIO®* 34.2 (2016): 88-94.
11. Bertram Stefan., *et al*. "Diagnosing TMJ internal derangement and osteoarthritis with magnetic resonance imaging". *The Journal of the American Dental Association* 132.6 (2001): 753-761.
12. Campos MIG., *et al*. "Analysis of magnetic resonance imaging characteristics and pain in temporomandibular joints with and without degenerative changes of the condyle". *International Journal of Oral and Maxillofacial Surgery* 37.6 (2008): 529-534.
13. Tomas Xavier., *et al*. "MR imaging of temporomandibular joint dysfunction: a pictorial review". *Radiographics* 26.3 (2006): 765-781.
14. Badel T., *et al*. "Diagnostics and management of temporomandibular joint disorder-a reported case with a review of literature". *Journal of Dental Problems and Solutions* 3.1 (2016): 018-023.
15. Maranini Beatrice., *et al*. "The role of ultrasound in temporomandibular joint disorders: an update and future perspectives". *Frontiers in Medicine* 9 (2022): 926573.

16. Manfredini D and L Guarda-Nardini. "Ultrasonography of the temporomandibular joint: a literature review". *International Journal of Oral and Maxillofacial Surgery* 38.12 (2009): 1229-1236.

17. Kang J-H., *et al*. "Influences of age and sex on the validity of bone scintigraphy for the diagnosis of temporomandibular joint osteoarthritis". *International Journal of Oral and Maxillofacial Surgery* 47.11 (2018): 1445-1452.

18. Kim JH., *et al*. "Effectiveness of bone scans in the diagnosis of osteoarthritis of the temporomandibular joint". *Dentomaxillofacial Radiology* 41.3 (2012): 224-229.

19. Suh Min Seok., *et al*. "Maximum standardized uptake value of 99mTc hydroxymethylene diphosphonate SPECT/CT for the evaluation of temporomandibular joint disorder". *Radiology* 280.3 (2016): 890-896.

Volume 23 Issue 4 April 2024