BALKAN JOURNAL OF STOMATOLOGY

BaSS

ISSN 1107 - 1141

A Review of the Imaging Modalities Available for TMD Diagnosis

SUMMARY

Temporomandibular disorders (TMD) affect more than 5% of the general population. Radiologic investigation of the temporomandibular joints (TMJ) and surrounding tissues offer information adding to the clinical examination, and establishing the final diagnosis. Plain radiographs are helpful as screening tools for the evaluation of bony surfaces of the TMJs. Transcranial, transpharyngeal and transmaxillary projections are used sometimes in combination. Orthopantomography or panoramic radiography is limited in functional disorders, such as hypermobility and recurrent dislocation of condyles. Tomography generates slices of the area of interest but the development of more modern imaging modalities has practically reduced its utilization. Arthrography is an invasive procedure that shows indirectly the position and the shape of the disc, as well as disc perforations or adhesions to the fossa. Computerized tomography offers advanced capabilities of imaging the hard tissues. Advancement of the equipment with cone beam CT further enhanced its diagnostic value for arthritides. Magnetic resonance imaging reproduces in detail the disc and soft tissues and provides acceptable imaging of the bone surfaces. Improvements in the technique, by using paramagnetic contrast medium intravenously or intraarticularly, render MRI the current golden standard in TMJ imaging. Ultrasound is a radiation free, non invasive and repeatable technique, recently proposed for use in TMD. Other examinations such as scintigraphy or single photon emission tomography have specific indications and restricted use in TMJ diagnostics. Finally, among the various techniques the clinician must choose the most appropriate to the kind of information needed.

Keywords: Temporomandibular Disorders, diagnostics; Temporomandibular Joint, imaging

Gregory Venetis[1], Anastasia Beketova[2], Ioannis Dimitrakopoulos[1], Petros Koidis[2]

Aristotle University of Thessaloniki
School of Dentistry, Thessaloniki, Greece
[1] Dept of Oral and Maxillofacial Surgery
[2] Dept of Fixed Prosthesis and
Implant Prosthodontics

REVIEW PAPER (RP)
Balk J Stom, 2010:14:52-58

Introduction

Temporomandibular disorders (TMD) represent one of the most common dysfunctions, affecting a large segment of population. In developed countries, more than 5% seek medical help for symptoms related to the masticatory system[1]. Prompt clinical diagnosis is the fundamental step towards effective treatment, although staging and classification of TMD may differ among clinicians. A radiologic examination of the temporomandibular joint (TMJ) gives the clinician the opportunity to: (a) support the clinical diagnosis and proceed to a differential diagnosis; (b) obtain new information, depending on the selected examination modality; (c) adapt the information to the clinical diagnosis and vice versa; and (d) develop the necessary skills that will enable him to choose the most appropriate and cost-effective solution for each case.

In the present study, 6 main radiologic examinations are compared with respect to their indications, limitations, and cost: plain radiography (transcranial, transpharyngeal, and transmaxillary projections), orthopantomography and its variants, arthrography, conventional as well as computerized tomography(CT) with emphasis on novel technology such as cone beam CT, magnetic resonance imaging (MM), and, finally, magnetic resonance arthrography. Other, specifically used diagnostic modalities, such as ultrasonography and scintigraphy, are also discussed.

Description of Radiologic Techniques

Plain Film Radiography

The term "plain" refers to radiographs made with a stationary x-ray source and film, or with a digital receptor. Radiographs of the TMJ in 1 plane are the simplest, fastest and easiest way to obtain certain information on TMJ hard tissues[3]. To get valid information on joint structures, at least 2 different views in perpendicular projections are necessary[4].

Lateral Oblique Transcranial Projection (Schuller) directs the x-ray beam in a manner that is approximately parallel to the long axis of the condyle. The 15 to 25 degree angle between the beam and the horizontal plane, described as "positive" when beam is directed from a point above the TMJ, and focused down on the examined joint, reveals the lateral aspect of the joint. The central and medial portions of the joint are projected downwards, superimposed on the rest of the condylar process.

The transcranial view can be used to examine the TMJ for gross arthritic changes, particularly in the lateral part of the joint, but may not reveal subtle osseous changes and will not display the disc[5]. An overall estimation of the space between osseous elements is also possible with this view (Fig. l).

In the *transpharyngeal projection*, the x-ray beam is projected to the TMJ through the mandibular sigmoid notch of the opposite side in front of, and below the joint. The mouth must be opened to avoid superimposition of neighbouring structures, and the film is placed parallel to the sagittal plane of the head[5]. This projection yields a lateral view of the condylar head and neck, and of its articular surface.

This view is effective for visualizing destructive changes, but less valuable in visualizing productive changes[6]. Information on the temporal component of the joint cannot be obtained with this modality (Fig. 2).

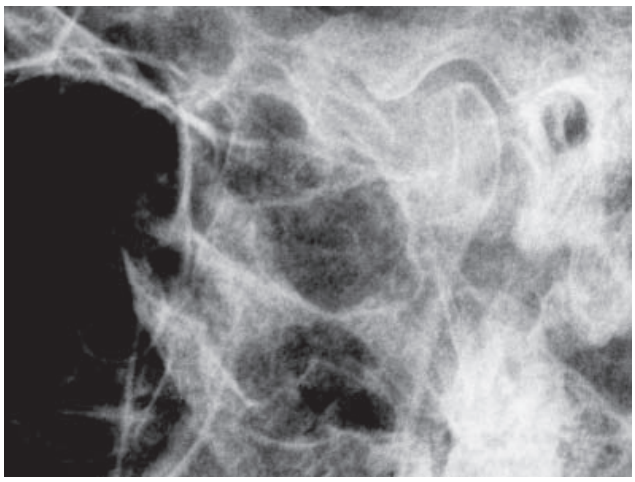

Figure 1. Transcranial view of the left TMJ shows quite regular articular surfaces and a space between them with normal dimensions and shape

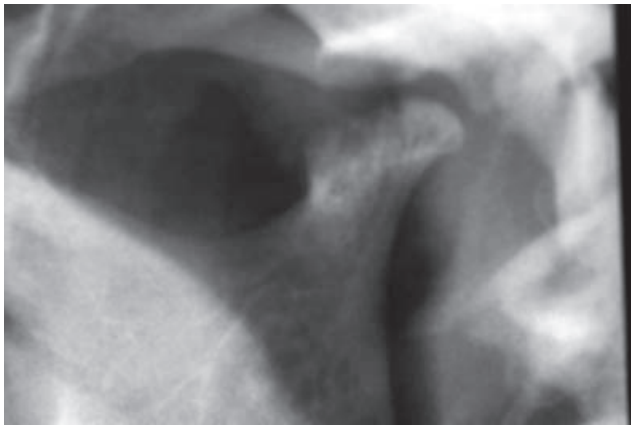

Figure 2. Transpharyngeal view - left TMJ: Destructive changes of the condylar articular surface; satisfactory view of the lateral pole of the condyle. Multiple superimpositions over the glenoid fossa

The ***transmaxillary (anterior-posterior or oblique infraorbital) projection*** directs the beam approximately perpendicular to the long axis of the condyle, at a vertical angulation of 10° from above and at a horizontal angulation of 35° from the mid-sagittal plane. The mouth must be opened so the condyle is out of the glenoid fossa. This allows evaluation of the medial and lateral poles of the condyle, as well as its articular surface, but gives no information on the internal relationships of the joint.

Imaging of the TMJ with plain radiographs is used mainly for initial study and draft evaluation of articular surfaces and articular space. Although there is no evidence to support the use of plain film radiography in diagnosing erosions and osteophytes, plain radiography is nevertheless of some value, since the most common areas of osteophyte growth are the anterior and lateral aspects of the condyle[9].

Orthopantomography

Panoramic radiograph (PR) is the technique of choice in general dental practice, and provides adequate screening images of the TMJ, mandible, maxilla, teeth and surrounding hard tissues. The effective radiation dose in PRs is low (compared to plain film radiography). Modern machines deliver a radiation dose of approximately 20 mGr (milligrays, 1 gray=100 rad) to the skin surface. With the use of digital equipment, the exposure can be reduced by about 43% with no loss image quality[10]. Some panoramic machines utilize special TMJ techniques that permit placement of opened and closed views of both condyles on a single film[11].

Generally, images with the mouth both closed and opened are mandatory in the diagnosis of hypermobility and recurrent dislocation of the condyle. Panoramic images may show only extensive erosions and large osteophytes in the TMJ[9]. Attempts have been made to identify internal derangement of the TMJs from

panoramic radiographs[5]; however, it is reminded that this is a radiographic technique, thus no information is available about soft tissue elements. Occasionally, the clinician can identify patients with potential internal derangements of the TMJ[11], but distortion effects may disturb image quality[5] (Fig. 3).

In conclusion, PR can give a general impression of the joint in 2 dimensions, but it is less sensitive in evaluating changes in condyles, its reliability is poor, and its accuracy in evaluating temporal components of the joint is low; thus its value for TMJ diagnostic purposes is questionable[13,14].

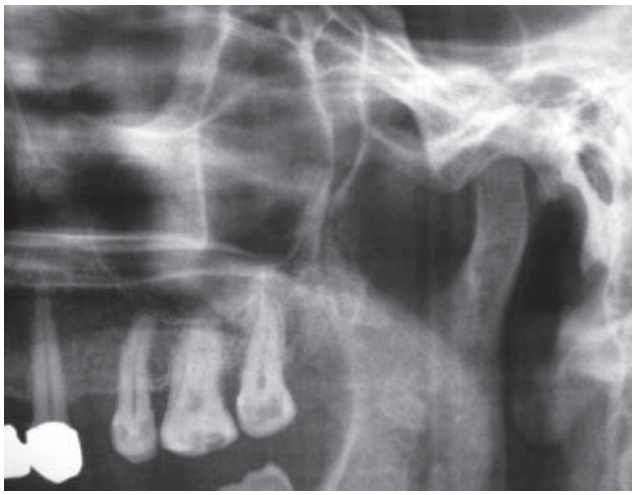

Figure 3. PR particularity showing the left TMJ with closed mouth. The "deep" fossa does not allow for visualization of the condylar or the temporal articular surface

Arthrography

In arthrography a non-ionic, water-soluble radiopaque contrast material (usually a derivative of iodine) is injected into either the lower or upper joint space, or into both compartments, sometimes under fluoroscopic guidance. The upper compartment is the one most frequently used. In double-contrast arthrography, a small amount of air is injected into the joint space after the injection of the contrast material. Comparative studies have not proven any statistically significant difference in accuracy between these 2 methods of projection[16].

Arthrography is indicated for evaluation of the location, shape, and movement of the disc, through observation of shape and flow of the contrast material within the articular compartment, as the patient opens and closes the mouth. Perforations of the disc can be determined by flow of the contrast medium from one space after injection into the other; capsular tears and disc adhesions can also be visualised by the same indirect observation of the shape of the medium. If video-fluoroscopy is used, the movement of the disc during function can be recorded.

Disadvantages of arthrography include its invasive nature, the risk of placing the needle outside the joint space, possible allergic reactions to the contrast material, and significant exposure of the patient to radiation. The advent of MRI has contributed to a decrease in the number of arthrographies performed over the last years, but in certain cases e.g. when there is a suspicion of perforations or adhesions, the use of the technique is still indicated[19].

Tomography

Conventional tomography is a sectional radiography procedure depicting a slice of the patient's body. The technical principle behind this modality is that the beam and the film move simultaneously on a predetermined tomographic and around a fixed rotation point, but in opposite directions. This yields a clear picture of objects located at the tomographic plane, whilst other structures appear blurred[14]. Tomography has been used for the study of the TMJ for decades now, either on its own or in combination with a contrast medium (arthrography), because it overcomes the problem of superimposition, which is very common in plain radiographs of the TMJ . Varying patterns and protocols of tomographic rotation have been developed to ensure the clearest possible view of all aspects of the TMJ. The equipment necessary to produce complex motion tomography is more expensive than a conventional x-ray machine and, on the other hand, conventional tomography shares with plain film radiography the problem of invalidity in depiction of soft tissues[5]. With the advent of standardized tomographic images, such as the ones obtained through computerized tomography and magnetic resonance imaging, conventional tomography is gradually being consigned to the history of dental practice.

Computerized Tomography

In computerized tomography (CT), thin sections of the structures of interest can be made in several planes. This imaging technique eliminates blurring of structures located outside the image layer, an inherent shortcoming of conventional tomography, and also overcomes the problem of distortion and superimposition encountered in plain film radiography (Fig. 4). CT can also provide 3-dimensional images through a reconstruction of the original data (Fig. 5).

According to a position paper of the American Academy of Oral and Maxillofacial Radiology published in 1997[5], CT is mainly suited for the diagnosis of bony abnormalities including fractures, dislocations, osteophytes, arthritides, ankylosis, and neoplasia. However, diagnosis of disc displacement cannot be ascertained through CT, although "some promise for CT in the detection of internal derangement" has been recognized[5].

New generation cone beam CTs (CBCT) utilize less expensive equipment, and expose the patient to approximately 20% of the radiation of helical CT[21].

Designation of this equipment is not based on the concept of sectional images but in computer processing of a single rotational scanning of the region of interest. CBCT has specialized imaging capabilities for assessing osteoarthritic changes in detail, and for accurately calculating joint space[22]. It is increasingly used for investigation of TMD because of its operability; another advantage of it is the short examination time which is of importance when a study of both TMJs with open and closed mouth is to be performed.

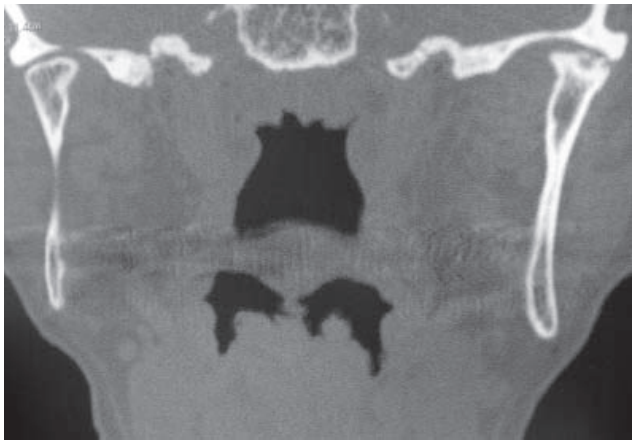

Figure 4. Coronal CT shows severe osteoarthritic changes in the left and mild in the right TMJ

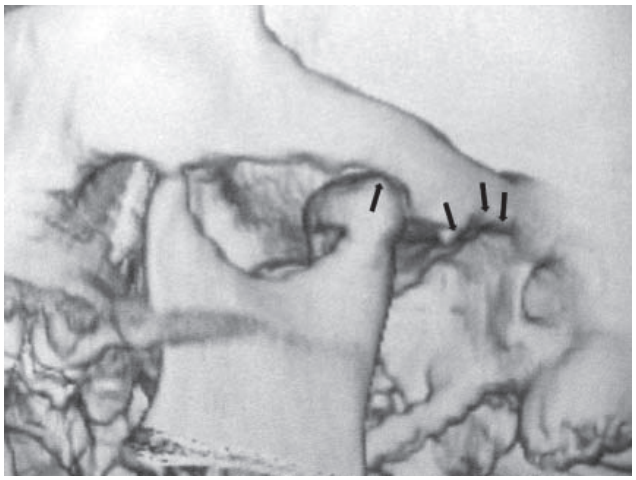

Figure 5. 3D reconstruction of a CBCT with open mouth reveals a recurrent dislocation of the left condyle, whilst provides information the osteoarthritic surfaces of the condyle and fossa (arrows)

Magnetic Resonance Imaging

MRI is an imaging technique in which not only bone, but also soft tissue structures can be reproduced in detail through the use of static and dynamic magnetic fields. MRI utilizes no radiation, and therefore has no harmful biological effects; the procedure is characterized as the gold standard for imaging internal derangement of the TMJ[24] (Fig. 6). However, diagnostic quality can vary widely between institutions, depending on the expertise of the technologists, radiologists interpreting the findings of the examination, on the field strength of the magnet, as well as on the quality of surface coils and software of the MR imager itself[5]. Many reports deal with the improvement of the diagnostic sensitivity of MRI[25], which is achieved by reconstructing images on video, thus enabling a dynamic TMJ display according to some, or by using an intravenously administered paramagnetic contrast medium, a technique referred to as "contrast enhanced" MRI of the joint, according to others. Research has upgraded the value of MRI as a diagnostic tool, but the presence of perforations and adhesions can still be only indirectly inferred through MRI[28]. Furthermore, supporters of arthrography, as well as the American Academy of Oral and Maxillofacial Radiology, state that disc perforations and capsular tears are more successfully detected through arthrography[5].

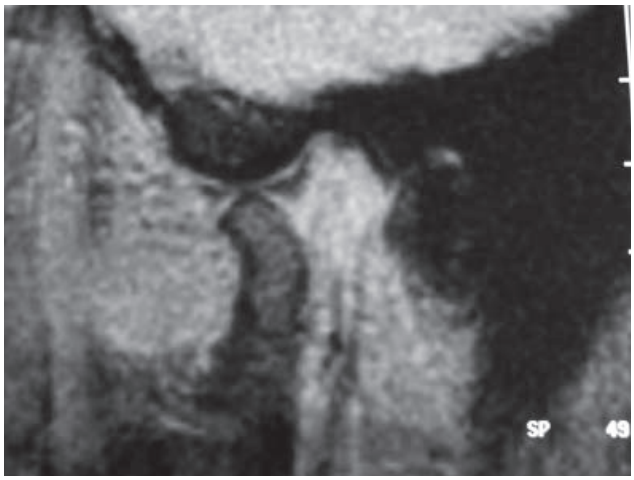

Figure 6. MRI of the left TMJ with open mouth in a patient with the anteriorly displaced disc shows clearly reduction of the condyle

In a paper published in 2000, a new technique of obtaining MR images of the TMJ was proposed, by means of injecting a paramagnetic contrast medium into 1 or both joint spaces (Fig. 7). According to prior developments in orthopedics, the technique is called "MR arthrography", but there is no sufficient data to establish its validity, accuracy, and sensitivity, when compared with classic MRI.

Ultrasonography (US)

TMJ ultrasonography is a non-invasive, readily available, and relatively inexpensive, as well as dynamic "real time" examination. The transducer is placed on the skin above the joint, almost parallel to the long axis of the mandibular ramus[15]. When used at a frequency of 7.5-12

MHz, it may depict the condyle and articular eminence, the narrow space of the joint, and the position of the disc (Fig. 8). High resolution US machines are sensitive in detecting the absence of internal derangement, and reliable in predicting the presence of it.

The most significant advantage of this biologically harmless examination is that allows for a close follow-up of the patient after any treatment applied for TMD. US is a promising modality but its sensitivity, accuracy and positive predictive value will have to be improved in the future, through the use of higher-resolution equipment[34].

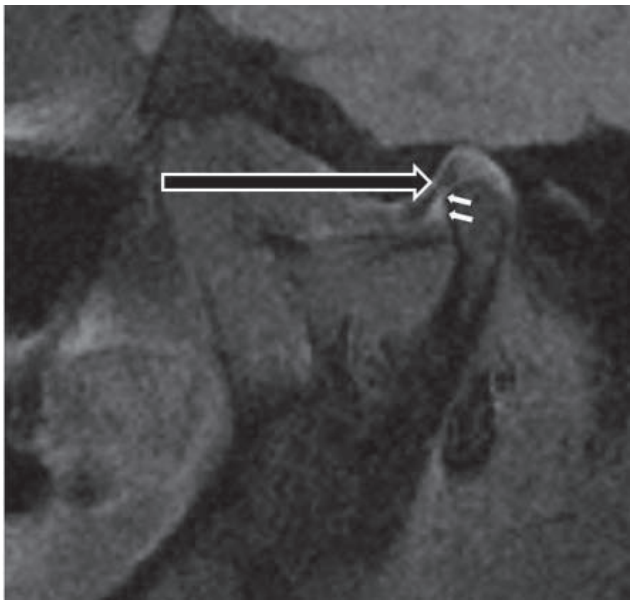

Figure 7. MR arthrography after injection of a paramagnetic medium into the upper articular compartment: A perforation of the anteriorly displaced disc (black arrow) allowed leakage of the medium to the lower compartment (white arrows)

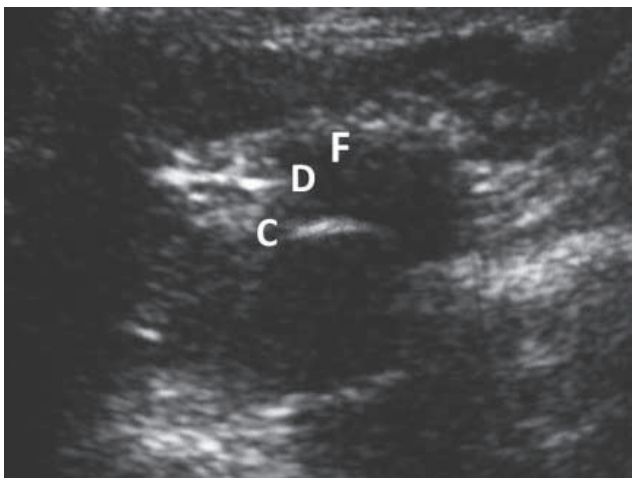

Figure 8. Ultrasound of the left TMJ with open mouth (C: condyle, disc; F: fossa)

Other Imaging Modalities

Nuclear medicine procedures are of specific value with respect to developmental or inflammatory disorders of the TMJ.

Scintigraphy is recommended when the activity of the augmentative centre of the condyle has to be assessed (condylar hyperplasia or avascular necrosis of the condyle). Radionuclide 99mTc is utilized in this examination. ***Single photon emission tomography*** (SPECT) is reported to give sensitive information on inflammatory conditions such as arthritides, but its specificity is low, thus its use is limited.

Discussion

TMJ imaging does not supplant clinical diagnosis, but it does complement it. The clinicians might make a selection among the various imaging modalities based on the criterion of the type of information needed in order to support or dispute their initial clinical diagnosis[15]. Moreover, sometimes their choice is limited (by economic or other issues) to the most appropriate modality among the ones that are available to them. A common error on the part of clinicians regarding the selection of the modality to be employed is that they resort to PR for first draft imaging of the TMJ, when by doing so they run the risk of obtaining false positive results. A possible cause of this practice could be both the clinicians' and the radiologic technicians' lack of familiarity with static projections. It is more informative to use terms for plain radiographs that describe the position of the beam and the film or, at least, a term as descriptive as possible i.e. occipito-mental instead of Water's, or transcranial instead of Schuller.

The clinical diagnosis of masseteric myalgia usually does not require any radiologic confirmation. If, however, it has to be distinguished from arthralgia or the first degree disc displacement with reduction (DWR), the ideal delineation of the diagnosis should be done by US, which gives information on intra-articular presence of liquid (arthralgia), absence of DWR, and masseteric hypertrophy (masseteric myalgia - bruxism). But US is an examiner-dependent examination, and there is not enough experience in its use as a TMJ imaging modality yet. Plain radiography and CT scan are of no use whatsoever in this case. MRI will show the position of the disc, and probably also a hypertrophy of the masticatory muscles. It has to be kept in mind that MRI-indicated disc displacement does not always match the clinical diagnosis, or the symptoms described by the patient. Overall, the group of myofascial pain disorders requires prompt clinical diagnosis, while imaging of the TMJ should be reserved for cases where a clinical suspicion of internal derangement or degenerative change has to be examined.

Disc displacement, with or without reduction, can be radiologically confirmed by either MRI or arthrography. At the moment, US is only valid when it yields negative results (absence of disc displacement). In addition to displacement, MRI may also show disc deformation which is predictive, not evidential, for the integrity of the disc[34]. In cases of chronic and painful disc displacement that is resistant to conservative treatment and indicative for surgery as a treatment option, more specific investigation of disc integrity is needed in order to draw up an accurate treatment plan. To this end, an invasive examination such as arthroscopy, arthrography or MR arthrography is appropriate. The latter is regarded as the preferred method, because it is less invasive than arthroscopy, and in all probability less likely to result in complications such as allergic reactions than conventional arthrography. Moreover, MR arthrography yields comprehensive information on the position of the disc and the existence of adhesions, and can be regarded as the optimal imaging modality for the group of disc displacement[29,31].

Osteoarthrosis and arthritides represent a separate entity of TMD in almost all staging and classification systems. Their difference, when compared with the group of simple disc displacement, lies in the more progressive nature of disc degeneration on the one hand, and in the presence of osseous lesions on the condylar bone surface on the other. Plain radiographs, especially transcranial projections, are sufficient to depict bone lesions[5]. CT scan and cone beam CT give a more detailed picture of the condyle, and 3D reconstruction is able to offer a comprehensive simulation of the operative field, when "shaving" of the condyle is planned[22]. The radiation dose is higher in CT modalities than in plain radiography, but in cone beam CT it is significantly lower. However, the primary concern when surgical intervention is decided upon for treatment of osteoarthritic cases is management of the disc. None of the above-mentioned imaging modalities are sufficiently informative on disc status. MRI and MR arthrography are, as has already been noted, the examinations of choice for the investigation of disc position and composition, but are inferior to CT in the depiction of osteoarthritic lesions[39]. Some authors may argue whether CT is preferable to MRI for pre-surgical evaluation of osteoarthrosis, although it is considered the imaging modality of choice for osseous changes[41,42].

Hypermobility may be considered one of the predisposing factors for internal derangement. Panoramic radiography in both open and closed mouth positions is sufficient for proving condylar dislocation during maximum opening. In later stages, where pain in chewing hard foods is added to the patient's symptoms, the possibility of disc displacement needs to be more specifically investigated through the use of either MRI or MR arthrography.

References

1. *Dimitroulis G*. Temporomandibular disorders: a clinical update. *Br Med J*, 1998; 317:190-194.
2. *Parker M*. A dynamic model of etiology in temporomandibular disorders. *J Am Dent Assoc*, 1990; 120:283-290.
3. *Terzic M, Stanisic* D. Radiologic examination of the temporomandibular joint 1. On plain radiographs. *Stom Glas S,* 1991; 37(4):425-334.
4. *Dias GJ, Premachandra IM, Machoney PM, Kieser JA*. A new approach to improve TMJ morphological information from plain film radiographs. *Cranio*, 2005; 23(l):30-38.
5. *Brooks SL, Brand JW, Gibbs J, et al.* Imaging of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 1997; 83:609-618.
6. *Whaites E*. The Temporomandibular Joint. In: *Whaites E*. (Ed): Essentials of dental radiography and radiology. 3rd ed. Toronto: Churchille Livingstone; 2002; pp 371-388.
7. *Omnel KH*. Radiology of the TMJ. In: *Irby WB* (Ed) Current advances in oral surgery. St Louis: CV Mosby, 1980; pp 196-226.
8. *Lewis EL, Dolwick MF, Abramowicz S, Reeder SL*. Contemporary imaging of the temporomandibular joint. *Dent Clin North Am*, 2008; 52:875-890.
9. *Hussain AM, Packota G*. Role of different imaging modalities in assessment of temporomandibular joint erosions and osteophytes. *Dentomaxillofacial Radiology*, 2008; 37:63-71.
10. *Bumann A, Lotzmann U*. TMJ Disorders and orofacial pain. Stutgart, New York: Thieme, 2002; pp 152-155.
11. *Ahn SJ, Kim TW, Lee DY, Nahm DS*. Evaluation of the internal derangement of the TMJ by panoramic radiographs compared with MRI. *Am J Orthod Dentofac Orthop*, 2006; 129(4):479-485.
12. *Dahlstrom L, Lindvall AM*. Assessment of temporomandibular joint disease by panoramic radiography: reliability and validity in relation to tomography. *Dentomaxillofac Radiol*, 1996; 25(4):197-201.
13. *Ruf S, Panzers H*. Is orthopantomography reliable for TMJ diagnosis? An experimental study on a dry skull. *J Orofac Pain*, 1995; 9(4):365-374.
14. *Schmitter M, Gabbert O, Ohlmann B Hassel A, Wolff D, Rammelsberg P, Kress B*. Assessment of the reliability and validity of panoramic imaging for assessment of mandibular condyle morphology using both MRI and clinical examination as a gold standard. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 2006; 102(2):220-224.
15. *Tvrdy P*. Methods of imaging in the diagnosis of temporomandibular joint disorders. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub*, 2007; 151(1):133-717.
16. *Westesson PL, Bronstein SL*. Temporomandibular Joint: Comparison of Single- and Double-Contrast Arthrography. *Radiology*, 1987; 164:65-70.
17. *Zhang S, Yang C, Zheng J, Wang X, Fan X*. Plain film arhrography applied to the diagnosis of intraarticular adhesions of the temporomandibular joint. *J Oral Maxillofac Surg*, 2007;65(2):212-217.
18. *Hall FM*. Arthography: Past, present and future. *Am J Radiol*, 1987; 149:561-563.
19. *Schellhas KP, Wilkes CH, Omlie MR, Peterson CM, et al*. The diagnosis of temporomandibular joint disease: Two-compartment arthrography and MR. *Am J Radiol*, 1988; 151:341-350.

20. *Helms CA. Kaplan P*. Diagnostic imaging of the temporomandibular joint: recommendations for use of the various techniques. *AJR*, 1990; 154:319-322.
21. *Quereshy FA, Savell TA, Palomo JM*. Applications of cone beam computed tomography in the practice of oral and maxillofacial surgery. *J Oral Maxillofac Surg*, 2008; 66:791-796.
22. *Alexiou K, Stamatakis H, Tsiklakis K*. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. *Dentomaxillofac Radiol*, 2009; 38(3):141-147.
23. *Tsiklakis K, Syriopoulos K, Stamatakis HC*. Radiographic examination of the temporomandibular joint using cone beam computed tomography. *Dentomaxillofac Radiol*, 2004; 33(3):196-201.
24. *Whyte AM, Mc Namara D, Rosenberg I, Whyte AW*. Magnetic resonance imaging in the evaluation of temporomandibular joint disc displacement - a review of 144 cases. *Int J Oral Maxillofac Surg*, 2006; 35:696-703.
25. *Sano T, Westesson PL*. Magnetic resonance imaging of the temporomandibular joint. Increased T2 signal in the retrodiscal tissue in painful joints. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 1995; 79:511.
26. *Burnett KR, Davis CL, Read J*. Dynamic display of the temporomandibular joint meniscus by using "fast scan" MR imaging. *Am J Roetgenol*, 1987; 1499(5): 959-962.
27. *Ogasawara T, Kitagawa Y, Ogawa T, Yamada T, Kawamura Y, Sano K*. Inflammatory change in the upper joint space in temporomandibular joint with internal derangement on gadolinium enhanced MR imaging. *Int J Oral Maxillofac Surg*, 2002; 31:252-256.
28. *Kuribayashi A, Okochi K, Kobayashi K, Kurabayashi T*. MRI findings of temporomandibular joints with disk perforation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 2008; 106(3):419-425.
29. *Toyama M, Kurita K, Koga K, Rivera G*. Magnetic Resonance Arthrography of the Temporomandibular Joint. *J Oral Maxillofac Surg*, 2000; 58:978-983.
30. *Hodler J*. Technical errors in MR arthrography. *Skeletal Radiol*, 2008; 37:9-18.
31. *Yang C, Zhang SY, Wang XD, Fan XD*. Magnetic resonance arthrography applied to the diagnosis of intraarticular adhesions of the temporomandibular joint. *Int J Oral Maxillofac Surg*, 2005; 34(7):733-738.
32. *Gateno J, Miloro M, Hendler BH, Horrow M*. The use of ultrasound to determine the position of the mandibular condyle. *J Oral Maxillofac Surg*, 1993; 51(10):1081-1086.
33. *Brandlmaier I, Rudisch A, Bodner G, Bertram S, Emshoff R*. Temporomandibular joint internal derangement: detection with 12.5 MHz ultrasonography. *J Oral Rehabil*, 2003; 30(8):796-801.
34. *Landes CA, Goral WA, Sader R, Mack MG*. Three-dimensional versus two-dimensional sonography of the temporomandibular joint in comparison to MRI. *Eur J Radiol*, 2007; 61(2):235-244.
35. *Bush FM, Harrington WG, Harkins SW*. Interexaminer comparison of bone scintigraphy and panoramic radiography of temporomandibular joints: correlation with signs and symptoms. *J Prosthet Dent*, 1992; 67:246-251.
36. *Nuebler-Moritz M, Marienhagen J, Held P, et al*. High-resolution SPECT of the temporomandibular joint in chronic craniofacial pain disorders: a pilot study. *Acta Stomatol Belg*, 1995; 92(3):125-128.
37. *Limchaichana N, Nilsson H, Ekberg EC, Nilner M, Petersson A*. Clinical diagnoses and MRI findings in patients with TMD pain. *J Oral Rehabil*, 2007; 34(4):237-245.
38. *Smolka W, Iizuka T*. Arthroscopic lysis and lavage in different stages of internal derangement of the temporomandibular joint: correlation of preoperative staging to arthroscopic findings and treatment outcome. *J Oral Maxillofac Surg*, 2005; 63(4):471-478.
39. *Dworkin SF, LeResche L*. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomand Disord*, 1992; 6:301-355.
40. *Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, John MT, Schiffman EL*. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 2009; 107(6): 844-860.
41. *Yajima A, Sano T, Otonari-Yamamoto M, Otonari T, Ohkubo M, Harada T, Wakoh M*. MR evidence of characteristics in symptomatic osteoarthritis of the temporomandibular joint: increased signal intensity ratio on proton density-weighted images of bone marrow in the mandibular condyle. *Cranio*, 2007; 25(4):250-256.
42. *Campos MI, Campos PS, Cangussu MC, Guimaraes RC, Line SR*. Analysis of magnetic resonance imaging characteristics and pain in temporomandibular joints with and without degenerative changes of the condyle. *Int J Oral Maxillofac Surg*, 2008; 37(6):529-534.

Correspondence and request for offprints to:

Gregory Venetis
Aristotle University of Thessaloniki
School of Dentistry
Dept of Oral and Maxillofacial Surgery
University Campus
54124 Thessaloniki
Greece
E-mail: gvenetis@dent.auth.gr