IJMA

International Journal of Medical Arts

VOLUME 6, ISSUE 2, FEBRUARY 2024

P- ISSN: 2636-4174
E- ISSN: 2682-3780

Available online at Journal Website
https://ijma.journals.ekb.eg/
Main Subject [Radiology]

Original Article

Correlation of Static and Dynamic Magnetic Resonance Imaging Sequences in Evaluation of Temporomandibular Joint Dysfunction

Ahmad Elsayed Mohamed Elnady *[1], Mostafa Fadel Sonble [2], Ahmed Bedeir Abd El-Salam [1]

[1] Department of Radiodiagnosis, Damietta Faculty of Medicine, Al-Azhar University, Damietta, Egypt
[2] Department of Radiodiagnosis, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Article information

Received: 31-08-2022

Accepted: 11-07-2023

DOI: 10.21608/IJMA.2023.159913.1506.

*Corresponding author

Email: a.elnady651@gmail.com

Citation: Elnady AEM, Sonble MF, Abd El-Salam AB. Correlation of Static and Dynamic Magnetic Resonance Imaging Sequences in Evaluation of Temporomandibular Joint Dysfunction. IJMA 2024 January; 6 [2]: 4106-4114. doi: 10.21608/IJMA.2023.159913.1506.

ABSTRACT

Background: Temporo-mandibular joint dysfunction [TMD] is a common condition affecting many adults. To diagnose TMD, physicians commonly use traditional Magnetic Resonance Imaging [MRI] scans of the jaw in multiple fixed positions - both with the mouth closed and open. Nowadays, several fast pulse sequences have been proposed for dynamic MRI by some investigators.

The Aim of the work: This study aims at evaluating the correlation between dynamic and static MRI sequences as diagnostic tools to diagnose temporomandibular joint dysfunction and their ability for diagnosis of the different types of displacement.

Patients and Methods: A prospective study included 40 patients with TMD dysfunction. Static and dynamic MRI studies were compared for different pathological findings.

Results: On comparing static and dynamic studies for various findings, for articular disc detection, dynamic MRI was good for detecting the disc in only 17 [42.5%] versus 30 [75%] by static MRI [P=0.038]. Regarding condylar translation, there was significant difference between the studied techniques as dynamic MRI identified 8 [20%] cases as hypermobile, 14 [35%] as hypomobile in contrast to 1 [2.5%] and 13 [32.5%] cases by static MRI [P=0.001]. Regarding condylar head detection, dynamic MRI was good for its detection in only 30 [75%] versus 37 [92.5%] by static MRI [P=0.012].

Conclusion: Using dynamic MRI, it is possible to observe the articular disc throughout the entire process of opening and closing the jaw, as well as the movements associated with internal derangement and the assessment of the relationship between the disc and the condyle. This method was faster than static MRI. However, there were some discrepancies between the two techniques, and dynamic sequences cannot replace static sequences when evaluating internal derangement disorders of the temporomandibular joint [TMJ], but can be used in conjunction with them.

Keywords: MRI; Temporo-mandibular; Dynamic.

INTRODUCTION

The temporomandibular joint [TMJ] is a crucial component involved in various activities such as speaking, eating, and swallowing, which require the mouth to open and close [1]. TMJ is a highly intricate joint found between the skull and the jawbone, specifically the mandibular condylar process and the temporal bone. It contains an articular disc positioned in the gap between these two structures [2].

TMJ disorder is a prevalent condition that affects a significant portion of the population, with some studies suggesting a prevalence of up to 28% [3]. Internal derangement is the leading cause of TMJ dysfunction, characterized by an abnormal positioning of the disk in relation to the condyle [4]. Disc displacement is the primary issue concerning the physiology of the disc, which can result from various factors such as injury, weakened ligaments, teeth grinding, changes in synovial fluid, or improper functioning of the lateral pterygoid muscle [5].

At present, Magnetic Resonance Imaging [MRI] is widely regarded as the most reliable technique for visualizing the soft tissue elements of the TMJ, including the articular disc, synovial membrane, and lateral pterygoid muscle. It has been identified as the optimal imaging method for identifying disc displacements. By using MRI, it is possible to detect early indications of TMJ dysfunction, such as thickening of the anterior or posterior band, ruptures in the retro discal tissue, alterations in the shape of the disc, and joint effusion [6].

Nevertheless, traditional MRI typically only provides a static and qualitative assessment of TMD, lacks the ability to track the sequential movement of the mandibular condyle and disc within the TMJ, and cannot capture the biochemical changes and potential pathological developments occurring in the disc and related muscles prior to structural damage. Additionally, it is less effective in detecting bony components of the TMJ [7-9]. These limitations may result in an incomplete assessment of TMD, possibly leading to incorrect diagnoses and treatments [10].

To replicate the movement of the joint, numerous researchers have conducted MRI assessments by capturing static images of the joint in various positions during different phases of movement. They then reconstructed the opening and closing of the mouth using specialized cinematic software [11]. However, dynamic assessments of joint function remain a serious challenge. Several attempts of dynamic MRI imaging of TMJ have been advocated since 1987 [12].

Dynamic or real-time MRI refers to rapid and continuous data acquisition followed by image reconstruction and visualization, ideally without noticeable delay [13]. The use of dynamic or real-time MRI is expected to significantly enhance the diagnosis of internal structural derangement, as the intricate and critical positional changes of the TMJ during movement are crucial to the assessment. Pathological conditions can cause alterations in the normal TMJ movement of rotation and translation, as well as protrusion, retraction, and retrusion. This technique will replace pseudo-dynamic MRI, which does not require active muscle contraction and cannot replicate natural motion accurately, in evaluating TMD [14].

The present study was concluded to evaluate the correlation between dynamic and static MRI sequences as diagnostic tools used to diagnose temporomandibular joint dysfunction and their ability to diagnose the different type of displacement.

PATIENTS AND METHODS

This prospective research involved 40 patients clinically diagnosed as temporomandibular joint dysfunction. They were referred to Radiodiagnosis department, Al-Azhar University Hospitals, Damietta.

Inclusion criteria: Patients diagnosed with chronic temporomandibular joint dysfunction and pain [for more than one month] as diagnosed clinically based on symptoms of TMJ dysfunction [joint pain, clicking, and decreased movement].

Exclusion criteria: Patients who are contraindicated for MRI examinations include those with metallic implants, artificial pacemakers, claustrophobia, mental or behavioral disorders that may cause uncooperative behavior, and those who have undergone previous TMJ or facial surgery or suffered facial bone fractures.

Ethical considerations: After obtaining approval of the institutional ethical committee, an informed written consent was received from all patients participating in this research after full explaining the benefits and risks of the study.

Magnetic resonance imaging: MRI examination was conducted using either a 1.5-T GE machine or a Philips Achiva 1.5 tesla machine. Patients were advised to remove any metal objects such as hairpins, coins, or earrings prior to the procedure. The process was explained to patients to provide reassurance, and they were informed about the duration of the examination and the importance of remaining still. Patients were instructed to slowly open and close their mouths for the dynamic study.

Static MRI included assessment of the following: [1] Multiplanar T1 weighted fast-spin-echo sequence [T1WFSE], [2] Multiplanar T2 weighted last-spin-echo sequence [T2WTSE], [3] Multiplanar PD fat-suppression sequences [PDW], and [4] Multiplanar gradient sequences.

The three different parameters were used to acquire parasagittal images in both closed and open mouth positions.

Dynamic MRI: A quick capture of static images was taken during the gradual opening and closing of the subject's mouth, using a single-shot fast spin echo [SSFSE proton density sequence]. About eight to ten images were obtained. Additionally, dynamic imaging was done in a straight sagittal orientation, following the expected path of condylar motion.

Disc morphology was assessed using static MRI. Clarity of the anatomical structures of both the articular disc and the condylar head was classified into three grades: good, fair, and poor.

Statistical analysis: Data were analyzed through the use of SPSS version 25 [Statistical Package for Social Studies] released by IBM, Illinois, Chicago, USA. Data were expressed as number and percentage mean and standard deviations. Tested Categorical variables was done by Chi square or Fisher's exact test [FET]. Sensitivity and specificity, in addition to positive and negative predictive values have been calculated for detecting diagnostic accuracy of dynamic MRI. $P < 0.05$ was set significant.

RESULTS

This prospective study involved 40 patients who had been clinically diagnosed with temporo-mandibular joint dysfunction, with 30 of them being female [75%] and 10 being male [25%] of the total patient pool. The age range of the selected patients was from 18 to 66 years, with an average age of 28.6 years. The majority of the patients experienced temporomandibular joint pain as a clinical symptom [33; 82.5%]. Other clinical symptoms included clicking sounds in 22 patients [55%] and limited movement in 17 patients [42.5%], as indicated in the table [1].

Regarding disc morphology, 20 patients [50%] were found to have normal biconcave disc shape was while deformed shape was found in 20 patients [50%]; folded in 4 patients [10%], flattened in 7 patients [17.5%], eyeglass in 4 patients [10%], 4 patients [10%] with amorphous and perforated in 1 patient [2.5%]. Joint effusion and degenerative changes were reported in 10 [25%] and 11 [27.5%] patients respectively [table 2].

On comparing static and dynamic studies for various findings, it was found that, regarding to disc position, dynamic MRI missed abnormal positions in three cases; No patients were reported to have medial or lateral displacement by dynamic MRI. Regarding disc mobility, static MRI showed that 38 patients were with normal disc mobility [95%] and 2 patients [5%] with stuck disc [non-mobile disc]. While dynamic MRI indicated that 36 patients with normal disc mobility [90%] and 4 patients with stuck disc [10%].

For articular disc detection, dynamic MRI was good for detecting the disc in only 17 [42.5 %] versus 30 [75%] by static MRI [P=0.038]. Regarding condylar translation, there was significant difference between the studied techniques as dynamic MRI identified 8 [20%] cases as hypermobile, 14 [35%] as hypomobile in contrast to 1 [2.5%] and 13 [32.5%] cases by static MRI [P=0.001]. Regarding condylar head detection, dynamic MRI was good for its detection in only 30 [75%] versus 37 [92.5%] by static MRI [P=0.012]. Also, 12 patients [30%] were found to have motion artifact in dynamic MRI, compared to 13 patients [32.5%] in static MRI [table 3].

When analyzing diagnostic accuracy, dynamic MRI had sensitivity ratio of 90%, while positive predictive value [PPV] was of 81.8% and accuracy of 92.5% for diagnosing anterior disc displacement with reduction [ADDR]. As regard to anterior disc displacement without reduction [ADDWNR], it had sensitivity of 80%, positive predictive value [PPV] of 100% while accuracy was of 92.5%. As regard to medial displacement, dynamic MRI could not diagnose any of them with 2 false-negative cases with sensitivity 0% and accuracy 95%. As

regard to lateral displacement, dynamic MRI could not diagnose any of them with 1 false negative patient with sensitivity of 0% and accuracy of 97.5%. As regard to posterior displacement, 1 patient was diagnosed by both dynamic and static MRI with sensitivity of 100%, PPV of 100%, and accuracy of 100%. As regard to stuck disc, dynamic MRI diagnosed 4 patients, 2 of them were true positive [diagnosed by static MRI] with 2 false-positive cases, nonetheless, it was later confirmed through arthroscopy that those two patients had a stuck disc. Therefore, when compared to static MRI, dynamic MRI demonstrated a sensitivity of 100% in identifying patients with a stuck disc, a positive predictive value of 50%, and an accuracy of 95% [table 4].

Table [1]: Demographic data and clinical presentation of studied patients

Variable		Results	
Age [years]	Mean SD	28.6	9.8
Sex	Male	10	25
	Female	30	75
Affected Side	Right	13	32.5
	Left	12	30
	Both	15	37.5
Clinical Presentation	Pain	33	82.5
	Clicking Sound	22	55
	Movement limitation	17	42.5

Table [2]: Disc Morphology and other pathological findings of TMJ

Finding		No.	%
Disc Morphology	Biconcave	20	50
	Folded	4	10
	Flattened	7	17.5
	Eyeglass	4	10
	Amorphous	4	10
	Perforated	1	2.5
Joint Effusion		11	27.5
Degenerative Change		10	25
Retro discal Tissue	Normal	29	72.5
	Rupture	1	2.5
	Pseudo disc	9	22.5
	Rupture + pseudo disc	1	2.5

Table [3]: Comparison of different TMJ examinations between static and dynamic MRI

		Static		Dynamic		P Value
		N	%	N	%	
Disc Position	Normal	15	42.5	18	50	0.47
	Anterior DDWR	9	27.5	9	27.5	
	Anterior DDWNR	12	35	12	30	
	Medial	2	10	0	0	
	Lateral	1	2.5	0	0	
	Posterior	1	2.5	1	2.5	
Disc Mobility	Normal	36	90	32	80	0.2
	Stuck Disc	4	10	8	20	
Disc detection	Good	30	75	17	42.5	**0.038**
	Fair	7	17.5	18	45	
	Poor	3	7.5	5	12.5	
Condylar translation	Normal	26	65	18	45	**0.031**
	Hypomobile	13	32.5	14	35	
	Hypermobile	1	2.5	8	20	
Condylar head detection	Good	37	92.5	30	75	**0.012**
	Fair	3	7.5	9	22.5	
	Poor	0	0	1	2.5	
Motion artifact	No	27	67.5	28	70	0.81
	Yes	13	32.5	12	30	

Table [4]: Diagnostic accuracy of dynamic MRI in the studied 40 patients with TMJ pain

Disc position	Dynamic MRI				Total	Diagnostic accuracy of dynamic MRI		
	True		False			Sensitivity	PPV	Accuracy
	–ve	+ve	–ve	+ve				
Anterior DDWR	29	8	1	2	40	90	81.82	92.5
Anterior DDWNR	24	11	3	0	40	80	100	92.5
Medial	38	0	2	0	40	0	–	95
Lateral	39	0	1	0	40	0	–	97.5
Posterior	39	1	0	0	40	100	100	100
Stuck disc	36	2	0	2	40	100	50	95

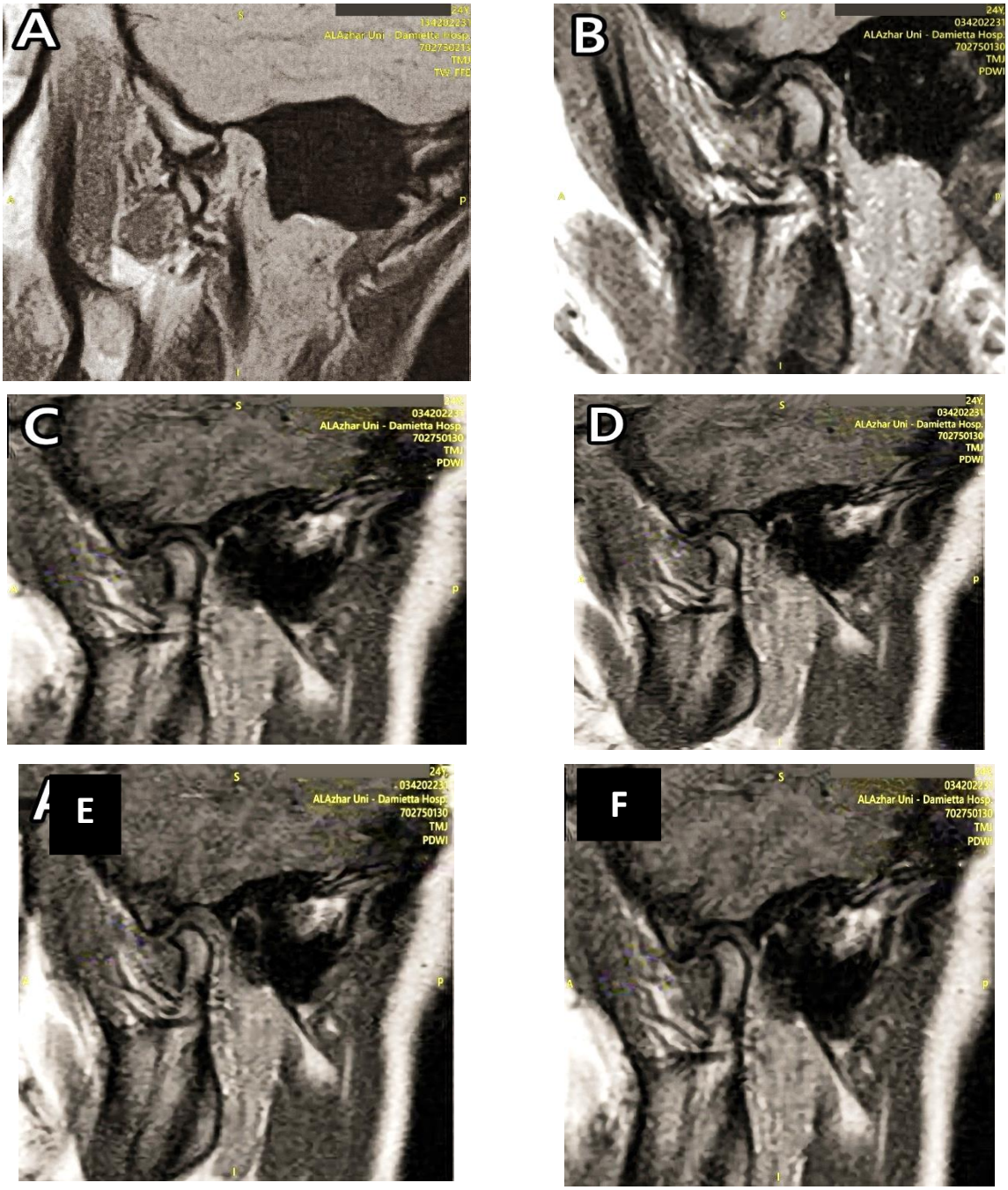

Figure [1]: A 24-year-old female patient presented clinically by left temporomandibular joint pain and clicking. Static MRI [A-B images]: sagittal PDWI MRI of right TMJ in open [A] and closed [B] mouth position revealed that the posterior band of the articular disc is seen anterior to the condyle in closed mouth view with normal position in open view. Thickening of the superior layer of retrodiscal tissue was noted giving pseudo disc sign. Dynamic MRI [C-F images]: dynamic MRI study of right TMJ revealed anteriorly displaced disc in relation to condylar head with reduction on opening of the mouth associated with normal condylar translation. **Diagnosis:** A case of right anterior disc displacement with reduction

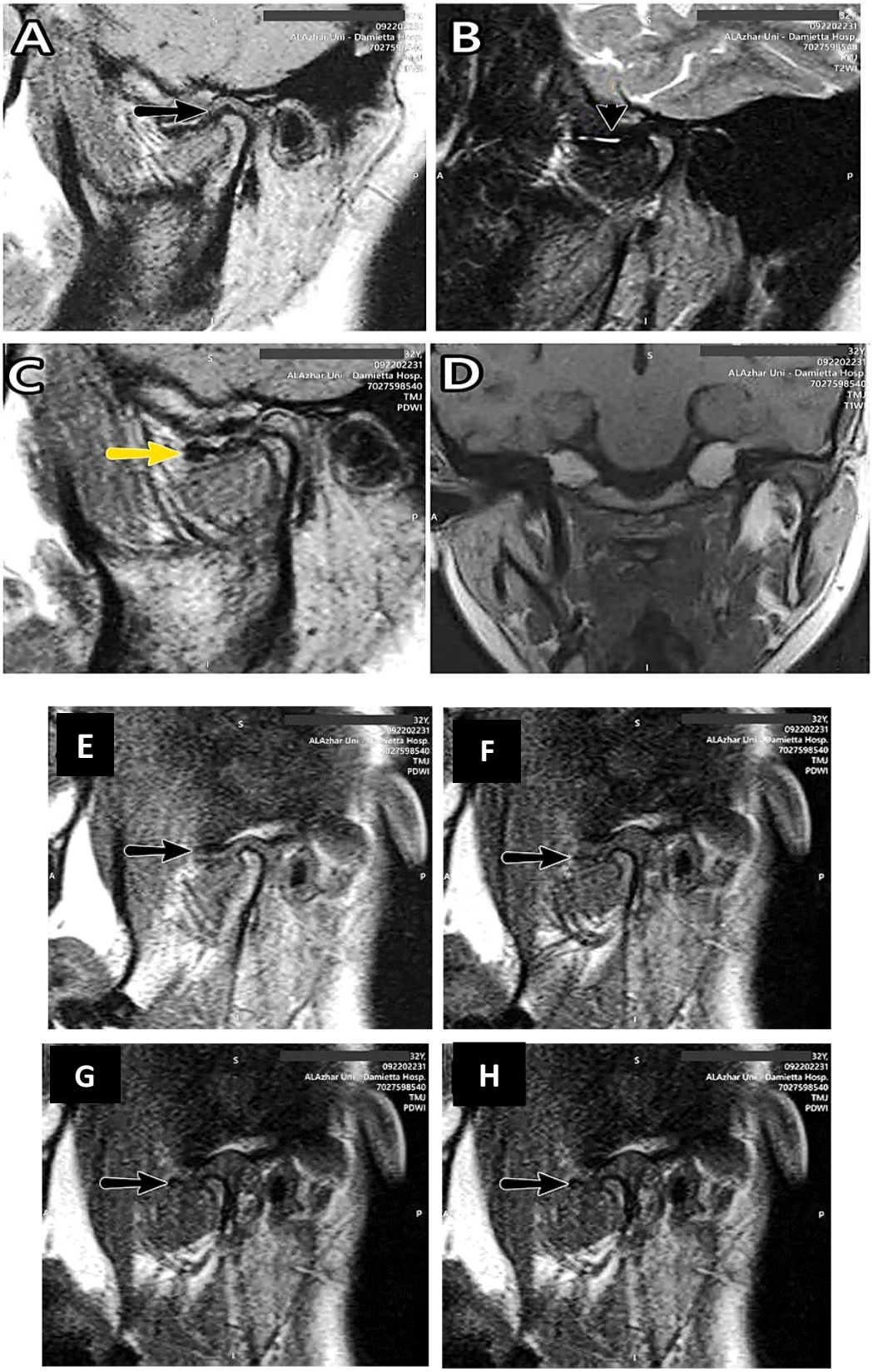

Figure [2]: A 32-year-old female patient presented clinically by temporomandibular joint pain and locked jaw in open position on the left side. Static MRI [A-D images]: sagittal PDWI and T2WI MRI of left TMJ in closed [A, B] and open [C] mouth position and coronal T1 revealed anteriorly displaced deformed disc [flattened] seen in closed-mouth position with no reduction in open mouth position [yellow arrow] [C], associated with joint effusion [arrow head] [B] and thickening of retrodiscal tissue "pseudo disc" [black arrow] [A]. No sideway displacement is noticed in coronal T1WI [D]. Dynamic MRI [E-H images]: dynamic MRI study of left TMJ revealed anteriorly displaced disc in relation to condylar head without reduction on opening of the mouth associated with limited condylar translation. **Diagnosis:** A case of left anterior disc displacement without reduction [ADDWNR]

DISCUSSION

Typically, the diagnosis of Temporomandibular Joint [TMD] requires the use of conventional MRI, which involves capturing several static images of the mouth in both closed and open positions. Nowadays, several fast pulse sequences have been proposed for dynamic MRI by some investigators [15].

Out of the 40 patients, 75% were females and 25% were males, resulting in a ratio of 3:1. This preponderance of females aligns with the findings of **Vieira-Queiroz *et al.*** [16] who applied his study on 185 patients; 78.9% of them were female and 21.1% were male with ratio 3.7:1.

According to clinical presentation, 33 [82.5%] patients were presented clinically by TMJ pain while clicking sounds were found in 22 [55%] patients and limitation of movement in 17 [42.5%] patients. Pain is the most common presentation of TMJ dysfunction. **Alarabawy *et al.*** [17] performed a similar study on 50 patients, 36 patients [72%] presented with pain, 32 patients [64%] were presented by clicking sounds and 21 patients [42%] were presented by limitation of movement.

According to disc morphology, normal disc shape [biconcave] was found in 20 patients [20%], while deformed shape was detected in form of: folded in 4 patients [10%], flattened in 7 patients [17.5%], eyeglass in 4 patients [10%], amorphous in 4 patients [10%], and perforated in 1 patient [2.5%]. This is in alignment with the study of **Kim *et al.*** [18] who performed his study on 157 patients [161 joints], Biconcave shape was found in 30 [18.6%], Folded in 45 patients [28.0%], Flattened in 33 patients [20.5%], Eyeglass-shaped in 37 patients [23.0%] and Amorphous in 16 patients [9.9%].

In this study, we assessed the position and movement of the disc using both static and dynamic MRI. Anterior disc displacement is the most frequent form of disc displacement, while posterior dislocation is the least prevalent [10]. In our study, posterior dislocation was observed in only 2.5% of patients [1 patient], which is consistent with the findings of **Afroz *et al.***'s [19] meta-analysis study. The study reported an overall prevalence of posterior disc displacement [PDD] of 0.7% for the number of joints affected and 0.9% for the number of patients affected.

In this study, with respect to disc position, dynamic MRI reported 20 patients [50%] as normal, 11 patients [27.5%] were reported to have anterior DDWR, 12 patients [30%] were reported to have anterior DDWNR, 1 patient was reported to have posterior displacement [2.5%], No medial or lateral displacements were determined. **Zhang *et al.*** [15] performed their study using dynamic MRI on 30 patients, they found that with respect to disc displacement, 41 cases [68.3%] were determined as normal, 10 cases [16.7%] as anterior DDWR, and one case [1.7%] as anterior DDWNR. No posterior, lateral, or medial displacements were observed.

Static MRI indicated that 36 patients had normal disc mobility, while 4 patients had a stuck disc. On the other hand, dynamic MRI showed that 32 patients had normal disc mobility, while 8 patients had a stuck disc. **Eberhard *et al.*** [20] evaluated disc mobility in 40 patients with TMJ dysfunction symptoms using dynamic MRI, which revealed 2 cases of a stuck disc [disc adhesions]. Additionally, in **Amin *et al.*'s** [21], who involved 28 patients, dynamic MRI identified 13 patients with normal disc mobility, 12 patients with limited asynchronous mobility, and 3 patients with a stuck disc.

As per condylar translation, it has been classified as either normal, hypomobile, or hypermobile. Static MRI reported 26 patients to have normal condylar translation, 13 patients to have hypomobile condylar translation and 1 patient had hypermobile condyles. On the other hand, dynamic MRI showed that 18 patients had normal condylar translation, 14 patients had hypomobile condylar translation and 8 patients had hypermobile condyles as [P-value was 0.001]. In the study of **Amin *et al.*** [21], dynamic MRI showed that 7 patients were with normal condylar translation, 14 patients with hypomobile condyles, and 7 patients with hypermobile condyle. This agrees with the study of **Beer *et al.*** [22] that demonstrated good correlation in the range of motion between dynamic. These findings contradict those of Wang et al. [23], who found that dynamic MRI is more effective at detecting normal motion than static MRI, while static MRI is better at detecting limited mobility [30.4%] than dynamic MRI [17.7%].

In our study, Dynamic MRI demonstrated a greater ability to detect hypermobile condyles than static MRI. This could be because dynamic MRI can capture the entire extent of condylar translation during voluntary motion, rather than relying on a fixed intraoral device to open the mouth.

Disc displacements are linked to pathological alterations such as joint effusion, degenerative changes, and changes in retro-discal tissue. In our study, joint effusion was observed in 11 patients [27.5%], while degenerative changes were present in 10 patients [25%]. **Higuchi *et al.*** [24] reported that joint effusion was identified in 63 patients [49%] out of 129 patients who presented with TMJ pain in their study. Campos ***et al.*** [25] also found degenerative changes in 104 patients, with 76 of them diagnosed with disc displacement.

The effectiveness of dynamic MRI as a diagnostic tool was assessed by comparing it to static MRI using two criteria. The first criterion was its ability to diagnose different types of disc displacement, while the second criterion was the quality of the resulting images in terms of the visibility of important TMJ structures such as the articular disc and mandibular condyle, as well as the presence of motion artifact. In terms of image quality, the ability of the dynamic MRI to detect the disc and condylar head was rated as good, fair, or poor and compared to that of static MRI. The results showed that the detection rate of the disc by the dynamic sequence was 87.5% compared to 92.5% for static MRI [with a P-value of 0.038], while the condylar head detection rate was 97.5% for dynamic MRI compared to 100% for static MRI [with a P-value of 0.012].

According to a study by **Shimazaki *et al.*** [26], the dynamic sequence had a high detection rate of 83% for the articular disc and 95% for the condylar head. However, in some cases, poor detection of the disc may be due to degenerative changes that cause the disc to become thinner and increase its signal, or due to sideways displacement of the disc, which shifts it away from the imaging plane.

A challenge of dynamic MRI is to capture images of moving objects with minimal motion artifact. In our study, the dynamic sequence resulted in fewer motion artifacts, despite the continuous joint movement. Motion artifact was found in 12 patients [30% of patients] using dynamic MRI, compared to 13 patients [32.5% of patients] using static MRI. This is consistent with **Wang et al** [23], who found that static examinations had a higher incidence of motion artifact than dynamic MRI [19.6% versus 6.9%, P-value: .016].

As regard to the diagnostic capability of dynamic MRI, it had reported 11 patients to have anterior DDWR with 90% of sensitivity, positive predictive value [PPV] was 81.8% and accuracy was 92.5%, anterior DDWNR in 12 patients with sensitivity of 80%, while positive predictive value [PPV] was of 100% and accuracy of 92.5%, and one patient with posterior displacement, with sensitivity of 100%, PPV of 100% and accuracy of 100%. The study of **Beer *et al.*** [22] found that sensitivity of dynamic MRI to diagnose disc lesions was relatively low76%.

Conclusion: Dynamic MRI allowed us to image the jaw joint disk during the whole process of opening and closing the jaw as well as the movement of displacement within the joint and how the disk relates to the condyle in a short time compared to static MRI. However, there wasn't a complete agreement between these two MRI methods. The dynamic sequences cannot be used instead of static sequences when evaluating displacement disorders of the TMJ but should be used together with it to provide a fuller picture.

Financial and non-financial relations and activities of interest: None

REFERENCES

1. Krohn S, Joseph AA, Voit D, Michaelis T, Merboldt KD, Buergers R, Frahm J. Multi-slice real-time MRI of temporomandibular joint dynamics. Dentomaxillofac Radiol. 2019 Jan;48[1]:20180162. doi: 10.1259/dmfr.20180162.

2. Chang CL, Wang DH, Yang MC, Hsu WE, Hsu ML. Functional disorders of the temporomandibular joints: Internal derangement of the temporomandibular joint. Kaohsiung J Med Sci. 2018 Apr;34[4]:223-230. doi: 10.1016/j.kjms.2018.01.004.

3. Petscavage-Thomas JM, Walker EA. Unlocking the jaw: advanced imaging of the temporomandibular joint. AJR Am J Roentgenol. 2014 Nov;203[5]:1047-58. doi: 10.2214/AJR.13.12177.

4. Wang YC, Shih TT, Yu CW, Chen YJ. Kinematic magnetic resonance imaging for the evaluation of active motion of the mandibular condyle in patients with temporomandibular joint disorders. J Formos Med Assoc. 2023 May;122[5]:411-418. doi: 10.1016/j.jfma.2022.12.009.

5. Manfredini D. Etiopathogenesis of disk displacement of the temporomandibular joint: a review of the mechanisms. Indian J Dent Res. 2009 Apr-Jun;20[2]:212-21. doi: 10.4103/0970-9290.51365.

6. Talmaceanu D, Lenghel LM, Bolog N, Hedesiu M, Buduru S, Rotar H, Baciut M, Baciut G. Imaging modalities for temporomandibular joint disorders: an

update. Clujul Med. 2018 Jul;91[3]:280-287. doi: 10. 15386/cjmed-970.

7. Ma RH, Li G, Sun Y, Meng JH, Zhao YP, Zhang H. Application of fused image in detecting abnormalities of temporomandibular joint. Dentomaxillofac Radiol. 2019 Mar;48[3]:20180129. doi: 10.1259/dmfr.20180129.

8. Alkhader M, Ohbayashi N, Tetsumura A, Nakamura S, Okochi K, Momin MA, Kurabayashi T. Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography. Dentomaxillofac Radiol. 2010 Jul;39[5]:270-6. doi: 10.1259/dmfr/25151578.

9. Eberhard L, Giannakopoulos NN, Rohde S, Schmitter M. Temporomandibular joint [TMJ] disc position in patients with TMJ pain assessed by coronal MRI. Dentomaxillofac Radiol. 2013;42[6]:20120199. doi: 10. 1259/dmfr.20120199.

10. Xiong X, Ye Z, Tang H, Wei Y, Nie L, Wei X, Liu Y, Song B. MRI of Temporomandibular Joint Disorders: Recent Advances and Future Directions. J Magn Reson Imaging. 2021 Oct;54[4]:1039-1052. doi: 10.1002/jmri. 27338.

11. Barchetti F, Stagnitti A, Glorioso M, Al Ansari N, Barchetti G, Pranno N, *et al.* Static and dynamic MR imaging in the evaluation of temporomandibular disorders. Eur Rev Med Pharmacol Sci. 2014 Oct; 18[20]:2983-7. PMID: 25392092.

12. Ingawalé S, Goswami T. Temporomandibular joint: disorders, treatments, and biomechanics. Ann Biomed Eng. 2009 May;37[5]:976-96. doi: 10.1007/s10439-009-9659-4.

13. Uecker M, Zhang S, Voit D, Merboldt KD, Frahm J. Real-time MRI: recent advances using radial FLASH. Imaging Med. 2012;4[4]:461. doi: 10.2217/iim.12.32.

14. Seemann R, Czerny C, Schicho K, Undt G, Piehslinger E, Ewers R, Wagner A. Pseudodynamic MRI differs from natural opening of the temporomandibular joint. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008 Mar;105[3]:371-8. doi: 10.1016/j.tripleo.2007. 02.003.

15. Zhang S, Gersdorff N, Frahm J. Real-time magnetic resonance imaging of temporomandibular joint dynamics. Open Med Imaging J. 2011;5:1-9.

16. Vieira-Queiroz I, Gomes Torres MG, de Oliveira-Santos C, Flores Campos PS, Crusoé-Rebello IM. Biometric parameters of the temporomandibular joint and association with disc displacement and pain: a magnetic resonance imaging study. Int J Oral Maxillofac Surg. 2013;42[6]:765-70. doi: 10.1016/j.ijom.2013.01.004.

17. Alarabawy RA, El Ahwal HM, El Sergany MA, Mehrez WW. Magnetic resonance imaging evaluation of temporo-mandibular joint disorders, criterial analysis and significance in comparison with arthroscopy. Egypt J Radiol Nucl Med. 2016 Jun 1;47[2]:467-75.

18. Kim JY, Jeon KJ, Kim MG, Park KH, Huh JK. A nomogram for classification of temporomandibular joint disk perforation based on magnetic resonance imaging. Oral Surg Oral Med Oral Pathol Oral Radiol. 2018 Jun;125[6]:682-692. doi: 10.1016/j.oooo.2018.02.009.

19. Afroz S, Naritani M, Hosoki H, Takechi K, Okayama Y, Matsuka Y. Prevalence of Posterior Disc Displacement of the Temporomandibular Joint in Patients with Temporomandibular Disorders: Systematic Review and Meta-Analyses. J Oral Facial Pain Headache. 2018 Summer;32[3]:277–286. doi: 10.11607/ofph.1924.

20. Eberhard D, Bantleon HP, Steger W. Functional magnetic resonance imaging of temporomandibular joint disorders. Eur J Orthod. 2000 Oct;22[5]:489-97. doi: 10.1093/ejo/22.5.489.

21. Amin MF, Hassan AM, Barakat KI. The accuracy of dynamic magnetic resonance imaging in evaluation of internal derangement of the temporomandibular joint; comparison with arthroscopic findings. Egypt J Radiol Nucl Med. 2012 Sep 1;43[3]:429-36.

22. Beer A, Kolk A, Neff A, Hof N, Treumann T, Rummeny EJ. Cine-MRT des Kiefergelenks im Vergleich zur konventionellen MRT und Achsiographie [Cine MRI of the temporomandibular joint in comparison to static MRI and axiography]. Rofo. 2004; 176[4]:506-12. German. doi: 10.1055/s-2004-813039.

23. Wang EY, Mulholland TP, Pramanik BK, Nusbaum AO, Babb J, Pavone AG, Fleisher KE. Dynamic sagittal half-Fourier acquired single-shot turbo spin-echo MR imaging of the temporomandibular joint: initial experience and comparison with sagittal oblique proton-attenuation images. AJNR Am J Neuroradiol. 2007 Jun-Jul;28[6]:1126-32. doi: 10.3174/ajnr.A0487.

24. Higuchi K, Chiba M, Sai Y, Yamaguchi Y, Nogami S, Yamauchi K, Takahashi T. Relationship between temporomandibular joint pain and magnetic resonance imaging findings in patients with temporomandibular joint disorders. Int J Oral Maxillofac Surg. 2020 Feb; 49[2]:230-236. doi: 10.1016/j.ijom.2019.06.028.

25. Campos MI, Campos PS, Cangussu MC, Guimarães 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 Jun;37[6]:529-34. doi: 10.1016/j.ijom.2008.02.011.

26. Shimazaki Y, Saito K, Matsukawa S, Onizawa R, Kotake F, Nishio R, Abe K. Image quality using dynamic MR imaging of the temporomandibular joint with true-FISP sequence. Magn Reson Med Sci. 2007; 6[1]:15-20. doi: 10.2463/mrms.6.15.

IJMA

International Journal of Medical Arts

Volume 6, Issue 2, February 2024

P- ISSN: 2636-4174
E- ISSN: 2682-3780