Relationship between Unilateral Temporomandibular Joint Arthralgia and Disc Positions and Degenerative Joint Changes- A Cross Sectional Study

A thesis submitted to the faculty of the University of Minnesota by

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Dedication

This thesis is dedicated to my parents, Dr. Mukesh Kumar Shrivastava and Ms. Mamta Shrivastava who devoted their lives to provide me with everything I need and my wife Ritu Sahu, strongest person I know for her unstoppable love and support which continuously encourages me to achieve my full potential.

Abstract

Background: This study simultaneously assessed for both temporomandibular joint (TMJ) disc displacement (DD) and degenerative joint disease (DJD) in participants with unilateral TMJ arthralgia using TMJ MRI and CBCT.

Methods: In the multi-center TMJ Impact Project, 401 subjects were examined by calibrated examiners that included rendering a diagnosis of TMJ arthralgia. All subjects had bilateral TMJ MRIs and CTs. Two radiologists rendered a consensus diagnosis of normal, DD with reduction (DDwR), or DD without reduction (DDw/oR) using MRI. CBCT consensus diagnoses included normal or grade I DJD and grade II DJD. Radiologist reliability was assessed by kappa. Descriptive analysis was performed using generalized linear mixed models. Models include a random intercept to account for correlations within subject. The level of significance is $p< 0.05$.

Results: Of the 401 subjects, 58 subjects had a clinical diagnosis of unilateral arthralgia. In 58 joints with arthralgia, 11(19%) had normal disc position, 19 (33%) had DDwR and 28 (48%) had DDw/oR compared to 58 joints without arthralgia: 13 (22%) were normal, 25 (43%) had DDwR and 20 (34%) had DDw/oR ($p=0.32$). In joints with arthralgia, 25 (43%) had normal osseous morphology and 33 (57%) had DJD compared to joints without arthralgia 32 (55%) had normal osseous morphology and 26 (44%) had DJD ($p=0.20$). Radiologist reliability was kappa: 0.73 (CI: 0.64–0.83) for DD and 0.76 (CI: 0.68-0.83) for DJD.

Conclusion: The presence of arthralgia is not significantly related to the radiographic findings of DD and DJD.

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List of Abbreviations

CBCT: Cone Beam Computed Tomography

DC/TMD: A New Diagnostic Criteria for Temporomandibular Disorders

DD: Disc Disorders

DDwR: Disc displacement with reduction

DJD: Degenerative joint diseases

DDw/oR: Disc displacement without reduction

k: Kappa Statistic

MDCT: Multidirectional Computed Tomography

MRI: Magnetic Resonance Imaging

OPPERA: Orofacial Pain Prospective and Risk Assessment

p= p-value

PD: Proton Density

RDC/TMD: Research Diagnostic Criteria for Temporomandibular Disorders

TMJ: Temporomandibular joint

TMD: Temporomandibular disorders

INTRODUCTION

The orofacial complex is composed of various hard and soft tissue anatomical structures. These anatomical structures, along with controlling neurological mechanism perform daily functions such as eating, speaking and swallowing. Temporomandibular joints (TMJs) are actively involved in performing those functions.

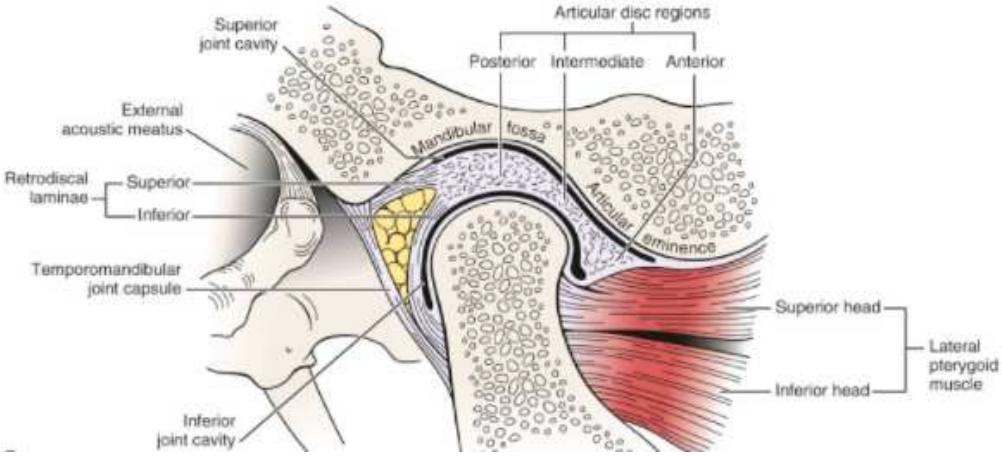
TMJs are bilateral, synovial joints which work as a single entity since they are both part of the mandible. Each TMJ is comprised of hard and soft tissue components. The hard tissue components of TMJ include the mandibular condyle, articular fossa, and articular eminence. The soft tissues include articular disc, joint capsule, synovial membranes, ligaments, and corresponding muscle attachments.

Generally, TMJs are distinct from other synovial joints of the body. Embryologically, most synovial joints are formed by a single condensation while TMJs are formed by two separate mesenchymal tissues. Also, it develops last in utero and remains underdeveloped at the time of birth compared to other joints (Bender, Lipin, and Goudy 2018).

Anatomically, TMJ is formed by mandibular condyle and articular fossa of the squamous part of the temporal bone. These bony components are made up of dense compact bone that forms the outer shell, and inner spongy trabecular or cancellous bone contains marrow cavities. The articular surfaces of the condyles, and articular fosse are covered by fibrocartilage which dissipates the load during jaw functions. Another feature of the TMJ is that it contains a dense collagenous fibrous articular disc. The articular disc is mostly avascular and biconcave with three bands, anterior band (approx. 2 mm thickness), intermediate zone (approx. 1 mm), and posterior band (approx. 3mm).

Structurally, the articular disc attaches anteriorly to the condylar head, articular eminence, and superior belly of the lateral pterygoid muscle. Posteriorly, the disc attaches to both the condyle and the temporal bone (Figure 1). The disc is attached medially and laterally by collateral ligaments to the condyle. The disc divides each joint into superior and inferior joint spaces containing synovial fluid that facilitates rotational and translational movements (Drake, Vogl, and Mitchell 2012).

Figure 1: Temporomandibular joint anatomy, Adopted from (Drake, Vogl, and Mitchell 2012)



Functionally, the articular disc along with other soft tissue components also serve as a "shock absorber" and distributes forces that occur during mastication or parafunctional behavior. When these biomechanical forces increase, or the functional capacity of the joint decreases, the relationship between the intraarticular structures and masticatory muscles gets disrupted which can lead to temporomandibular joint derangement or muscle dysfunction (Stegenga 2001). These terminologies are often used for diagnosis of

disorders related to TMJ however, temporomandibular joint derangement is a subclassification or descriptive term not a diagnosis. For diagnosis of TMJ disorders the most validated and widely accepted term used in the research and clinical settings is "Temporomandibular disorders" (TMD) (Schiffman, Ohrbach et al. 2014).

Temporomandibular disorders (TMD): Temporomandibular disorders (TMD) are an umbrella term for clinical conditions affecting the muscles of mastication, the temporomandibular joint (TMJ), and the related structures (Schiffman, et al. 2014). In the literature, various methods have been used for diagnosing TMD. These methods were not standardized until the development of Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) (Dworkin and LeResche 1992). The RDC/TMD criteria included an Axis I clinical examination and an Axis II behavior and psychosocial assessment. In 2014, Schiffman et al. established a new Diagnostic Criteria for TMD (DC/TMD) Axis I and Axis II assessment protocol that can be implemented in the clinical and research settings. Table 1 presents the TMD taxonomic classification system for the most common TMD (Schiffman, et al. 2014).

Epidemiology: Different epidemiological studies mentioned the prevalence of TMD. According to the National Institute of Dental and Craniofacial Research, the prevalence of TMD is 5% to 12% of the United States population (NIDCR 2013). Also, a systemic review reported prevalence of up to 13% for masticatory muscle pain, 16% for disc disorders (DD), and 9% for TMJ pain disorders in the general population (Manfredini, et al. 2011).

Table 1. Taxonomic classification for Temporomandibular Disorders

1. Temporomandibular Joint Disorders
    a. Joint Pain
        i. Arthralgia
        ii. Arthritis
    b. Joint Disorders
        i. Disc disorders
            a) Disc displacement with reduction
            b) Disc displacement with reduction with intermittent locking
            c) Disc displacement without reduction with limited opening
            d) Disc displacement with reduction without limited opening
        ii. Other hypomobility disorders
            a) Adhesions
            b) Ankylosis-fibrous and osseous
        iii. Hypermobility disorders
            a) Dislocation Subluxation Luxation
    c. Joint Diseases
        i. Degenerative joint diseases
            a) Osteoarthritis
            b) Osteoarthrosis
        ii. Systemic arthritis
        iii. Condylysis/Idiopathic condylar resorption
        iv. Osteochondritis dissecans
        v. Osteonecrosis
        vi. Neoplasm
        vii. Synovial Chondromatosis
    d. Fractures
    e. Congenital developmental disorders
2. Masticatory Muscle Disorders
    a. Muscle Pain
        i. Myalgia
            a) Local Myalgia
            b) Myofascial pain
            c) Myofascial pain with referral
        ii. Tendonitis
        iii. Myositis
        iv. Spasm
    b. Contracture
    c. Hypertrophy
    d. Neoplasm
    e. Movement disorders
        i. Orofacial Dyskinesia
        ii. Oromandibular Dystonia

f. Masticatory muscle pain to systemic disorders/central pain disorders
    i. Fibromyalgia/widespread pain
3. Headache attributed to TMD.
4. Associated structures
    i. Coronoid hyperplasia

Etiology: TMD has multifactorial etiologies and consists of various contributing factors including trauma, either physical or emotional, biological process such as aging, postural condition such as abnormal head and cervical position, systemic predisposition, sleep disorders and psychosocial alterations(Chisnoiu, Picos et al. 2015, Cortese, Mondello et al. 2017). Genetic and sensory processing also contributes to the etiology of TMD. Recently, the Orofacial Pain Prospective and Risk Assessment (OPPERA) study reported that TMD is best viewed using a biopsychosocial model to emphasize the importance of psychosocial and behavioral factors to the onset of TMD pain. (Fillingim, et al. 2018). Typically, these etiological factors contribute to the development of acute or chronic conditions.

Clinical Symptoms: The major reason for TMD patients to seek treatment is pain (Dworkin and LeResche 1992). In addition to pain, limited or asymmetric mandibular range of motion, joint noises, headaches and other symptoms including ear pain, tinnitus, dizziness and cervical pain are also associated with TMD. However, joint noises are non-specific and can be noticed in asymptomatic joints. Similarly, TMJ pain can occur from intra-articular structures and from an extraarticular location as referred pain including from the masticatory muscles.

Diagnostic methods for TMD: For diagnosis of these disorders, a special attention should be given to the history and clinical assessment. A descriptive history is required to render TMD diagnoses and identify the contributing factors. The clinical examination includes observation and measurement of mandibular range of motion, palpation of masticatory and cervical muscles, palpation and auscultation of the TMJ, examination of occlusion, dentition, salivary glands, cranial nerves and auscultation of carotid arteries. In some cases, clinical examination and history are not reliable and provide limited diagnostic information (Aiken, Bouloux, and Hudgins 2012). The history and clinical examination have a poor diagnostic accuracy for some TMJ intra-articular disorders (Schiffman, 2014). Therefore, diagnostic imaging is needed, in some cases to render a definitive TMJ diagnosis and to rule out other pathology.

Diagnostic imaging of the TMJ: The goals of TMJ imaging are to evaluate the integrity of the structures and to assess the presence, extent, stage, or progression of the disorders. To achieve these goals, different TMJ imaging examinations have been used to assess the hard, and soft tissue structures.

Previously, 2-dimensional imaging modalities e.g., trans-cranial view, reverse Towne, trans-maxillary, trans-pharyngeal, sub-mento-vertex, lateral, posteroanterior cephalometric and panoramic radiographs were used for diagnosing hard tissue pathologies related to the TMJ. However, these modalities have a limited role in the evaluation of the TMJ specifically due to the superimposition of adjacent structures and poor resolution. Also, they do not provide any information about soft tissue changes.

In the last decades, clinicians have adopted Multidirectional Computed Tomography (MDCT) and Cone Beam Computed Tomography (CBCT) as imaging modalities of choice for assessing the hard tissue components of the TMJ. CBCT employs a cone shaped X-ray beam to record the images of the craniofacial structures. These images can display hard tissues in the three anatomical planes i.e., sagittal, coronal, and axial. It also aids in three-dimensional reconstruction through specific software (Ferreira, et al. 2016). There are studies that compared the diagnostic accuracy of CBCT with CT and panoramic for assessing hard tissues (Honey, et al. 2007). The investigators observed that for diagnosing TMJ degenerative changes, CBCT has better interobserver reliability compared to regular CT with a lower radiation dose (Zain-Alabdeen and Alsadhan 2012). In another comprehensive study Ahmad et al, observer performance for diagnosing degenerative joint changes were assessed. They observed that panoramic radiograph had poor reliability [kappa(K)=0.16] for diagnosing the degenerative changes. In the same study, the diagnostic reliability for degenerative changes was fair for Magnetic Resonance Imaging (MRI) (k=0.46) and good for CT (k=0.71) (Ahmad, et al. 2009). In addition, nuclear medicine imaging techniques such as bone scintigraphy, single photon emission tomography with technetium-99m methylene diphosphate (SPECT/CT with 99m Tc-MDP), has also been used to determine the metabolic rate in osseous changes. However, these techniques do not differentiate among infections, osteoarthritic manifestations, or tumors (Ferreira, et al. 2016).

Relative to soft tissue imaging of the TMJ, arthrography was previously used to assess the disc morphology positioning and functioning, by radiopaque contrast injection into

the superior and inferior joint spaces (Panmekiate, Petersson et al. 1995). Currently, arthrography is rarely used since it is an invasive procedure which carries a risk of infection, allergies, iatrogenic disc perforation and facial palsy (Ferreira, et al. 2016). Besides this, ultrasound is used to evaluate the soft tissues of the TMJs. Recently, a study reported high diagnostic accuracy for assessing disc positions and effusion using ultrasound (Yılmaz and Kamburoğlu 2019). Conversely, ultrasound has insufficient specificity to accurately identify hard tissue structures of the TMJ and to diagnosis osteoarthrosis (Bas, et al. 2011).

Currently, MRI is the examination of choice for soft tissue analysis. Tasaki and Westesson noticed a diagnostic accuracy of 95% in the assessment of disc position with MRI imaging (Tasaki, et al. 1996). Ahmad et al, using a combination of oblique sagittal and coronal MR images assessed the inter-observer agreement for diagnosing the disc position. They found an excellent agreement for the diagnosis of disc displacement with reduction (kappa=0.78) and disc displacement without reduction (kappa=0.94). Authors inferred that MRI is the gold standard for evaluating the disc position and other soft tissue components of the TMJs and CT for assessing the hard tissues. (Ahmad, et al. 2009; Tamimi, Jalali, and Hatcher 2018).

TMD Pain: Investigators have tried to determine the relationship between TMJ intra-articular disorders and pain. Studies observed that the abnormal position of the disc, joint effusions, and arthritic changes could be related to pain in the TMJ (Palconet, et al. 2012; Bertram, et al. 2001; Rudisch, et al. 2001). Some studies have investigated the relationship of unilateral TMJ pain with disc displacements and degenerative changes

using MRI (Rudisch, et al. 2001; Emshoff, et al. 2002; Haley, et al. 2001). These studies provided contrasting results with poor correlation between symptoms and TMJ intra-articular findings.

Studies have claimed that anterior disc displacement is an important cause of joint pain, particularly in joints with disc displacement without reduction (Koh, et al. 2009). However, a later study could not duplicate these reported findings and found that anterior disc displacement without reduction does not necessarily correlate with joint pain (Suenaga, et al. 2016). To find the relationship between pain and disc displacements some investigators have also imaged asymptomatic TMJs with MRI. They observed a significant number of asymptomatic joints with disc displacement (Kircos, et al. 1987; Katzberg, et al. 1996; Larheim, et al. 2001).

Some researchers have investigated the relationship between pain and osteoarthrosis using different imaging modalities (Palconet, et al. 2012; Bertram, et al. 2001). They reported that osteoarthrosis does not necessarily correlate with the pain. Lack of concordance was also noticed with the data showing the prevalence of degenerative changes of TMJ in both symptomatic subjects and asymptomatic subjects (Al-Ekrish, et al. 2015; Shahidi, et al. 2018). However, few studies found a correlation between pain and degenerative changes of TMJ (Stegenga, et al. 1992; Kurita, et al. 2004; Cevidanes, et al. 2010). The results from previous studies vary considerably due to different methodologies, analysis and imaging techniques. This study was conducted to simultaneously assess both temporomandibular joint (TMJ) disc displacement (DD) and degenerative joint disease (DJD) using TMJ MRI and CBCT, respectively, in participants

with unilateral TMJ pain. In the present study, we assessed the relationship between the clinical diagnosis of unilateral joint pain versus imaging findings of different stages of TMJ disc positions and different grades of degenerative changes. The hypothesis of our study is that there is no relationship between disc positions and degenerative changes in participants with unilateral joint pain.

Methods

Study Design: The present cross-sectional study conformed with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for human observational investigations (von Elm, et al. 2014).

Study Population: Clinical and radiographic data were analyzed from the existing dataset of the multicenter TMJ Impact Project which was an 8-year follow up study of participants in the baseline Validation project (Schiffman, Truelove et al. 2010). The study population comprised of 401 participants which were included from three study sites: The University of Minnesota, University of Washington and University at Buffalo. All participants were informed about the project and signed a consent form. IRB approval at all three study sites as well as informed consent was obtained from all the participants.

Sample Size: The study employed a convenience sample, consisting of clinical and community TMD cases with the full spectrum of TMD signs and symptoms, as well as healthy controls. –Inclusion and exclusion criteria and demographics have been previously reported (Schiffman, et al. 2010). In the TMJ Impact Project, 401 participants were recalled and had a follow up clinical exam and bilateral TMJ MRI and CBCT.

Diagnostic Nomenclature: The nomenclature used in the present study for clinical diagnosis of unilateral joint pain is "Arthralgia" and for radiographic interpretation of CBCT images is "degenerative joint diseases" (DJD). We have adopted these terminologies from the DC/TMD per Schiffman et al. 2014 and the grading criteria for DJD as per Ahmad, et al. 2009. According to the investigators, "degenerative joint

diseases" is the best term to use for interpretation of radiographs and images when no clinical information is available. Similarly, for MR images we have used disc displacement with reduction (DDwR) and disc displacement without reduction (DDw/oR).

Clinical Assessment: Of the 401 participants from the multicenter TMJ Impact Project, participants who had a clinical diagnosis of unilateral TMJ arthralgia based on the DC/TMD were included in the study. Diagnosis of arthralgia was rendered by calibrated examiners. All examiners were experienced TMD and Orofacial Pain Specialists. Arthralgia diagnoses in the TMJ Impact Project were algorithmically derived using the Axis I Diagnostic Criteria for TMD (DC/TMD) protocol – Table 2 (Schiffman, et al. 2014).

Of 401 participants, 224 participants had no arthralgia, 119 participants had bilateral TMJ arthralgia, and 58 had unilateral TMJ arthralgia. Thus, 58 participants fulfilled the criteria of unilateral TMJ arthralgia which were included in the study. Of these, 35 participants had a diagnosis of right TMJ arthralgia and 23 had left TMJ arthralgia (Figure 2).

Table 2: Criteria for clinical diagnosis of arthralgia

Criteria for Arthralgia (ICD-10 M26.62)	
Description	Pain of joint origin that is affected by jaw movement, function, or parafunction and replication of this pain occurs with provocation testing of the TMJ
History AND	Positive for both of the following: 1. Pain in the jaw, temple, in the ear or in front of ear; AND 2. Pain modified with jaw movement, function or parafunction
Exam	Positive for both of the following: 1. Confirmation of pain location in the area of the TMJ(s); AND 2. Report of familiar pain in the TMJ with at least one of the following provocation tests; a. Palpation of the lateral pole or around the lateral pole; OR b. Maximum unassisted or assisted opening, right or left lateral movements, or protrusive movements.
Validity	Sensitivity 0.89; Specificity 0.98
Comments	The pain is not better accounted for by another pain diagnosis

Fig: 2 Flow chart showing inclusion of study participants

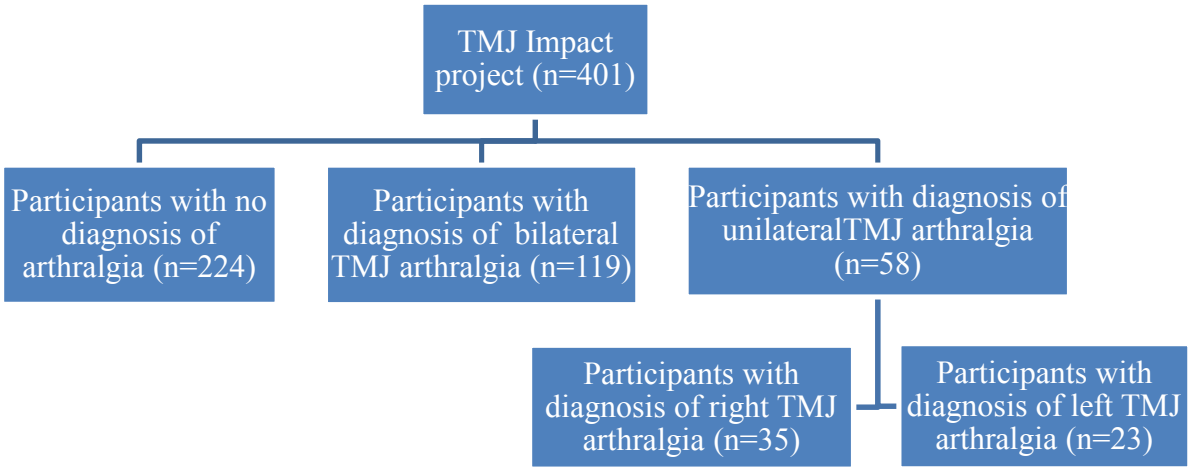


Image Database: All 58 participants had bilateral TMJ MRI and CBCT images. Each research site had one study radiologist. These three radiologists were calibrated for diagnoses of soft and hard tissue changes using MRI and CBCT, respectively. For disc position analysis, images were acquired using 3T MR units. For assessment of degenerative joint diseases, images of TMJ in closed mouth position were acquired using CBCT units.

MRI acquisition protocol: Closed mouth MRIs were acquired in proton density (PD) and T2 algorithm by using a TMJ surface coil. For open- mouth MR images, only PD images were acquired. At least six slices of each joint were obtained in axially corrected sagittal, and coronal views. Axially corrected coronal views were obtained in closed-mouth views only, for which sections were made through long axes of the condyles.

CBCT Acquisition protocol: CBCT scans were acquired in closed mouth position. At least 12 sections of each condyle (0.20 mm thickness slices) were generated in axially corrected sagittal and coronal views. The long axis of the condylar head was determined on axial slices. The corrected sagittal views of the condyles were obtained perpendicular to the long axis of the condyle. The corrected coronal images were obtained in a plane parallel to the long axis of the condyle. Open- mouth views were not obtained with CBCT to reduce radiation dose. Range of translation of the condyle was evaluated using MRI (Schiffman, et al. 2017).

Image Assessment: Images from MRI and CBCT were used for assessing disc positions and grading of degenerative joint diseases. Image diagnosis were made using criteria developed for the Validation Project (Ahmad et al. 2009) and subsequent development of criteria for subdividing the DJD into Grade 1 DJD and Grade 2 DJD (Ahmad and Schiffman 2016, Schiffman, et al. 2017). All radiologists were blinded to subject identity and clinical findings. A consensus protocol was used for all imaging diagnosis which was rendered by the two radiologists. The radiologists' reliability was assessed by the kappa statistic (k).

For MRI diagnosis disc positions of normal/indeterminate, DDwR and DDw/oR were included in the study (Table 3). CT diagnosis of normal/indeterminate, Grade 1 DJD and Grade 2 DJD were included in the study (Table 4).

Study measure: Image diagnoses of different stages of disc displacements (DD) and grading of degenerative joint disease (DJD) were used as an outcome measure to assess relationship between the joints with and without arthralgia. In both degenerative joint disease and disc displacement diagnoses, myalgia/myofascial pain was a concomitant

diagnosis which acts as a confounding factor in the study and was addressed through statistical analysis.

Data analysis: Descriptive statistics were performed using-generalized linear models. Models include a random intercept to account for correlations within participants. The level of significance is $p< 0.05$. Kappa statistic (k) was used for assessing clinical and radiologists' reliability. According to Fleiss et al., k values < 0.40 are considered poor reliability, values between 0.40-0.75 are considered fair to good reliability and values >75 are considered excellent (Fleiss, Levin, and Paik 2003). To account for dependence of right and left images from one individual, 95% confidence intervals (CI) for kappa was calculated using the bootstrap method. For soft tissue diagnoses the radiologists' inter-rater reliability was good (k=0.73; 95% CI 0.64-0.83) and for hard tissue diagnosis it was excellent (k=0.76; 95% CI 0.68-0.83). The inter-examiner reliability of participants' specific diagnosis for arthralgia was excellent (kappa=0.86; 95% CI 0.75-0.97).

Table 3: Criteria for diagnosis of different disc positions

Table 3. Diagnostic Criteria for Disc Positions	
Normal Disc Position	Closed mouth position: Relative to the superior aspect of the condyle, the border between the low signal of the disc and high signal of the retrodiscal tissue is located between 11:30 and 12:30 clock positions, AND Intermediate zone is located between the anterior-superior aspect of the condyle and posterior-inferior aspect of the articular eminence. Open mouth position: Intermediate zone is located between the condyle and articular eminence.
Indeterminate Position	Closed mouth position: 1. Relative to the superior aspect of the condyle, the low signal of the disc and high signal of the retrodiscal tissue is located anterior to 11:30 AND the condyle contacts the intermediate zone located between the anterior-superior aspect of the condyle and posterior-inferior aspect of the articular eminence. 2. Relative to the superior aspect of the condyle, the low signal of the disc and high signal of the retrodiscal tissue is located between 11:30 and 12:30 clock positions AND the

	intermediate zone of the disc is not in contact with the condyle. Open mouth position: Intermediate zone is located between the condyle and articular eminence.
Disc displacement with Reduction (DDwR)	Closed mouth position: Relative to the superior aspect of the condyle, the low signal of the disc and high signal of the retrodiscal tissue is located anterior to the 11:30 clock position AND the intermediate zone of the disc is located anterior to the condyle. Open mouth positions: location of posterior band of the disc is not critical or same as normal and the intermediate zone is located between the condyle and the articular eminence.
Disc displacement without Reduction (DDw/oR)	Closed mouth position: Posterior band is located anterior to the 11:30 clock position and intermediate zone is located anterior to the condyle. Open mouth positions: Persistent disc displacement or the intermediate zone is located anterior to the condylar head.

Table 4: Criteria for grading of degenerative joint diseases

Table 4. Diagnostic Criteria for Degenerative Joint Diseases	
Normal	No osseous change
Indeterminate	Localized sclerosis and flattening of the articulating surfaces
Grade 1 DJD	Osteophyte (the greatest length of the osteophyte is < 2mm from tip of condyle to expected contour of condyle, erosion or subcortical pseudocyst < 2mm in depth and width (limited to single occurrence only)
Grade 2 DJD	Osteophyte ≥ 2mm, erosion ≥ 2mm or more than one erosion of any size, and/or pseudocyst ≥ 2mm or more than one pseudocyst of any size, and/or a combination of two or more imaging signs of Grade 1 DJD.

RESULTS

The study sample was comprised of 58 participants with a clinical diagnosis of unilateral TMJ arthralgia, combining right and left TMJs (116 individual TMJs).

1. Relationship between clinical diagnosis of arthralgia and disc positions using MR images:

Distribution of imaging diagnosis of disc displacements based on presence and absence of arthralgia (combining right and left side) are in Table 5. No significant difference was noticed between imaging diagnosis of different disc positions and sides with and without arthralgia (p=0.32).

Table 5: Distribution of normal and different disc positions on sides with and without arthralgia.

Imaging diagnosis (Disc positions)	Sides without arthralgia	Sides with arthralgia
Normal/Indeterminate	22.4% (n=13)	18.9% (n=11)
Disc Displacement with Reduction (DDwR)	43.1% (n=25)	32.7% (n=19)
Disc Displacement without Reduction	34.4% (n=20)	48.2% (n=28)

(DDw/oR)		

Table 6 depicts overall distribution of normal/indeterminate and combined DDwR and DDw/oR. No significant difference was noticed between imaging diagnosis of disc positions and sides with and without arthralgia (p=0.65).

Table 6: Distribution of normal disc position and disc displacements on sides with and without arthralgia.

Imaging diagnosis (Disc Positions)	Sides without arthralgia	Sides with arthralgia
Normal/Indeterminate	22.4% (n=13)	18.9% (n=11)
Disc Displacement with Reduction (DDwR) / Disc Displacement without Reduction (DDw/oR)	77.5% (n=45)	81.0% (n=47)

2. Relationship between clinical diagnosis of arthralgia and grading of degenerative joint diseases using CBCT images.

Distribution of radiographic diagnosis of DJD based on presence and absence of arthralgia (combining right and left side) are demonstrated in Table 7. No significant

difference was noticed between imaging diagnosis of different grades of DJD and sides with and without arthralgia (p=0.22).

Table 7: Distribution of normal and different grades of DJD on sides with and without arthralgia.

Radiographic diagnosis	Sides without arthralgia	Sides with arthralgia
Normal / Indeterminate	55.1% (n=32)	43.1% (n=25)
Grade 1 DJD	18.9% (n=11)	15.5% (n=9)
Grade 2 DJD	25.8% (n=15)	41.3% (n=24)

Table 8 depicts the combination of distribution of normal/indeterminate and Grade 1 and Grade 2 DJD. No significant difference was noticed between imaging diagnosis of DJD and sides with and without arthralgia (p=0.20).

Table 8: Distribution of normal and DJD on sides with and without arthralgia.

Radiographic diagnosis	Sides without arthralgia	Sides with arthralgia
Normal / Indeterminate	55.1% (n=32)	43.1% (n=25)
Grade 1 DJD / Grade 2 DJD	44.8% (n=26)	56.9% (n=33)

Discussion

This is the first study to simultaneously assess in symptomatic participants the relationship between unilateral TMJ arthralgia versus normal disc position and different stages of disc displacement, as well as normal osseous structures and different grades of degenerative joint disease. Results of this study showed no significant relationship existed between the clinical diagnosis of arthralgia and imaging diagnoses for normal or any stage of disc displacement or any grade of degenerative joint diseases.

Disc positions:

Literature review on studies showing similar results using MRI for assessment of DDwR between sides with and without arthralgia:

In our study participants, only 33% (n=19) of 58 joints with arthralgia had DDwR. Interestingly, in joints without arthralgia, a significantly higher number of joints 43% (n=25) had MRI diagnosis of DDwR (p=0.32). Findings of our study are similar to the study by Haley et al., in which 85 joints were imaged by 1.5T MRI (Haley, et al. 2001). This study showed 15% of DDwR on symptomatic joints compared to 34% of DDwR on asymptomatic joints (p=0.07). In another study, Emshoff et al., noticed 10% of symptomatic joints had DDwR while 33% had DDwR on the asymptomatic side (p=0.07) (Emshoff, et al. 2001). Rudisch et al also observed 22% of symptomatic joints with DDwR compared to 20% of asymptomatic joints with DDwR (Rudisch, et al. 2001). Some studies also have focused on MRI findings and presence of pain in patients with

TMD. A study evaluated 84 clinically symptomatic joints and noticed 37% with DDwR and of 60 asymptomatic joints 22% had DDwR (p=0.06) (Maizlin et al 2010). Similarly, Takahara et al., investigated the association of pain and MRI findings in TMD patients. Of 424 asymptomatic joints and 222 symptomatic joints, they observed 25% cases with DDwR on asymptomatic side compared to 14% cases of DDwR on symptomatic side (p=0.44). Recently, Higuchi et al 2020, evaluated abnormal MRI findings related to TMJ pain. Of 129 symptomatic joints and 116 asymptomatic joints, they observed 22% with DDwR on symptomatic side compared to 52% on asymptomatic side (p=0.21)

Several other studies had evaluated the relationship between disc position in asymptomatic volunteers. These studies also used MR imaging to assess anatomic positions of the disc (Katzberg, et al. 1996; Larheim, et al. 2001). These studies report 30 to 35% of the asymptomatic volunteers with DDwR which is similar to the findings in the present study. Similarly, in a prevalence study from age 6 years to 25 years (Ribeiro, et al.) observed 34% of asymptomatic volunteers with disc displacement (p=0.001) (Ribeiro, et al. 1997). In another study with a population of 51 patients, researchers observed that pain was not characteristic of any kind of disc displacement (Cholitgul, et al. 1997).

Literature review on studies showing contrasting results using MRI for assessment of DDwR between sides with and without arthralgia:

Previous studies have assessed different stages of disc displacements based on different criteria and noticed higher percentage of disc displacement in symptomatic participants compared to asymptomatic volunteers (Tasaki, et al. 1996; Tallents, et al. 1996; Larheim,

et al. 2001). These studies observed 77-86% of symptomatic joints with DDwR and 30-33% of asymptomatic joints with DDwR which is contrary to our study. Similarly, another study used RDC/TMD criteria to identify clinical signs and symptoms which included clicking, reduction in range of motion, and pain (Kumar, et al. 2015). They observed that in 44 TMJs, 25% of symptomatic joint had DDwR diagnosed by MRI, while 4.5% of asymptomatic joints had DDwR (p=0.000). The reason for significant differences in the contrasting studies may be due to different selection criteria which is symptomatic participants vs asymptomatic volunteers, and imaging criteria and parameters for assessing disc position. Also, fewer studies correlated different clinical signs, symptoms and diagnoses based on RDC/TMD. In the current study, only participants diagnosed with unilateral arthralgia based on DC/TMD which reported excellent sensitivity and specificity were used (Schiffman, et al. 2014). Also, in the current study we used different methodology and imaging criteria which had excellent reliability for diagnosis of DDwR (k=0.78) (Ahmad, et al. 2009).

Clinical relevance of DDwR:

From previous studies, it is still not clear whether DDwR is related to arthralgia. Our study and several other studies showed a higher number of DDwR in asymptomatic joints with no significant difference compared to symptomatic joints. This implies joints may have a displaced disc and yet remain clinically asymptomatic. Based on this observation it can be assumed that if a patient complains of joint pain it is less likely that pain is related to DDwR. In such cases, the clinician should look for other factors to rule out the likely cause of the pain. MRI of the joint, which helps in evaluating the disc position, may not provide sufficient information on reasons for symptoms, particularly pain.

Literature review on DDw/oR: Our data showed 48% (n=28) of arthralgic joints with DDw/oR. In non-arthralgic joints, we observed 34% (n=20) with DDw/oR (p=0.32).

Findings of our study are similar to the study by Higuchi et al 2020 which is incongruent with the current literature data. They observed 129 symptomatic joints and 116 asymptomatic joints and noticed 78% with DDw/oR on symptomatic side compared to 48% on asymptomatic side using multivariate logistic regression analysis (p=0.21) These findings are incongruent with current literature data. However, majority of studies observed significant relationship between DDw/oR and pain. In a recent study, (Takahara, et al. 2017) observed 61% symptomatic joints with DDw/oR compared to 25% asymptomatic joints with DDw/oR. Researchers concluded that the risk of arthralgia increases significantly with DDw/oR compared to DDwR (<0.01). Reports of previous studies observed 53 to 65% of symptomatic joint with DDw/oR compared to 25% to 40% asymptomatic joint with DDw/oR (Rudisch, et al. 2001; Bertram, et al. 2001; Haley, et al. 2001; Emshoff, et al. 2003). These studies concluded that although clinical pain is related to TMJ related MRI findings, the presence of clinical pain itself is not a reliable predictor of TMJ disc displacements.

Another study focused on MRI findings and presence of pain in patients with (Maizlin, et al. 2010). Their data showed 17% of 84 symptomatic joints had DDw/oR. However, there was no DDw/oR in asymptomatic joints (p<0.001). Kumar et al. showed 25% of symptomatic joints had DDw/oR while none of the asymptomatic joints had DDw/oR (p<0.001) (Kumar, et al. 2015). The reason for no subjects with DDw/oR in asymptomatic joints is probably due to the difference in inclusion criteria. In the above

studies, the authors included asymptomatic volunteers who had no clinical signs or symptoms of TMD such as noises, pain, and limitation in mouth opening. Also, authors observed difference between symptomatic participants and asymptomatic volunteers while in the current study we observed differences in symptomatic and asymptomatic joints of the same participants.

Clinical Relevance of DDw/oR: Our study and majority of other studies showed a higher number of DDw/oR in symptomatic joints compared to asymptomatic joints. Based on this observation it can be assume that if patients' complaints of joint pain and DDw/oR it is more likely due to disruption in the balance between host adaptive capacity and increased functional loading which leads to more mechanical strains in the posterior disk attachment or surrounding structures and eventually pain. (Haley, et al. 2001). In such cases, the clinician should pay attention in managing the pain and improving jaw function limitation. MR imaging is warranted to supplement clinical findings or in selected cases (Schiffman, et al. 2014).

Also, the finding of DDw/oR on joints without arthralgia showed that pain is not always associated with DDw/oR. A possible explanation is due to adaptive nature of tissues. Also, pain is a subjective symptom which may vary over time and does not appear to be directly related to joint pathology.

Literature review on normal disc position and arthralgia:

In our study, we also observed 19% (n=11) normal disc position in participants with symptomatic joints. This means in almost one out of five subjects; arthralgia is not

related to either stage of disc displacement. A range of 11 to 20% of symptomatic joints with normal disc position were noted by various studies (Haley, et al. 2001; Ribeiro, et al. 1997; Bertram, et al. 2001; Emshoff, et al. 2003; (Kumar, Pallagatti et al. 2015). Recently, in a study conducted in Japan 24% of symptomatic joints had normal disc position (Takahara, et al. 2017).

Clinical Relevance: These findings suggest symptomatic joints can have normal disc position. A study concluded that disc displacement can be a mechanical disorder and pain in these conditions can also be attributed to biopsychosocial factors rather than disc displacement (Fujiwara, et al. 2013). Therefore, TMJ pain has a more complex cause than simply disc position. Pain in the joint can be attributed to referred pain from muscles or other maxillofacial structures and central sensitization. Based on these findings we may emphasize that clinicians should perform comprehensive clinical and radiographic examinations to properly evaluate and manage complexity of arthralgia.

Degenerative joint changes (DJD):

Degenerative bony changes are characterized by destruction of articular surfaces of the mandibular condyle, glenoid fossa and/or eminence. Radiographic signs of degenerative changes included erosion, pseudocyst, and osteophyte (Ahmad and Schiffman 2016). Using axially corrected sagittal and coronal CBCT images, we evaluated severity of degenerative joint changes as normal/indeterminate, Grade I and Grade II. We observed radiographic diagnosis of DJD is not significantly related to the clinical diagnosis of arthralgia ($p=0.20$). In our study subjects, 57% (n=33) of 58 joints had DJD (Grades I and II) on joints with arthralgia. Interestingly, 45% (n=26) of the joints without arthralgia had

Grades I and II DJD. Many studies evaluated TMJ osseous changes in symptomatic and asymptomatic participants using different imaging modalities.

Literature review on studies showing similar results between DJD and sides with and without arthralgia using CBCT and CT as an imaging modality:

Our findings are in agreement with other studies in which poor correlation was reported between the degenerative changes of symptomatic and asymptomatic joints (Shahidi, et al. 2018; Al-Ekrish, et al. 2015). In a study, 56 joints with arthralgia and 128 joints without arthralgia were analyzed using CBCT imaging to observe for degenerative changes (Al-Ekrish, et al. 2015). In this study, prevalence of degenerative changes with at least one type of osseous change was 79% in the symptomatic group and 80% in the asymptomatic group. The most common degenerative changes were erosion and osteophyte. Similarly, (Shahidi, et al. 2018) observed 90% and 87% of degenerative changes in symptomatic and asymptomatic participants. They observed flattening and sclerosis as the most common degenerative changes. Although these studies had similar results as ours, they differed in study design and criteria as both sclerosis and flattening are not indicative of DJD in the current study (Ahmad, Hollender et al. 2009). These studies evaluated prevalence of radiological signs such as erosion, osteophyte, subchondral cyst and sclerosis using different patient selection and imaging criteria. In our study, we used well-defined imaging criteria in the same participant to evaluate the relationship between arthralgia and degenerative changes (Schiffman, et al. 2017). In another study on a pool of 30 patients with a diagnosis of degenerative diseases,

researchers observed a poor correlation between condylar radiographic changes and pain (Palconet, et al. 2012).

Researchers have also investigated the degenerative changes on articular surface of condyle and relationship of these degenerative changes such as flattening, sclerosis, erosion, subcortical cyst and osteophyte to pain using traditional CT (Lim et al., 2014). They concluded pain on palpation, noise, and mouth opening range was not related any of degenerative changes. Similarly, Bertram et al. observed joints with arthralgia which do not differ from joints without arthralgia relative to the presence of degenerative change using MRI (Bertram, et al. 2001). Their study included 131 joints with arthralgia and 131 joints without arthralgia. In joints with arthralgia 54 % had degenerative changes. In joints with no arthralgia, 39% had DJD changes. These findings are similar to our results.

Literature review on studies showing contrasting results between DJD and sides with and without arthralgia using CBCT:

Some studies showed a significant relationship between pain and degenerative changes. Recently, in a study Bae et al., 2017 studied the correlation between pain intensity using numeric rating scale and degenerative changes. After analyzing the 283 TMJ with DJD, authors find correlation between pain intensity and erosion ($p=0.05$) and osteophyte ($p=0.04$). Similarly, Emshoff et al 2016 assess the association between TMJ arthralgia and erosion. In this case-control study 198 patients diagnosed with arthralgia based on the RDC/TMD criteria and 90 controls who did not report any pain were included in the study. They assess the severity of erosion as grade I, II and III instead of other degenerative joint changes which is used in the present study. Investigators observed an

association between TMJ arthralgia and erosion ($p<0.01$). Another study explores the relationship between clinical symptoms and radiographic findings of different types of bony changes (Nah 2012). After analyzing the 129 joints, they observed 65% (n=85) of joints with surface erosion and sclerosis with a positive relationship between a patient complaint of pain and erosion ($p<0.05$).

A study by Cevidanes et al 2010 reported that–patients with painful TMJ had a significantly higher percentage of radiographic evidence of degenerative changes than asymptomatic individuals using CBCT. They investigated influence of pain and degree of condylar resorption. In 29 patients with TMJ pain and 36 asymptomatic volunteers, they observed a positive correlation between the extent of resorptive changes and pain in symptomatic patients ($p=<0.05$) Another study that contrasts our results was reported by (Kurita, et al. 2004) in which 178 joints were clinically assessed for pain on mandibular function as well as on lateral palpation of the TMJ and radiographic evidence of bone changes on the articular surface and resorption at the lateral part of condyle were investigated using CBCT. Investigators observed a significant relationship between pain and radiographic changes on the articular surfaces and resorption on the lateral part of condyles ($p<0.01$). In another study, correlation between pain and CBCT findings of degenerative changes were observed. In 117 TMJs of degenerative changes, they observed a poor correlation between osseous changes and pain. The most frequent condylar change was erosion and flattening. However, flattening of the articular surface is indicative of indeterminate stage not DJD as per Ahmad, Hollender et al. 2009.

A possible reason for contrasting results in the above studies is due to different inclusion criterions and different imaging techniques. In these contrasting studies, symptomatic groups were participants that meet radiographic diagnosis for DJD and those without DJD changes were in the control group. In our study we used clinically diagnosed unilateral arthralgia cases and analyze both joints to see if there are any radiographic degenerative changes noticed on the contralateral joint or not. Also, in our study we have used different imaging criteria which includes all the characteristic features of degenerative changes. We used osteophyte, erosion, and pseudocyst as a radiological sign for grading the extent of degenerative changes. We did not observe radiologic signs individually as reported previously by the above-mentioned studies.

Also, as discussed previously we used DC/TMD instead of RDC/TMD which showed good interobserver reliability to assess the relationship between arthralgia and radiographic diagnosis of degenerative changes while in other studies no interobserver reliability have been assessed.

Although there is a slightly higher percentage of degenerative changes in symptomatic joints, our results also showed asymptomatic joints with degenerative changes. Based on this finding, it can be assumed that radiological signs of degenerative diseases were not always a determinant factor for pain. Interestingly, in the present study, joints with arthralgia, 41.3% had Grade 2 DJD and in joints without arthralgia 26% had Grade 2 DJD. Even though Grade 2 is more severe and being non-significant results ($p=0.20$), it is typically not necessarily related to pain.

Clinical Relevance: For patients with arthralgia and radiographic findings of DJD, clinicians should perform a comprehensive history, clinical examination to understand the complexity of joint pain. CBCT imaging would help the clinician in obtaining more information joint status and in confirming the radiographic diagnosis of DJD. Also, Schiffman et al., 2014, reported that clinical examination for diagnosing degenerative joint diseases has low specificity and sensitivity and radiographic diagnosis of CBCT is a reliable method for assessing grading of DJD. However, given the percentage of asymptomatic joints with positive radiographic degenerative changes it can be inferred that prediction of radiographic findings from clinical symptoms is challenging (Palconet, et al. 2012). Another possible reason is that patients may experience pain before bony changes are evident on radiographs. As discussed earlier, we did not analyze past conditions of the joint. There may be a possibility that asymptomatic joints had pain previously which was not reported at the time of clinical and radiographic evaluation. Thus, to clarify these variabilities, longitudinal studies are needed to evaluate the exact nature of pain and radiographic findings instead of analyzing the data at one point of time.

Literature review on normal bony morphology and arthralgia:

In our study, we also observed normal bony morphology in 43% (n=25) of 58 joints with a clinical diagnosis of arthralgia. One study observed normal bony morphology in 133 (59%) of painful 222 TMJs (Takahara, et al. 2017). The reason for higher percentages is probably due to different inclusion criteria for symptomatic joints. Also, they have used MRI in their studies with different imaging parameters to assess the joint. In another study, 11.6% of 112 patients with symptomatic joint had no signs of degenerative

changes using CBCT (Shahidi, et al. 2018). Other studies also observed higher percentages of radiological signs typically sclerosis and flattening in patients with pain (Emshoff, et al. 2002) (Al-Ekrish, et al. 2015. These findings in our study are reported as normal/indeterminate.

Clinical Relevance: It appears pain may develop without features of degenerative changes on radiographs. In such cases, pain may occur from other factors that trigger nociception as mechanical trauma, referral pain from muscles, psychosocial distress or impaired psychosocial functioning and sensitization (Lee Y.H et al., 2019). In these cases, imaging is only needed to rule out the other hard tissue pathologies and for validating the diagnosis and a thorough history and clinical examination are necessary for establishing a diagnosis of pain.

Diagnostic agreement of MR images:

As discussed previously, the strength of the inter-observer reliability of the radiologist for MR imaging diagnosis of disc displacements was good (kappa=0.73; 95% CI, 0.68 to 0.83). There are studies in the literature which measure the inter-observer performance for diagnosing disc position. In a study, a combination of oblique sagittal and coronal MR images was used for assessing anterior disc position (Nebbe, et al. 2000). The interobserver agreement was lowest for diagnosis of anterior disc displacement (k=0.19) and highest for DDw/oR (k=0.91). Thus, the strength of agreement in diagnostic assessment of disc positions ranged from poor to excellent. Similarly, Emshoff, et al 2001 (k=0.20), Rudisch et al 2001, k= (0.34) Manfredini et al 2009, (k=0.63) observed poor to

fair inter-observer reliability in assessing the disc position using criteria by Landis JR, Koch GG. 1977.

In contrast, (Ahmad, et al. 2009), observed excellent reliability for anterior disc displacement with reduction (k=0.78) and DDw/oR (k=0.94). The reason for excellent reliability for assessing disc displacements is that our examiners used more precise classification for diagnosing disc positions compared to previous above-mentioned studies. Also, in the above studies, the interobserver agreement for DDw/oR was nearly equal. Therefore, the high interobserver agreement makes the imaging diagnosis of DDw/oR more reliable than other types of disc displacements (Larheim, et al. 2018).

It has also been shown that the quality of MR images has an impact on observer performance. (Larheim et al 2018). Therefore, in our study, we used 3T MRI images which have substantially better resolution and quality compared to 1.5 T which were used in other studies for assessing disc positions (Stehling, et al. 2007).

Diagnostic agreement of CT, CBCT

In our study the strength of interobserver reliability for CBCT imaging diagnosis of degenerative joint disease was excellent (kappa=0.76; 95% CI, 0.68 to 0.83). While in other studies poor to fair interobserver reliability was observed Limchaichana et al. 2007, DJD (k=0.53) Poveda-Roda et al. 2015. DJD (k=0.19). A comprehensive study by Ahmad et al., compared the reliability of three imaging modalities in diagnosing degenerative changes. The authors observed inter-examiner reliability of the radiologist

was poor for panoramic images (k=0.16), fair for MRI images (k=0.47), good for CT images (k=0.71) and excellent for CBCT images (k=0.76).

Also, some studies have used CBCT for investigating osseous changes and compared its diagnostic accuracy with other imaging modalities. In a study, researchers did a blinded in-vitro cross-sectional study to compare diagnostic accuracy of observers viewing images of CBCT, panoramic radiography, and linear tomography (Honey, et al. 2007). Investigators concluded that CBCT can more accurately depict erosive changes compared to other imaging. Another study (Zain-Alabdeen and Alsadhan 2012) assesses accuracy and reliability of CBCT images compared with multidetector CT images for detection of surface osseous changes in temporomandibular joints. They concluded CBCT and MDCT accuracy was comparable in detecting surface osseous changes. However, results also indicated about 40% of CT diagnosed degenerative changes were not detected with MRI. CBCT requires a substantially lower radiation dose than MDCT and is a preferred modality of imaging in assessing TMJ (Ahmad et al) Therefore, in this study, we used CBCT imaging with good to excellent diagnostic agreement between the radiologist for DJD.

Strength: Although our study demonstrates no significant relationship between unilateral TMJ arthralgia and disc position and DJD, this is the first study which has simultaneously assessed the relationship between unilateral TMJ arthralgia and normal DD and DJD using TMJ MRI and CBCT. Another strength is that clinical diagnosis of unilateral arthralgia was rendered by the calibrated examiners and imaging diagnosis of normal,

DD and DJD were rendered by radiologists with excellent inter-observer reliability. To best of our knowledge none of the previous studies have reported similar diagnostic reliability. Also, we used the DC/TMD criteria which reported excellent sensitivity and specificity in making a diagnosis of TMJ arthralgia. Similarly, for quantifying the imaging diagnosis of DD and DJD we adopted well defined criteria reported by (Ahmad, et al. 2009) which reported an excellent diagnostic reliability. Additionally, the quality of diagnostic images used in our study have shown substantially better resolution as 3T MRI was used while in majority of the studies 1.5 T MRI were used. Also, all images were studied and imaged using standardized protocol. Also, in our study both clinical and imaging database were extracted from TMJ Impact project which was a multicenter research study. This explains that recruitment of participants was done from a diverse population which showed generalizability of the results.

Limitations:

Our study has a few limitations in which should be addressed for future studies. In our study only 58 joints had unilateral arthralgia. A future study may specifically enroll a larger number of subjects with unilateral arthralgia. However, our sample is a subset of 401 participants recruited from the multicenter TMJ Impact Project which explains that recruitment of participants with unilateral arthralgia may be challenging.

Another limitation is initial calibration and reliability study for the radiologists were done at one site, with all radiologists in the same location. Later, annual recalibration and reliability were done with radiologists at their own site. This reduces discussion between radiologists which may have led to a lower reliability than if the radiologists were

together. All discussions for recalibration were done over the phone rather than physical presence. A better option would be to conduct recalibration at one site.

Furthermore, this is a multicenter study which has used three different kinds of CBCT and MRI units. There were differences in image quality, but all images were completely diagnostic. Also, the design of our study is cross-sectional. Therefore, these confounding variables are necessary to rectify in the future studies to obtain results with more definitive conclusion.

. In order to rectify the variables, researchers should focus on recruiting a larger sample of patients with unilateral arthralgia and imaging diagnosis of DD and DJD to increase generalizability of the results. Pain is a subjective symptom which varies with time or depending on the chronicity of the condition, and demographics. With this cross-sectional design it is not possible to understand the complexity of pain and imaging diagnosis. Thus, an additional prospective cohort study will be needed to find exact relationship between arthralgia and imaging diagnosis of DD and DJD as this would help in establishing a definitive conclusion. Also, clinicians and radiologist should follow the criteria based diagnostic system and taxonomy for diagnosing arthralgia, DD and DJD with high inter-examiner reliability to obtain results with more diagnostic validity.

In conclusion, our study observed a non-significant relationship between clinical diagnosis of arthralgia versus disc positions, and presence or absence of degenerative joint diseases. The possible reason for these non-significant results is that both joints are dependent and work together with unified action. This also indicates that pain is not a reliable marker for predicting imaging diagnosis of disc positions and degenerative joint

diseases or vice versa. Therefore, a thorough history and clinical examination are necessary for establishing a diagnosis and manage complexity of joint pain. Combining imaging with clinical assessment would help to determine the extent of joint changes and to rule out other TMJ pathologies which may improve patient outcome.

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