Diagnostic Accuracy of Panoramic Radiograph and MRI for Detecting Signs of TMJ Degenerative Joint Disease

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Abstract

Background: To determine the diagnostic accuracy of panoramic radiograph and magnetic resonance imaging (MRI) for detection of signs of temporomandibular joint (TMJ) degenerative joint disease (DJD). *Methods:* Panoramic radiographs, bilateral TMJ MRI and bilateral TMJ computed tomography (CT) were performed on 705 subjects. Three calibrated board-certified radiologists blinded to the subjects' clinical findings interpreted all images. Assessment of diagnostic accuracy of panoramic radiographs and MRI for detecting signs of DJD was compared to the reference-standard diagnoses derived from the CTs. DJD was defined by the presence of subcortical cyst, surface erosion, osteophyte or generalized sclerosis. Target sensitivity and specificity were $\geq$ 70% and $\geq$ 95%, respectively. *Results:* For panoramic radiographs, sensitivity and specificity were: subcortical cysts - 14%, 100% respectively; erosion - 20%, 100% respectively; osteophyte - 12%, 100% respectively and generalized sclerosis - 33%, 100%, respectively. For MRI, sensitivity and specificity were: subcortical cysts - 32%, 100% respectively; erosion - 35%, 99% respectively; osteophyte 71%, 98% respectively and generalized sclerosis 50%, 100% respectively. For diagnosis of signs of DJD based on panoramic radiographs, radiologists' inter-examiner reliability was slight (k=0.16), moderate (k=0.47) when using MRI and substantial with CT images (k=0.71). *Conclusions:* Panoramic radiographs and MRI had below target sensitivity but above target specificity in detecting all CT-depicted signs of DJD with the exception of detection of MRI-depicted osteophytes, which had adequate diagnostic accuracy. *Practical Implications:* Use of CT to diagnosis signs of TMJ DJD is recommended to address the false negatives that can occur with panoramic radiographs and MRI.

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Introduction

Degenerative joint disease (DJD) is the most common joint pathology affecting the temporomandibular joint (TMJ)[1]. Degenerative changes are believed to result from dysfunctional remodeling, due to a decreased host-adaptive capacity of the articulating surfaces and/or functional overloading of the joint that exceeds the normal adaptive capacity[1]. It is characterized by a progressive loss of articular cartilage with increased loading of the subchondral bone. This results in signs and symptoms of focal degeneration and osteophyte formation[2]. It is important to diagnose TMJ DJD as progression of the condition is associated with loss of joint function or late-stage ankylosis, joint instability, and facial deformity attributable to loss of posterior mandibular vertical dimension as pathologic osteolysis decreases the height of the condyle and condyloid process resulting in an apertognathia, that is, anterior open bite[3]. A valid diagnosis of TMJ DJD is based on radiographic findings since clinical assessment is associated with poor diagnostic accuracy[4]. The imaging analysis criteria use subcortical cyst, surface erosion, osteophyte and/or generalized sclerosis to diagnose TMJ DJD[5]. Currently, computed tomography (CT) is considered the reference standard (i.e., gold standard) for diagnosis of DJD.

Panoramic radiographs are widely used in dentistry and magnetic resonance imaging (MRI) is commonly used to assess the TMJ. Panoramic radiography has the advantage for the general dentist of being readily available, cost-effective and low radiation dose compared to a CT. MRI has the advantage of having no exposure to ionizing radiation. It has been suggested that both panoramic radiography and MRI are accurate screening instruments to detect gross osseous changes associated with TMJ DJD[6]. We have previously reported that the diagnostic accuracy of panoramic radiograph for detection of TMJ DJD, compared to CT, has a sensitivity of 26% and specificity of 99%[5] suggesting that panoramic radiographs do not reveal approximately three-fourths of DJD detected on CT. Magnetic resonance imaging (MRI) is primarily used to evaluate the soft tissue structures in the TMJ since its capacity to assess osseous structures is limited. We have previously reported that the MRI has reduced sensitivity (59.4%) but excellent specificity (98.0%) for detection of TMJ DJD[5]. However, panoramic radiograph and MRI may be appropriate for the initial screening for DJD by detecting gross osseous changes associated with DJD.

The aim of this study was to evaluate the diagnostic accuracy of panoramic radiographs and MRI to detect specific signs associated with TMJ DJD compared to CT. These signs are subcortical cyst, surface erosion, osteophyte and generalized sclerosis.

Methods

Study Design

In this multicenter cross-sectional Validation Project, participants were consecutively recruited from August 2003 to September 2006 at the University of Minnesota, University of Washington, and University at Buffalo. The Institutional Review Boards of these three universities approved the study. Informed consent was obtained for all participants. Health Insurance Portability and Accountability Act (HIPAA) guidelines were followed.

Study Population

A total of 1410 joints (705 subjects) were assessed with panoramic, CT and MR imaging. A full description of the participants' demographics and clinical characteristics has been published as well as details on study settings and location, recruitment methods, informed consent process and participant reimbursement[4].

Imaging modalities, Image acquisition and interpretation

Panoramic imaging, multi-detector CT (MDCT) and MRI were used in this study. At the University of Minnesota, Sirona Orthophos digital panoramic machine, Siemens Vision 1.5T and Siemens Avanto 1.5T, and Siemens Sensation 16 MDCT were used. At the University of Washington, Siemens Orthophos panoramic machine, GE Signa 1.5T MRI scanner, and GE LightSpeed VCT were used. At the University at Buffalo, Siemens Orthophos 3 panoramic machine, Siemens Symphony 1.5T system, and Toshiba Aquilion CT were used[5]. Panoramic radiograph was obtained with proper subject positioning as recommended by the manufacturer and without any modification of the protocols used in the three sites. Criteria for participant preparation and image acquisition for both CT and MRI have been previously published[5].

Three board-certified radiologists interpreted these radiographs blinded to subjects' clinical histories and clinical diagnoses. Specific image analysis criteria were used and these have been previously published[5]. The kappa statistic or kappa coefficient (k) was used to measure the diagnostic agreement between the radiologists taking into account chance agreement. A kappa of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement equivalent to chance[7]. For osseous tissue diagnosis of DJD based on panoramic radiographs, the inter-examiner agreement of the radiologists was slight[8] ($k=0.16$). The reliability of the radiologists in diagnosing hard tissue status was moderate[8] ($k=0.47$) when using MRI and substantial[8] when diagnosis of hard tissue status was conducted using CT images ($k=0.71$). Positive percent agreement for diagnosing DJD was 19% for panoramic radiography, 59% for MRI, and 84% for CT. Negative percent agreement was ≥88%[5].

Scoring criteria

Evaluation of the TMJ osseous components was recorded on a scoring form. Four criteria were used in diagnosing DJD (Table 1). Erosion was evaluated in the condylar head and fossa/eminence while subcortical cysts, osteophyte formation and generalized sclerosis were evaluated only in the condylar head. Each scoring factor had a Yes/No option.

Statistical Analysis

The sensitivity and specificity for the panoramic radiograph and the MRI were estimated for each of the four signs of DJD - surface erosion, subcortical cysts, osteophyte formation and/or generalized sclerosis using CT as the reference standard. In this study, sensitivity is the ability of the test (i.e., panoramic radiograph and MRI) to correctly identify those with the signs of DJD when the CT is positive for these signs (true positive rate). Specificity is the ability of the test (i.e., panoramic radiograph and MRI) to correctly identify those without the signs of DJD when the CT is negative for these signs (true negative rate). Sensitivity and specificity vary between 0 and 1 (i.e., 100%). The 95% confidence interval for each of these measures was calculated. Target sensitivity and specificity were $\geq$70% and $\geq$95% respectively[9].

Results

Panoramic radiographs, CT and MRI from 1410 joints (705 subjects) were evaluated for erosion in the condylar head and eminence. For the other individual variables (sub-cortical cysts, osteophyte and generalized sclerosis) data was missing resulting in fewer than 1410 joints (range of 1396-1408 joints) being evaluated. The subjects included 579 females (82%) and 126 males (18%). Subject demographics have previously been reported[4]. Panoramic radiograph showed poor sensitivity, but excellent specificity for detection of the four signs of DJD compared to the reference standard, the CT (Table 2). The MRI was superior to panoramic radiograph in detecting osseous changes associated with DJD. MRI had poor[5] sensitivity for subcortical cysts and erosion, marginal[5] sensitivity (50%) for generalized sclerosis and close to excellent (71%) for osteophyte formation. The specificity was excellent for all four signs of DJD with an MRI (Table 3). Figures A, B, C, D and E illustrates the findings for DJD using a panoramic radiograph, MRI and CT performed on the same subject.

Discussion

The results of this study found that panoramic radiographs and TMJ MRI, with the exception of osteophyte detection on MRI, have excellent specificity but inadequate sensitivity for the detection of surface erosion, subcortical cysts, and generalized sclerosis. Positive findings of signs of DJD on a panoramic radiograph or MRI are definitive. However, a negative finding with a panoramic radiograph and MRI does not rule out the possibility that the patient has a sign of TMJ DJD but it was not detected due to the significant rate of false negatives associated with these imaging modalities. Relative to using these modalities as screening tests, typically screening tests have high sensitivity and low specificity for detection of non-morbid “target diseases”. Therefore panoramic radiography and MRI are not suited for screening for DJD. Alternatively, for TMD, it has been recommended that sensitivity should be $\geq$70% and specificity $\geq$95%[9,10]. This criterion for interpreting diagnostic accuracy is based on the objective to not over diagnose these disorders. Given this criterion, MRI detection of osteophytes had acceptable diagnostic accuracy.

Implications for the clinician

The importance of detection of TMJ DJD for the clinician, beyond its potential to affect jaw pain and function, is that is can cause malocclusions. It has been previously reported that TMJ DJD is associated with the development of skeletal anterior open bite, overjet greater than 6 to 7 mm and RCP/ICP slides greater than 4 mm[11]. These malocclusions can result in compromised chewing ability and esthetic changes thus impacting the quality of life of an individual.

Dental restorative procedures are dependent on a stable maxillo-mandibular position and occlusion, and TMJ DJD can change these relationships. Although patients can have TMJ DJD with no occlusal or skeletal changes, there is a risk with dental intervention that this stability can be altered resulting in the above noted occlusal changes that have been compensated for by the proprioceptive input from the patient's teeth. Thus the clinician has an interest in detection of TMJ DJD especially if extensive dental intervention is being recommended to their patient since its detection is vital both from a treatment perspective as well as for prognosis. This also has medico-legal consequences, as the patient with TMJ DJD needs to be informed about the potential instability of the occlusion and the guarded prognosis when having certain dental procedures.

Review of literature

The results of this study are consistent with prior reports. An earlier study showed similar results when comparing panoramic radiography with tomography[12]. Although the variables were slightly different, when evaluating for the presence of condylar flattening and osteophyte, they found that panoramic radiographs had high specificity for the absence of osteophytes (0.90) and condylar flattening (0.85) while sensitivity was low (0.29 and 0.33, respectively)[12]. Another study compared panoramic examination, sagittal (lateral) scanography and tomography for detection of TMJ condylar flattening, defect (defined as a local area of rarefaction) and osteophyte[13]. Mean sensitivity values ranged from 0.10-0.50 while specificity values were high ranging from 0.86-0.99. They found no significant difference in diagnostic accuracy between the methods and favored the use of panoramic examination, which is simpler to undertake, and results in less radiation burden than sagittal cross-sectional tomography[13]. Another study evaluated the efficacy of panoramic radiograph in diagnosing TMJ DJD and found it had a low diagnostic value[14].

A systematic review evaluated the role of different imaging modalities in diagnosing TMJ erosions and osteophytes and concluded that only extensive erosions and large osteophytes in the TMJ can be identified with panoramic imaging[15]. This is in agreement with current guidelines as described in a position paper by the American Academy of Oral and Maxillofacial Radiology (AAOMR) for the use of panoramic radiography[16]. The results from our study do not support the position paper of the AAOMR. However, this position paper was issued in 1997 prior to the introduction of cone-beam CT. Currently, AAOMR is developing new guidelines (M Ahmad, BDS, PhD, oral communication, June 2016). Additionally, some of the discrepancy may be explained with the imaging technique. Patient positioning has been shown to be crucial in panoramic radiography. If the head is inclined posteriorly, the condylar image appears flattened and can simulate an osteophyte. Conversely, if the head is inclined anteriorly, the condyle may appear sclerotic[17]. Another study evaluated panoramic imaging of the TMJ using cadaveric skulls. They found that it was not possible to accurately determine condylar morphology because of the radiographic variations produced by differences in condylar angulation[18]. A disadvantage of panoramic radiography is that the glenoid fossa and articular eminences are not well visualized because of the superimposition of the base of the skull and zygomatic arches. It would be of interest if panoramic radiography were assessed for their diagnostic accuracy with the patient's jaw positioned anteriorly to see if this improved visualization of the TMJ.

Location of osteophytes has also been cited as a possible cause for the limitation in diagnostic capabilities of panoramic radiography. Osteophytes usually are located on the anterior surface of the condyle, where they will be superimposed on the condylar head and are hidden on images taken in the coronal plane. Lesions in the central and medial locations are more accurately detected than lateral locations[19].

TMJ MRI is intended to visualize the soft tissue components such as disc position and effusions. Its capacity to identify osseous structures is limited[20]. However, the results from our study indicate that it is a much better tool for diagnosing DJD, especially osteophyte formation, compared to panoramic radiography (Figures D & E). Erosions, which are not well detected by MRI, can be present in the early stage of degenerative changes, indicating that the TMJ is unstable and alteration of bony joint surfaces is occurring. Osteophytes are often present in the later stage of DJD when the body is adapting to repair the joint. Osteophytes are created to stabilize and broaden the surface of the joint in an attempt to spread out the load over a greater surface area and appear radiographically as marginal hypertrophic bone formation. In our study population, the prevalence rate was close to 30% for both erosion and osteophyte formation. A recent study evaluated DJD in a sample of older people who were virtually asymptomatic with gadolinium enhanced MRI and found a prevalence of 70%. They concluded that the high prevalence of DJD in persons aged 74-78 years was due to using a contrast agent with MRI, which resulted in the MRI displaying fine details[21]. It also suggested that signs of TMJ DJD are related to aging. Our study was carried out without the use of a contrast agent and it is possible that minor alterations in form or structure may have been missed. If this is true, contrast- enhanced MRI has the potential to become a viable diagnostic tool for the diagnosis of DJD since it may more accurately depict both hard and soft tissues. Information about disc position, joint fluid, bone marrow changes, and bone structure at multiple levels of the joint can be obtained with an MRI without exposure to ionizing radiation. However, MRI is expensive compared to panoramic radiography and CT. MRI also has many contraindications including patients with pacemakers, intracranial vascular clips and metal particles in vital structures. Other relative contraindications include obesity, claustrophobia and the inability to limit motion during the examination.

In this study we used multi-detector CT (MDCT). Given that CT is the gold standard for the diagnosis of TMJ DJD, the emergence of CBCT provides a viable alternative to conventional CT since they have similar diagnostic accuracy[22]. CBCT uses a lower scanning time and lower radiation doses than MDCT while producing images of high diagnostic quality. Thus, when a definitive diagnosis of TMJ DJD is needed, CBCT is an excellent imaging technique to use. A recent study looked at evaluation of the TMJ involved in different conditions including DJD using CBCT. They concluded that CBCT was comparable to MDCT for evaluation of cortical bone. However, they found that CBCT is more sensitive to patient motion than MDCT, making the diagnosis of small cortical abnormalities uncertain[23].

Strengths and limitations of the study

A strength of this study is the large sample size with participant demographics comparable to the general population[10]. The three radiologists interpreting these images were calibrated and blinded to the clinical histories and clinical diagnoses of the study participants. Additionally, four different calibration and reliability studies for the radiologists were undertaken over the course of this study[5]. Statistical analyses for this study used sensitivity and specificity estimates, which theoretically are independent of the prevalence of the target condition, in this case TMJ DJD[24]. A literature search did not reveal any large population-based studies on the prevalence of TMJ DJD. One possible limitation of this study could be the exclusion of articular surface flattening and subcortical sclerosis as signs of TMJ DJD. These two signs were designated as "indeterminate" for TMJ DJD[5]. Flattening can be present in normal joints and a variant of normal. Both signs can be present due to aging. These two signs may also indicate remodeling of the TMJ and as such are not specific for the presence of TMJ DJD. Finally, they may be a precursor to development of TMJ DJD. To address these issues, longitudinal follow-up of subjects would be needed. The diagnostic criteria for radiologic interpretation of TMJ DJD that included the designation of “indeterminate’ for these two signs had content validity since the criteria was developed from a review of the literature, recommendations by the members of an External Advisory Panel appointed by the National Institute of Dental and Craniofacial Research (NIDCR) for this study and suggestions from members of the TMD and radiology community[5].

Conclusion

This study assessed the diagnostic accuracy of panoramic radiograph and TMJ MRI using CT as the reference standard in diagnosing subcortical cyst, surface erosion, osteophyte and generalized sclerosis, which are signs of TMJ DJD. The results from our study indicate that panoramic radiography is not suitable for the definitive diagnosis of these four signs of DJD because of inadequate sensitivity. TMJ MRI is much better than panoramic radiography for diagnosing the four signs of DJD, especially osteophyte formation. However, CT is needed for accurate diagnosis of DJD. CBCT may well replace MDCT because it clearly depicts the TMJ osseous structures at a lower radiation dose. The clinical significance of this study is that clinicians may need to consider CT, including CBCT, as the radiograph of choice when assessing for TMJ DJD. The advantage of CBCT is that a panoramic view is also obtainable. Conventional panoramic radiographs are still useful if the clinician needs to rule out in their patients’ odontogenic or non-odontogenic causes of orofacial pain.

Table 1: Definition of Scoring Criteria for TMJ Degenerative Joint Disease

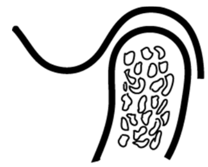
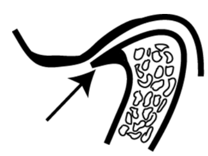
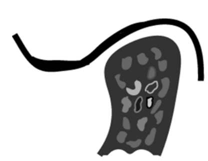
Scoring Criteria	Definition		Line Diagram
Normal (No DJD)	i. Normal relative size of the condylar head; and ii. No subcortical sclerosis or articular surface flattening; and iii. No deformation due to subcortical cyst, surface erosion, osteophyte or generalized sclerosis.		
DJD	Deformation due to subcortical cyst, surface erosion, osteophyte or generalized sclerosis.		
	Surface Erosion	Loss of continuity of the articular cortex or cortical margin.	
	Subcortical Cyst	A cavity below the articular surface that deviates from normal marrow pattern.	
	Osteophyte	Marginal hypertrophy with sclerotic borders and exophytic angular formation of osseous tissue arising from the surface.	
	Generalized Sclerosis	No clear trabecular orientation with no delineation between the cortical layer and the trabecular bone that extends throughout the condylar head.	

Table 2: Diagnostic Accuracy of Panoramic Radiography for DJD* compared to CT**

Signs of Degenerative Joint Disease	Sensitivity	95% Confidence Interval	Specificity	95% Confidence Interval
Subcortical Cysts (n=56)	14.3%	5.5-32.4	99.7%	98.8-99.9
Surface Erosion (n=256)	19.5%	13.6-27.3	99.7%	98.6-99.9
Osteophyte Formation (n=182)	12.1%	6.8-20.5	99.8%	98.8-100
Generalized Sclerosis (n=24)	33.3%	13.1-62.4	100%	-

* DJD= Degenerative Joint Disease

** CT = computed tomography

Table 3: Diagnostic Accuracy of MRI for DJD* compared to CT**

Signs of Degenerative Joint Disease	Sensitivity	95% Confidence Interval	Specificity	95% Confidence Interval
Subcortical Cysts (n=56)	32.1%	17.6-51.1	99.9%	99-100
Surface Erosion (n=256)	35.9%	28.1-44.6	99%	97.7-99.5
Osteophyte Formation (n=184)	70.7%	60.6-79	97.9%	96.4-98.8
Generalized Sclerosis (n=24)	50%	24.4-75.6	99.7%	98.9-99.9

* DJD= Degenerative Joint Disease

** CT = computed tomography

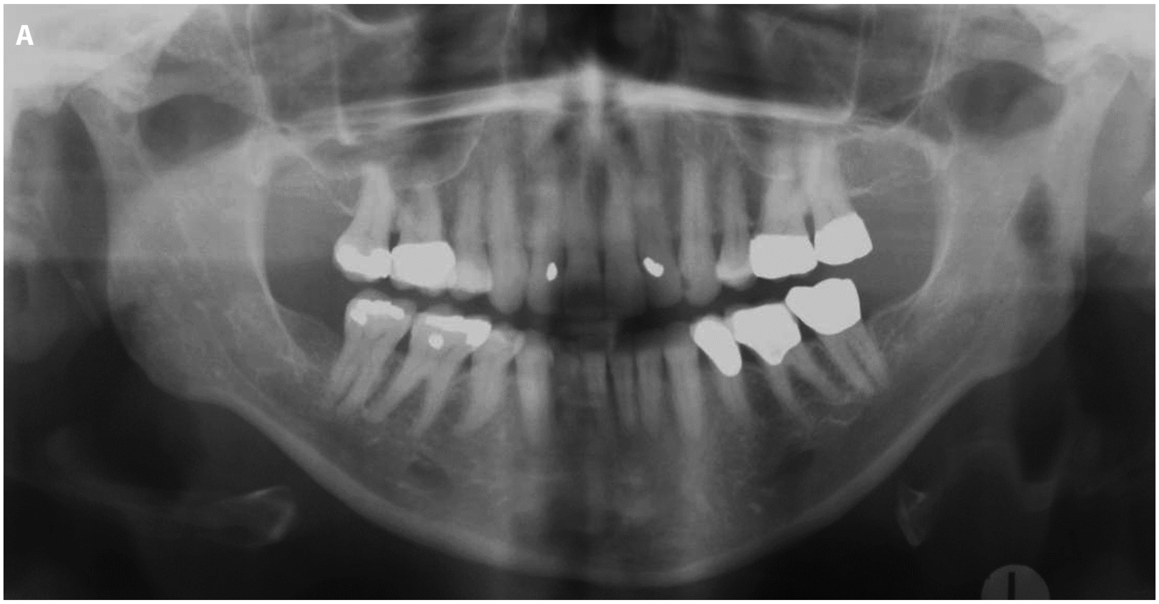


Figure A: Panoramic radiograph showing poor visualization of right and left condylar heads.

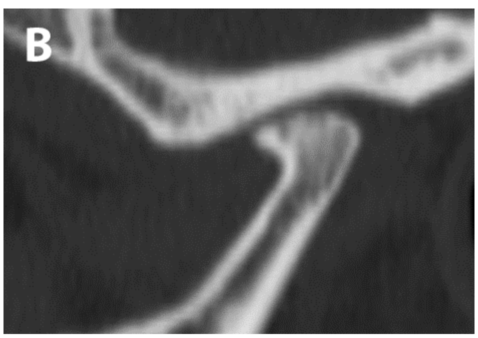


Figure B: Sagittal computed tomography view of condyle from the same subject showing osteophyte formation, subcortical cyst and surface erosion. Sclerosis of the eminence and neck of the condyle is also noted.

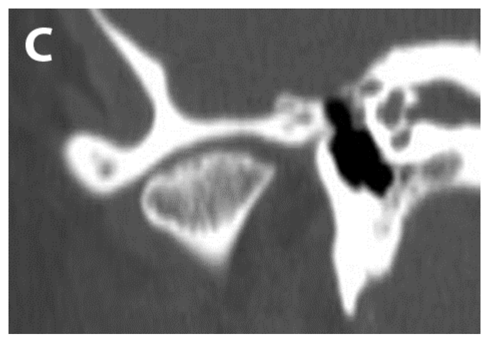


Figure C: Axially corrected coronal computed tomography view of condyle from the same subject showing surface erosion. Sclerosis of the eminence is also displayed.

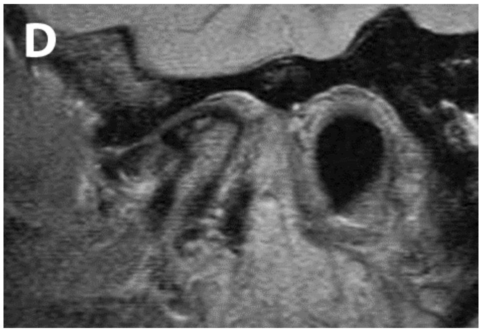


Figure D: Sagittal proton density magnetic resonance imaging in closed-mouth position from the same subject showing osteophyte formation of the condylar head. Anteriorly displaced disc is also revealed.

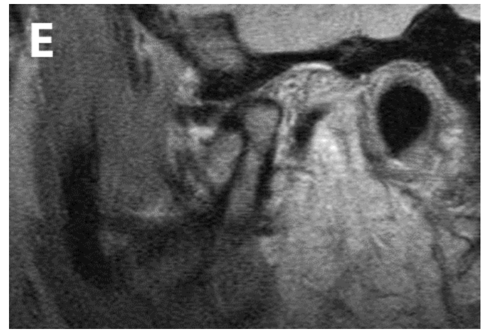


Figure E: Sagittal proton density magnetic resonance imaging in open mouth position from the same subject showing osteophyte formation of the condylar head. Non-reduction of the disc position is also displayed.

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