Relationship Between Clinical and Magnetic Resonance Imaging Diagnoses and Findings in Degenerative and Inflammatory Temporomandibular Joint Diseases: A Systematic Literature Review

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Aim: *To describe evidence for a relationship between diagnoses and findings of clinical examination and diagnoses and findings of magnetic resonance imaging (MRI) examination for degenerative and inflammatory temporomandibular joint diseases.* ***Methods:*** *PubMed and the Cochrane Library were searched using specific indexing terms and reference lists were hand-searched. Included publications satisfied pre-established criteria. Primary studies were interpreted using a modification of the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool.* ***Results:*** *The literature search yielded 219 titles and abstracts. Eighty-two studies were selected and read in full-text. After data extraction and interpretation with the QUADAS tool, 23 studies remained. There was a vast heterogeneity in study design, clinical examination methods, and diagnostic criteria. No clear evidence was found for a relationship between clinical and MRI diagnoses and findings. Several studies reported a relationship between clinical pain and internal derangements diagnosed with MRI, but the calculated odds ratio (OR) for this relationship was generally low (1.54–2.04). ORs for the relationship between pain and disc displacement without reduction (4.82) or between crepitation and disc displacement without reduction (3.71) were higher.* ***Conclusion:*** *This review reveals a need for studies with improved quality in reporting of samples, examination techniques, findings, and definitions and rationales for cutoffs, categories, and diagnoses. We recommend that standardized protocols such as the Research Diagnostic Criteria for temporomandibular disorders (RDC/TMD) and the Standards for Reporting of Diagnostic Accuracy (STARD) statement be implemented in future studies.* J OROFAC PAIN 2009;23:123–139

Key words: clinical examination, internal derangement, magnetic resonance imaging, pain, temporomandibular disorders

Clinical examination and an imaging technique are frequently applied together to diagnose temporomandibular disorders (TMD). The clinical examination assesses mandibular range of motion and associated pain, joint sounds, and muscle and joint tenderness (through palpation). Some findings vary from one assessment to the next in the same individual since TMD can be a transient or recurrent condition. In 1992, Dworkin and LeResche proposed the Research Diagnostic Criteria (RDC) for TMD so that diagnostic categories would be standardized and replicated in clinical research.[1] The RDC/TMD involves guidelines and procedures that allow examiners to achieve acceptable levels of inter-observer reliability with operationalized diagnostic criteria for investigating muscle pain, disc displacements, and degenerative diseases of the temporomandibular joint (TMJ).

An imaging examination is indicated when additional information on a patient's status is needed to substantiate results of the clinical examination to facilitate clinical decision-making. Because magnetic resonance imaging (MRI) defines hard and soft tissue, this technique has gradually replaced other imaging techniques in the examination of the TMJ. MRI is reported to be the most accurate imaging technique for diagnosing the disc position of the TMJ[2] and presents osseous changes of the TMJ with high accuracy.[3] A recent systematic literature review of the diagnostic efficacy of MRI found that evidence was insufficient and that high-quality studies on the diagnostic efficacy of TMJ imaging are needed.[4] This review[4] focused on studies of MRI efficacy per se. Such studies are limited because they do not mimic clinical practice: MRI of the TMJ is often performed after the clinical examination and should underpin the results of the clinical examination. But some data indicate a disparity in the diagnosis and findings of the clinical examination and the MRI examination.[5,6]

Therefore, the aim of this systematic literature review was to describe evidence for a relationship between clinical findings and diagnoses and MRI findings and diagnoses in degenerative and inflammatory TMJ diseases. Intended readers are clinicians who treat patients with pain and dysfunction of the temporomandibular region, radiologists, and related field professionals.

Materials and Methods

This literature review used the systematic approach of Goodman[7] and comprised these steps: (*1*) problem specification, (*2*) formulation of a plan for the literature search, (*3*) literature search and retrieval of publications, and (*4*) data extraction, interpretation of data, and evaluation of evidence from the literature retrieved.

Problem Specification

In the diagnosis of degenerative and inflammatory TMJ diseases:

- What is the evidence for a relationship between clinical and MRI diagnoses?
- What is the evidence for a relationship between clinical and MRI findings?

Medical Subject Headings (MeSH) Definitions of the Terms Used in the Literature Search

- Temporomandibular Joint: An articulation between the condyle of the mandible and the articular tubercle of the temporal bone. Year introduced: 1997
- Magnetic Resonance Imaging (MRI): Non-invasive method of demonstrating internal anatomy based on the principle that atomic nuclei in a strong magnetic field absorb pulses of radiofrequency energy and emit them as radio waves, which can be reconstructed into computerized images. The concept includes proton spin tomographic techniques. Year introduced: 1988

Various definitions of pain (spontaneous, at rest, at motion, number of motions), tenderness on palpation (at lateral pole, posterior aspects of TMJ), joint sounds (clicking, crepitus), and mouth opening capacity were the clinical findings used to determine which studies were relevant for the review.

Plan for Literature Search

Table 1 presents the indexing terms and limits used in the search. Inclusion criteria were that the publication should describe *(i)* a clinical diagnosis or finding and an MRI diagnosis or finding in the assessment of degenerative or inflammatory TMJ diseases and *(ii)* a relationship between diagnoses or findings of a clinical examination and of MRI. Exclusion criteria were studies that *(i)* reported clinical findings of muscle disorders, not TMD, *(ii)* reported laboratory findings instead of patient clinical findings or MRI findings, *(iii)* investigated TMJ tumors, trauma, and synovial chondromatosis, *(iv)* were case reports, and *(v)* evaluated other TMJ imaging techniques such as arthrography, arthrotomography, arthroscopy, ultrasonography, and scintigraphy.

Literature Search and Retrieval of Publications

Table 1 illustrates the first step in the search of the PubMed electronic database. Two authors independently read the title and abstract of all publications that matched the MeSH search terms. When at least one author considered a publication relevant, it was ordered and read in full-text. The Cochrane Database of Systematic Reviews (the Cochrane Library) was searched using the search term "temporomandibular joint."

The second step of the search was a hand-search of the reference lists of publications included in the first step of the search as described in Fig 1. Reference lists of review articles were also hand-searched. Titles were searched for those that contained the terms (*1*) magnetic resonance imaging, MR, or MRI together with temporomandibular joint or (*2*) words suggesting a clinical examination method or clinical finding such as pain, mouth opening capacity, joint sound, clicking, or crepitus/crepitation together with temporomandibular joint. No publication date limits were specified in this step. The inclusion and exclusion criteria in the first step were used in the hand-search. Book chapters and reviews were excluded because the focus of the review was primary studies. Abstracts of the selected references were ordered. The publication was ordered in full-text when (*1*) there was no abstract or (*2*) at least one author considered an abstract relevant.

Data Extraction, Interpretation of Data, and Evaluation of Evidence

Two authors independently read half of the articles and extracted data by using protocol 1 (Fig 2), and the other two authors did the same with the other half of the articles. Protocol 1 was based on literature describing how to critically appraise studies on diagnostic methods.[8–10] Publications were included only if criteria for the diagnosis or finding was reported. The criteria could be explicitly described or be referenced. Included publications were interpreted according to a modification of the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool.[11] Figure 3 describes this protocol (protocol 2).

Evidence was evaluated based on *1)* study design, *2)* quality items of protocol 2 (Fig 3), and *3)* the direction and magnitude of results of the included studies, ie, similarity in reported results. When sufficient data were available, the authors calculated predictive values and odds ratios (ORs) of clinical diagnoses or findings using MRI as a criterion standard.

Results

Systematic Literature Search

Figure 1 depicts a flow diagram of the selection process for publications relevant to our review. The PubMed search yielded 172 abstracts. No review was identified in PubMed or in the

Table 1 PubMed Search Strategy and Number of Retrieved Publications

	Indexing term	Publications (n)
#1	Temporomandibular joint [MeSH]	1,122
#2	Magnetic resonance imaging [MeSH]	23,163
#3	#1 AND #2	172

Publication date: 1988/01/01 to 2007/12/31. Database search date: 2007/12/31.
Limits: (*1*) Adult subjects: 19+ years; (*2*) Items with abstract; (*3*) English; (*4*) Human; (*5*) Clinical trial, meta analysis, practice guideline, randomized controlled trial, review, or comparative study.

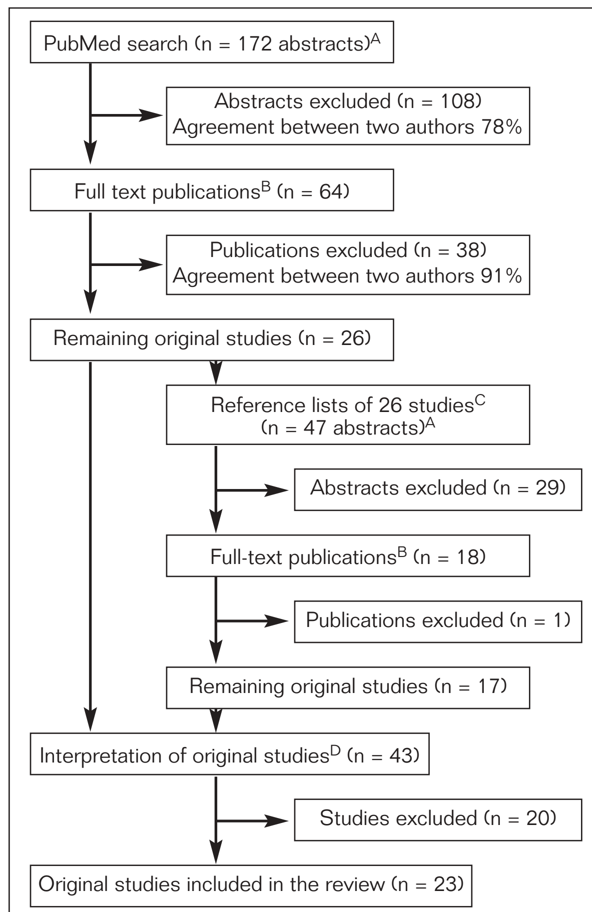

Fig 1 Flow diagram of the process used to include and exclude publications. The PubMed search resulted in 172 abstracts and the hand search of the reference lists in 47 abstracts. In total, 219 abstracts were found. [A]Two authors read abstracts; [B]Two authors using protocol 1 read publications; [C]Hand search of reference lists of original studies to find additional studies; [D]Two authors using protocol 2 interpreted studies.

1st author: ______________________ Publication no. ____________
Journal: ______________________ Year: ________ Volume: ________ Pages: ________

Publication type: ☐ Primary study ☐ Review Other: ______________________

Relevance for this review: ☐ Yes ☐ No
If No reason for exclusion: ______________________

Is there a well-defined hypothesis/aim of the study? ☐ Yes ☐ No ☐ Cannot tell
My interpretation is: ______________________

TMJ Diagnosis: ☐ Arthralgia ☐ Disc displacement ☐ Disc perforation
☐ Osteoarthrosis ☐ Osteoarthritis ☐ Internal derangement ☐ Other: ________

Classification system: ☐ RDC ☐ AAOP ☐ Other: ______________________

Clinical examination: ☐ Pain ☐ Tenderness ☐ Limited opening/maximum opening
☐ No sound ☐ Clicking ☐ Crepitus ☐ Other: ______________________

MRI examination: ☐ Disc position ☐ Disc configuration ☐ Disc perforation
☐ Disc adhesion ☐ Osseous changes ☐ Joint effusion ☐ Bone marrow changes

Comparison was performed by the authors: ☐ Yes ☐ No
If Yes how was the comparison described? ______________________

Overall results: ______________________
____

Data extraction made by: ______________________ Date: ______________________

Fig 2 Protocol 1 for inclusion/exclusion of publications. AAOP = American Academy of Orofacial Pain.

Cochrane Library. The reading of 64 full-text articles and interpretation of data with protocol 1 reduced the number to 26 publications. The second step of the search, ie, the hand search of the reference lists of the 26 publications, yielded 47 abstracts. After these abstracts were read, 18 publications were ordered and read in full-text, again using protocol 1. Thus, 82 primary studies were read in full-text; 39 of these were excluded with the aid of protocol 1. The principal reasons for excluding studies were *1)* the relationship between clinical diagnoses or findings and MRI diagnoses or findings was not reported or *2)* clinical findings were not described. Tables 2 through 7 list the 23 publications[12–34] that remained after interpretation according to protocol 2. Table 8 lists the publications that were excluded because they did not meet the criteria listed in protocol 2.[5,6,35–52]

Relationship Between Clinical and MRI Diagnoses

Eight publications[12–19] reported a relationship between a clinical and an MRI diagnosis (Table 2). The studies used various systems and criteria for the clinical examination and diagnosis and for the MRI diagnosis; only four studies[12,14,15,19] used the RDC/TMD.[1] The relationship was expressed as agreement in percentage, Kappa, and correlation. The results of studies that used MRI as the standard criterion were expressed as accuracy, sensitivity, specificity, OR, or predictive values of the clinical examination.

The conclusions of the studies were contradictory. While some concluded that disc displacement can be accurately diagnosed using well-defined clinical examination and criteria,[16,18,19] others concluded that reliability of the clinical examination is insufficient to determine disc position.[12–15,17] Poor agreement was found between clinical and MRI diagnoses of osteoarthrosis.[13]

1st author: ______________________ Publication no. ______________
Journal: ______________________ Year: ________ Volume: ________ Pages: ________

A. Are the results of the study valid?

☐ Yes ☐ No ☐ Can't tell

Did the sample include an appropriate spectrum of objects (patients) to whom the diagnostic method will be applied in clinical practice concerning for example:

☐ Number of patients (joints) ☐ Type of patients (joints) ☐ Description (disease status, prevalence, severity)

Were selection criteria of the sample clearly described?

☐ Yes ☐ No ☐ Can't tell

Was the time period between the examinations short enough to be reasonably sure that the TMJ condition did not change between the two examinations?

☐ Yes ☐ No ☐ Can't tell

Were the methods for performing the clinical examination described in sufficient detail to permit replication?

☐ Yes ☐ No ☐ Can't tell

Was a protocol followed that described the examination for:

☐ Self-report of pain/pain on movement ☐ Pain on palpation/tenderness ☐ Joint sounds ☐ Maximum opening (mm)

Was the classification system of TMJ diagnosis described?

☐ RDC/TMD ☐ AAOP ☐ Other: ______________________

Were the methods for performing the MR images described in sufficient detail to permit replication?

☐ Yes ☐ No ☐ Can't tell

Was a protocol followed that described the settings for the production of the images such as:

☐ Type of machine ☐ Field strength – T ☐ Pulse sequence type ☐ 2D/3D sequence
☐ Pulse sequence parameters: ☐ Repetition time ☐ Echo ☐ Turbo factor
☐ Field of view (cm) ☐ Matrix size ☐ Slice thickness ☐ Number of slices
☐ Slice direction (orientation in relation to condyle axis done in axial localizers) ☐ Sagittal and/or coronal slices
☐ Surface – TMJ coil ☐ Closed and open mouth

Was the setting for the image interpretation described concerning:

☐ Diagnostic categories and criteria for the diagnosis ☐ Number of observers
☐ Prior knowledge of the results of the clinical examination

Relationship between clinical and MRI diagnoses/findings:

Was the method for calculating the relationship described in sufficient detail and was the method adequate?

☐ Yes ☐ No ☐ Can't tell

B. What are the results?

Diagnosis/findings:

Results:

Summary:

☐ Include ☐ Exclude
Reason(s) for exclusion: ______________________

Signature: ______________________ Date: ______________

Fig 3 Protocol 2 for interpretation of included primary studies on relationship between clinical and MRI results of the TMJ.

Table 2 Relationship Between Clinical and MRI Diagnoses of the TMJ

Study	No. of subjects	No. of TMJs	Sample characteristics	Clinical examination and diagnosis	MRI diagnosis	Statistical method	Reported results	Comments
Barclay 1999[12]	39 consecutive	78	DDR in at least one joint	RDC/TMD • NDD • DDR • DDNR	• NDD • DDR • DDNR	• % agreement •κ	Agreement for all TMJ 54% (κ 0.36)	• Only 13 of 78 TMJs had NDD • Authors conclude: a positive RDC/TMD examination is predictive but not reliable for ID type
Emshoff 2001[13]	163 consecutive patients with TMD	326	137 patients with pain 189 patients without pain	CDC/TMD • Absence of ID • DDR • DDNR • Osteoarthrosis	• Absence of ID • DDR • DDNR • Osteoarthrosis	• % agreement • κ	Poor agreement: • ID (κ 0.36) • osteoarthrosis 62% (κ 0.09)	Authors conclude: reliability of CDC/TMD is insufficient to determine ID and osteoarthrosis
Huddleston Slater 2004[14]	42	84	32 patients with clinical signs of ID in one joint 10 patients with no signs of ID	RDC/TMD • no ID • ADDR • PDDR	• no ID • ADDR • ADDNR • PDDR	• % agreement • Cohen's κ between clinical examination and MRI	Poor agreement for all TMJ 32% (κ 0.12)	Of 40 TMJs clinically diagnosed with no ID, only 23 TMJs were diagnosed with no ID with MRI
Limchaichana 2007[15]	60	120	19 patients with myofascial pain 41 patients with myofascial pain in combination with arthralgia/osteoarthritis	RDC/TMD • NDD • DDR • DDNR	• NDD • DDR • DDNR	• % agreement	Clinical diagnosis of NDD versus DDR and DDNR was confirmed by MRI in 50/109 TMJ (46%)	• All patients had pain • Disc position cannot be diagnosed with accuracy with clinical examination according to RDC/TMD
Marguelles-Bonnet 1995[16]	242 with unilateral or bilateral ID	484	123 patients with unilateral TMD, 119 patients with bilateral TMD	• Normal TMJ • ADDR • ADDNR • Stuck disc • Degenerative arthrosis	Diagnoses identical with clinical diagnoses	• Yates' corrected χ^2 for correlation	Significant correlation between clinical and MRI diagnoses for all categories of ID; highest for arthrosis and normal TMJ	Calculated accuracy: for clinical diagnosis with MRI as criterion standard: 0.59
Paesani 1992[17]	110	220	81 normal TMJs based on MRI	• Normal • DDR • DDNR • DDNR and arthrosis	Diagnoses identical with clinical diagnoses	• accuracy in % • sensitivity • specificity	• accuracy 43% • ID: - sensitivity 0.78 - specificity 0.52 • osteoarthrosis: - sensitivity 0.42 - specificity 0.90	Authors conclude: clinical examination not reliable to determine status of TMJ with ID
Ribeiro 1997[18]	181 symptomatic TMD 56 asymptomatic volunteers	362 112		• Symptomatic TMD (pain > 4 on a 10-point VAS) • Asymptomatic	• Normal • DD	• OR to evaluate association between TMD and DD	• OR 12.2 for TMD and DD	Authors conclude: association between DD and TMD is strong
Üşümez 2004[19]	40	80	Referred for TMJ complaints	RDC/TMD • NDD • DDR • DDNR	• NDD • DDR • DDNR	• % agreement	Agreement for: • all TMJ 76% • NDD 83% • DDR 72% • DDNR 81%	Authors conclude: DD can be diagnosed with considerable accuracy with clinical examination

CDC = clinical diagnostic criteria; DD = disc displacement; NDD = no disc displacement; DDR = disc displacement with reduction; DDNR = disc displacement without reduction; A = anterior; P = posterior; ID = internal derangement; k = kappa.

Relationship Between Clinical and MRI Findings

Pain. Three studies analyzed the relationship between spontaneous pain and MRI findings (Table 3).[20–22] Güler et al[21] considered that there is a relationship between pain and joint effusion, while Adame et al[20] reported that "it is not possible to relate pain and effusion." A third study,[22] where many asymptomatic volunteers participated, found no relationship between disc displacement and pain.

Table 3 Relationship Between Spontaneous Pain and MRI Findings of the TMJ

Study	No. of subjects	No. of TMJs	Sample characteristics	Clinical finding spontaneous pain	MRI finding	Statistical method	Reported results	Comments
Adame 1998[20]	Study group: 111 Control group: 31	123 with effusion 46 without effusion		• Articular pain (in the preauricular region) • Radiating pain (in the temporal, masseter, or cervical area)	• Effusion	• Pearson's χ^2 test to compare study and control groups ($P < .05$)	• Not possible to relate pain and effusion •76% of study group and 84% of control group patients had pain	All patients had articular pathology
Güler 2003[21]	Study group: 64 with bruxing behavior Control group: 30 without bruxing behavior but with ID	128 60	All patients reported muscle tenderness	• Pain in the preauricular area and muscles of mastication Evaluated on a VAS	• Normal disc position • DD • Bony changes • Joint effusion	χ^2 test was used for analysis between study and control group ($P < .05$)	• Relationship between joint effusion and pain ($P < .05$) • In joints with DDNR: 30% with pain in study group and 59% with pain in control group had joint effusion	Type of pain not stated when relationship between pain and effusion was calculated
Katzberg 1996[22]	102 with joint sounds and pain 76 asymptomatic volunteers			• TMJ pain • Ear pain • Headache • Neck pain	• Normal disc position • DDR • DDNR	• Logistic regression analysis ($P < .05$) • Outcome variable: DD (present or absent)	• No association between DD and ear pain, headache, and neck pain	

VAS = visual analog scale. See Table 2 for key to other abbreviations.

Four studies[23–26] examined the relationship between provoked pain and MRI findings (Table 4) as the relation between pain and disc displacement with and without reduction,[23,24] between pain and osteoarthritis,[23] between pain and changes of the retrodiscal tissue,[25] or between pain and effusion.[26] Bertram et al[23] found a significant relation between pain and internal derangement and between pain and osteoarthritis. Sensitivity of pain to identify disc displacement was low while specificity was high.[24] A significant relation was reported between provoked pain and joint effusion[26] and between provoked pain and a higher signal intensity in the retrodiscal tissue.[25]

Seven studies examined the relationship between spontaneous and provoked pain and MRI findings (Table 5).[27–33] Significant relationships were found between pain and these MRI findings: internal derangement/disc displacement,[27,29,32] osteoarthrosis,[28,29] effusion[28,29,31,32] and bone marrow edema.[30] Sensitivity of effusion to detect arthralgia was reported to be 0.85 and specificity 0.28.[33] One study found no relationship between pain and disc displacement.[31] Poor agreement, expressed as low κ values, was reported between pain and internal derangement.[27,28,32]

Joint Sounds (Clicking or Crepitation). Three studies on patients and asymptomatic subjects[22,24,34] and three studies on different patient samples[12,19,20] reported a relationship between joint sounds and MRI findings (Table 6). Three studies found a relationship between joints with reciprocal clicking and disc displacement with reduction[12,19,22] and three studies reported varied results on the relationship between crepitation and MRI findings.[19,22,24]

Limited Mouth Opening. Limited mouth opening was defined as interincisal opening less than 35 mm[20] or below 40 mm.[34] There was no significant difference in limited mouth opening (< 35 mm) between patients with effusion or without effusion.[20] Most patients (90%) with anterior disc displacement without reduction were reported to have restricted mobility, but mean values and statistical comparisons were not presented.[34]

Table 4 Relationship Between Provoked Pain and MRI Findings of the TMJ

Study	No. of subjects	No. of TMJs	Sample characteristics	Clinical finding provoked pain	MRI finding	Statistical method	Reported results	Comments
Bertram 2001[23]	131 consecutive patients	131 with pain 131 with no pain	Unilateral orofacial pain referred to the TMJ	• Joint and muscle pain on palpation; pain score 0-3 on palpation; positive if score is ≥ 2 in two or more muscle sites • Pain on unassisted and assisted mandibular opening	• No ID • DDR • DDNR • OA	• χ^2 test to compare TMJ pain side and TMJ nonpain side ($P < .05$) • κ test for agreement between pain and MRI diagnoses	Relationship between: • Pain and ID ($P = .000$) • Pain and type of ID ($P = .000$) - 53% with pain were DDNR - 25% without pain were DDNR • Pain and OA ($P = .013$) • κ values low between pain and diagnoses and ID, OA, ID + OA	κ inadequate for expressing relation between pain and MRI finding.
Orsini 1999[24]	137 patients 23 asymptomatic volunteers	274 with signs and symptoms of TMD 46		• Bilateral manual palpation of TMJ according to RDC/TMD • Muscle pain •TMJ pain during assisted opening Positive score as described in paper	• Normal disc position • DDR • DDNR	• Sensitivity • Specificity of pain to identify - DDR - DDNR	• TMJ pain and DDR: sensitivity 0.05; specificity 0.93 • TMJ pain and DDNR: sensitivity 0.19; specificity 0.96 • Muscle pain and DDR: sensitivity 0.16; specificity 0.93 • Muscle pain and DDNR: sensitivity 0.15; specificity 0.93 • TMJ pain during opening - and DDR: sensitivity 0.18; specificity 0.79 - and DDNR: sensitivity 0.56; specificity 0.91	
Sano 1995[25]	33 patients referred for MRI	48		Patient rated degree of pain on chewing: no pain, mild pain, moderate pain, severe pain, or extreme pain	• Signal intensity for T2-weighted images from retrodiscal tissue	• Unpaired Student's *t* test to analyze difference between signal intensity of TMJ with and without pain	• Average signal intensity from retrodiscal tissue higher in TMJ with pain than in those without pain ($P < .05$)	Only 9 TMJs were without pain. No definition of higher signal
Takahashi 1999[26]	26 patients with ID and OA	38	Painful TMJ: 25 in 24 patients Pain-free TMJ: 13 in 11 patients	• Palpation of masticatory muscles and TMJ for tenderness • Joint tenderness or complaint of pain in preauricular region on mouth opening or closing	Joint effusion as: • Positive • Negative	• Fisher's exact test to assess relationship between incidence of effusion and pain	• Effusion in 80% (20/25) of painful TMJs and in 39% (5/13) pain-free TMJs ($P < .05$)	

OA = osteoarthritis. See Table 2 for key to other abbreviations.

Table 5 Relationship Between Spontaneous and Provoked Pain and MRI Findings of the TMJ

Study	No. of subjects/sample characteristics	No. of TMJs	Clinical findings spontaneous and provoked pain	MRI finding	Statistical method	Reported results	Comments
Emshoff 2001[27]	163 consecutive TMJ pain patients	137 pain side 189 non-pain side	• Muscle and joint pain on palpation • Pain on mandibular function, and/or during unassisted and assisted mandibular opening • Self-reported orofacial pain referred to TMJ	• normal • ID as: - DDR - DDNR	• χ^2 analysis to test relationship between TMJ pain and MRI imaging findings of ID and ID type ($P < .05$)	Pain associated with ID ($P < .001$) and ID type ($P = .000$) • Poor agreement between TMJ pain and: - ID (κ 0.16); - DDR (κ 0.09); - DDNR (κ 0.26)	Interpretation and description of statistics unclear
Emshoff 2002[28]	112 consecutive TMJ pain patients		• Unilateral pain during palpation, function, unassisted and assisted mandibular opening • Muscle pain on palpation assessed as painful or nonpainful	• OA • Effusion	• χ^2 analysis of relationship between pain and MRI finding ($P < .05$) • Kappa test to evaluate agreement between pain and MRI finding	• Relationship between TMJ pain and: - OA ($P = .000$); - effusion ($P = .000$) • Poor agreement between pain and: - OA κ 0.22; - effusion κ 0.29; - OA and effusion κ 0.30 • Relationship between TMJ pain and MRI:	Definition of self-reported orofacial pain unclear
Emshoff 2003[29]	169 patients with unilateral or bilateral TMJ pain	Presence of pain: 165 Absence of pain: 173	• TMJ pain on palpation during unassisted and assisted mandibular opening • Pain of muscles on palpation assessed as painful or nonpainful	• ID as: - DDR; - DDNR • OA • Effusion • Bone marrow edema assessed as absent or present	• χ^2 test for analysis of relationship between pain and MRI finding ($P < .05$) • Multiple logistic regression analysis for calculation of OR of TMJ pain as a function of MRI finding ($P < .05$)	- ID ($P = .000$); - OA ($P = .015$) - effusion ($P = .002$); - bone marrow edema ($P = .016$) • Increased risk of pain in TMJ with DDNR and: - OA and bone marrow edema OR 3.7 - effusion OR 2.8 • No increase in risk of pain in TMJ with:	All patients had TMJ disorders and only 22 patients were without pain
Emshoff 2003[30]	TMJ disorder group: 118 patients with painful TMJs Control group: 46 subjects with no TMJ pain		See Emshoff 2003[29]	See Emshoff 2003[29]	See Emshoff 2003[29]	- DDR OR 0.18; - OA OR 1 • Increase in risk of pain in TMJ with: - DDNR OR 10.2 - bone marrow edema OR 15.6 • Relationship between pain and effusion:	Patient sample probably similar to that of Emshoff 2003[29]
Haley 2001[31]	85 patients with unilateral pain	85 TMJ with pain 85 TMJ without pain	• Patients complaint of unilateral pain and masticatory muscle pain • Palpation of TMJ and masseter muscle as described in paper	• Normal disc position • DDR • DDNR • Effusion	• χ^2 analysis and McNemar's matched- pairs test for relationship between TMJ pain and MRI findings ($P = .01$)	($P = .001$) • No relationship between pain and DD ($P = .332$) Relationship between pain and:	Reliability of examinations reported
Rudisch 2001[32]	41 consecutive patients reporting pain of unilateral TMJ region as primary problem and clinical absence of DD	41 TMJ with pain 41 TMJ nonpain	• Patients report of unilateral pain near TMJ • TMJ pain on palpation during unassisted and assisted mandibular opening (positive pain score) • Pain of muscles by bilateral palpation (positive or negative)	• Normal • DDR • DDNR • TMJ effusion	• χ^2 test for analysis of relationship between pain and MRI findings • Agreement between pain and MRI findings evaluated by κ ($P < .05$)	- DD ($P = .001$); - effusion ($P = .004$) • Poor agreement between pain and: - DD (κ 0.34); - effusion (κ 0.32) - DD and effusion (κ 0.27) • Sensitivity 0.85	Description of pain score limited
Shaefer 2001[33]	30 consecutive patients with unilateral or bilateral DD (defined by RDC), 14 with bilateral jaw pain;16 with no jaw pain		• TMJ arthralgia according to RDC • Patients completed modified Symptom Severity Index (SSI) with 5 subscales via VAS • Pain pressure threshold over lateral pole of TMJ	• Normal • DDR • DDNR • TMJ effusion	• Sensitivity • Specificity of effusion to detect TMJ arthralgia	• Specificity 0.28	• Clear inclusion and exclusion criteria • Algometer used

See Table 2 for key to other abbreviations.

Table 6 Relationship Between Joint Sounds (Clicking or Crepitation) and MRI Findings of the TMJ

Study	No. of subjects	No. of TMJs	Sample characteristics	Clinical findings spontaneous and provoked pain	MRI finding	Statistical method	Reported results	Comments
Adame1998[20]	Study group: 111 patients Control group: 31 patients	123 with effusion 46 TMJ without effusion	Selected on report by the same radiologist	• Clicking on clinical examination • Clinical staging based on Wilkes stages: 1. Clicking 2. Pain and clicking	• ADDR • ADDNR • Effusion	• Pearson's χ^2 test to compare study and control groups ($P < .05$)	• TMJs with effusion had a lower incidence of clicking than TMJ without effusion ($P < .0001$) • 41% of study group patients and 76% of control group patients had clicking	All patients had articular pathology.
Barclay 1999[12]	40 consecutive patients	80	DDR in at least one joint	According to guidelines of RDC/TMD Reciprocal clicking: (1) on vertical opening and closing and eliminated on protrusive opening (2) on either opening or closing and click during lateral excursion or protrusion	• NDD • DDR • DDNR	• Agreement in percent	• Out of 32 TMJ with reciprocal click, 23 (72%) had DDR	• Only 13 of 78 TMJ had NDD according to MRI • 8 TMJ had a atypical reciprocal click • 7 TMJ had a single click
Katzberg1996[22]	102 patients 76 asymptomatic volunteers	204 with joint sound and pain 152		Sound assessed with stethoscope: • Clicking as a single distinct sound emitted during either opening or closing • Crepitation as multiple scraping or grating sounds	• NDD • DDR • DDNR	• Logistic regression analysis ($P < .05$) • Outcome variable: DD (present or absent)	• Clicking associated with DDR ($P < .05$) • No association between DD and crepitus	
Orsini 1999[24]	137 patients 23 asymptomatic volunteers	274 with signs and symptoms of TMD 46		• Presence or absence of clicking • Crepitus recorded through bilateral palpation of lateral aspect of TMJ	• NDD • DDR • DDNR	• Sensitivity and • Specificity of clicking or crepitus for DD	• Clicking - DDR: sensitivity 0.51; specificity 0.83 - DDNR: sensitivity 0.23; specificity 0.76 • Crepitus DDNR: sensitivity 0.08; specificity 1	Calculated number of TMJ with crepitus: 6
Rammelsberg 1997[34]	88 patients 47 asymptomatic volunteers	123 reciprocal clicking or restricted mobility 89		Reciprocal clicking	• Disc position was quantified according to Drace and Enzmann[61] • Anterior - posterior disc position	• Agreement in percent	• 81% (100/123) TMJ with reciprocal clicking demonstrated ADDR • Disc position in asymptomatic TMJ varied	
Üşümez 2004[19]	40 patients	80	Referred patients for TMJ complaints. 59 TMJs with click.	According to guidelines of RDC/TMD auscultation of: • Click • Crepitation	• NDD • DDR • DDNR	• Agreement in percent • LR+ of click or crepitation to detect DD	• Click found in - 80% (20/25) of TMJ with NDD - 89% (34/38) of TMJ with DDR (LR+ 1.5) - 29% (5/17) with DDNR (LR+ 0.3) • Crepitation found in - 12% (3/25) of TMJ with NDD - 11% (4/38) of TMJ with DDR (LR+ 0.3) - 71% (12/17) with DDNR (LR+ 6.4)	• All subjects had TMJ complaints • Many TMJ with NDD clicked • 19 of 80 TMJ (24%) had crepitation

LR = Likelyhood ratio. See Table 2 for key to other abbreviations.

Table 7 Predictive Values and ORs of Clinical Diagnosis or Findings of the TMJ with MRI as Criterion Standard

Study	Clinical diagnosis/Clinical findings	Criterion standard MRI	Predictive value: Positive	Predictive value: Negative	OR
Barclay 1999[12]	RDC/TMD	DD	0.92*	0.38	2.84
	DD	DDR	0.65*		
Limchaichana 2007[15]	RDC/TMD DD	DD	0.88	0.40	0.88
Marguelles-Bonnet 1995[16]	ADDR	ADDR	0.57	0.83	2.87
	ADDNR	ADDNR	0.73	0.75	2.93
	AR	AR	0.64	0.94	10.26
Paesani 1992[17]	ID	ID	0.73*	0.58*	2.14
	AR	AR	0.35*	0.92*	5.29
Ribeiro 1997[18]	Symptomatic TMD	DD			12.2*
Üşümez 2004[19]	RDC/TMD DD	DD	0.84	0.83	5.15
Bertram 2001[23]	Provoked pain	ID	0.78	0.44	1.54
		OA	0.54	0.61	1.36
Emshoff 2002[28]	Spontaneous and provoked pain	AR	0.88	0.34	1.57
		Effusion	0.48	0.80	1.80
Haley 2001[31]	Spontaneous and provoked pain	DD			1.8 *
		Effusion			3.8 *
Orsini 1999[24]	Provoked pain	DDR	0.17	0.80	2.02
		DDNR	0.65	0.84	4.82
Rudisch 2001[32]	Spontaneous and provoked pain	ID	0.80	0.54	2.04
		Effusion	0.59	0.73	1.93
Shaefer 2001[33]	RDC/TMD spontaneous and provoked pain	Effusion	0.86	0.28	1.22
Takahashi 1999[26]	Provoked pain	Effusion	0.80	0.62	1.92
Orsini 1999[24]	Clicking	DDR	Clicking and DDR		
	crepitation	DDNR	0.42	0.87	3.27
			Clicking and DDNR		
			0.17	0.80	1.88
			Crepitation and DDNR		
			1.00	0.78	3.71

*The value calculated in this review. AR = arthrosis. See Table 2 for key to other abbreviations.

Predictive Values and ORs

Table 7 presents predictive values and ORs for clinical diagnoses and findings. ORs for the clinical diagnosis on disc displacement varied, as did the ORs for pain. In a sample of symptomatic TMD patients and asymptomatic volunteers,[18] the OR was 12.2, which suggests a strong relation between symptomatic TMD and disc displacement. When the RDC/TMD were used in patients with TMJ complaints and pain, the OR was rather high (5.15) in one study[19] but low (0.88) in another.[15] The OR for the clinical diagnosis osteoarthrosis was high (10.26[16] and 5.29[17]), as were the negative predictive values, which indicated that the clinical examination accurately identifies TMD patients who do not have osteoarthrosis. The ORs for pain were generally low (1.36–2.04) in relation to an MRI finding of internal derangement,[23,31,32] or osteoarthritis.[23,28] For pain and joint effusion, four studies showed low ORs (1.22–1.93),[26,28,32,33] while one study had a higher OR (3.8).[31] But for joints with disc displacement without reduction, the OR for provoked pain was rather high (4.82), as was the OR for crepitation (3.71).[24]

Evaluation of Evidence

No meta-analysis could be done as there was wide heterogeneity among the studies. Study design and outcome variables varied, as did clinical examination methods and criteria for diagnosis and findings. The most obvious shortcoming of the studies was the insufficient description of the clinical examination methods and of the criteria applied. Although the examination protocols and criteria for MRI findings and diagnosis also varied, they

Table 8 Excluded Studies and Reasons for Exclusion

Study	Reasons for exclusion
Aoyama 2002[35]	Clinical examination insufficiently described to permit replication.
de Laat 1993[36]	Study on treatment outcome. Limited mouth opening not defined.
Emshoff 2000[6]	Study on pre- and postoperative findings after arthrocentesis and hydraulic distension; not on relation between clinical and MRI findings.
Emshoff 2001[37]	Study and control groups not described in sufficient detail to permit replication.
Emshoff 2002[38]	Study and control groups not described in sufficient detail to permit replication.
Hans 1992[39]	Not possible to relate clinical and MRI findings.
Imirzalioglu 2005[40]	Too few subjects (n=10); study on TMJ changes over time.
Kurita 1998[41]	Study on splint repositioning appliance; not on relation between clinical and MRI findings.
Larheim 2001[42]	Clinical examination insufficiently described to permit replication.
Müller-Leisse 1996[5]	No description of MRI diagnosis; no references for criteria.
Murakami 1996[43]	Inadequate statistical method.
Ohnuki 2003[44]	Study on pre- and postoperative findings after arthroscopic surgery, not on relation between clinical and MRI findings.
Raustia 1994[45]	Study not on relation between clinical and MRI findings.
Sanchez-Woodworth 1988[46]	Study not on relation between clinical and MRI findings.
Sano 2000[47]	Inadequate statistical method.
Sato 1999[48]	Study not on relation between clinical and MRI findings.
Schellhas 1989[49]	Study not on relation between clinical and MRI findings.
Segami 2001[50]	Comparison between arthroscopic and MRI findings, not between clinical and MRI findings.
Tallents 1996[51]	Study of prevalence, not on relation between clinical and MRI findings.
Westesson 1992[52]	No description of pain. Statistical method not described.

were found to be more uniform, generally well described, or referenced to previous studies. But the settings and diagnostic procedures were seldom described. Measures of examiner reliability of the clinical examination and of MRI were only presented in four studies.[12,14,27,31] Overall there is room for improvement in definitions and rationales for cutoffs and categories. Choice of statistical method was inadequate in some studies, such as the choice of Kappa to express the relation between pain and MRI findings.[23,27,28,32]

Discussion

Methodological Considerations of the Systematic Review

Systematic reviews aim to identify and evaluate available research evidence relating to a particular objective. Another aim of systematic reviews is to identify gaps of knowledge to propose important future research. In the present review, the assessment problem specified before the search was the relationship between diagnoses or findings of clinical and MRI examinations, which are often used together to diagnose patients with TMD. A standardized approach to data extraction and interpretation of the studies is important when determining whether or not a study is to be included in a review. For example, when materials and methods are not described in enough detail to permit replication, potential bias of the study results cannot be evaluated. In the present review, two protocols were created, one based on literature about critical appraisal of studies on diagnostic methods[9,10] and a second based on the QUADAS tool.[11] This tool was the first systematically developed, evidence-based assessment tool to be used in systematic reviews of studies on diagnostic methods. QUADAS is a generic tool that allows more topic-specific items to be incorporated, as in the present study for the examination methods. The main advantage of using this tool is that it was developed to evaluate studies on diagnostic methods because the criteria needed to assess the quality of diagnostic methods differ from those used to assess studies on therapeutic interventions.

The QUADAS tool[11] does not incorporate an overall quality score for each included study, which is frequently used in systematic reviews of therapeutic topics to assess the level of evidence. Overall summary scores to find high quality studies on diagnostic tests can be problematic and lead to different conclusions regarding the effect of study quality on estimates of diagnostic methods.[53] Instead, a component approach where the association of individual quality items with estimates of diagnostic performance is supported.[53]

Considerations of the Results

Clinical Examination and Diagnosis. One of the most obvious shortcomings of the included studies was the insufficient description of clinical examination methods and criteria. The RDC/TMD were proposed in 1992,[1] so it is surprising that they have gained such little acceptance. RDC/TMD diagnoses were found to be reliable in adults,[54,55] adolescents,[56] and cross-cultural studies.[57]

Articles that report TMD signs and symptoms with acceptable reliability (pain, joint sounds, and mouth opening capacity)[54,55,58] were included in this review. Reported pain could be *(1)* spontaneous pain, for example, pain upon wakening in the morning or pain in the afternoon that is not related to a specific stimulus or *(2)* provoked pain, for example, pain upon movement of the jaw or in response to a stimulus such as TMJ palpation. One study reported high sensitivity (0.98) and specificity (0.90) for self-reported pain in the face and jaw and for RDC/TMD diagnosis of TMD pain.[59] Studies that evaluate presence or absence and type of TMJ sounds according to the RDC/TMD have also reported acceptable reliability.[56,60] Jaw mobility measured in millimeters has repeatedly been found to exhibit excellent reliability.[56,60] Although most studies in this review mentioned limited mouth opening capacity, only two[20,34] evaluated it in millimeters.

MRI Examination and Diagnosis. MRI results are influenced by such factors as MRI technique and imaging protocol, diagnostic criteria, and observer performance. So several parameters were included in the QUADAS protocol of the present study to describe machine settings during image production. A combination of sagittal and coronal images was used in the majority of the reviewed studies. This combination yields higher accuracy compared to sagittal images alone in the diagnosis of disc position and osseous changes.[4] Most MRI machines had a field strength of 1.5 Tesla and a dedicated TMJ or surface coil; T1 or proton density sequences were usually used in combination with T2 images. Thus, differences in MRI technique among the reviewed studies were small and probably had minimal effect on the results.

On the other hand, diagnostic criteria and classification systems for disc position varied. Some studies used previously presented systems[52,61,62] and several used their own classification systems.[14,17–19,22,24] Although the classification system of Tasaki et al[62] comprises 10 categories, studies that use this system[12,23,32] presented only two or three categories. Indicators for osteoarthritis and osteoarthrosis—bony (osseous) changes such as flattening, sclerosis, erosion, and osteophyte formation—were similar to the RDC/TMD.[1] But results were probably affected by the different descriptions of joint effusion used.[20,21,26,31,52] Since the included studies emanated from different research centers, there is reason to believe that observer performance greatly influenced MRI diagnosis of disc position and joint effusion. Interobserver variation concerning disc position,[4,63] presence of joint fluid, and diagnosis of TMJ disease and bone marrow changes were large.[63] Moderate observer agreement was found for anterior disc displacement without reduction and no joint fluid.[63]

Relationship Between Clinical and MRI Diagnoses and Findings. Consistency in the relationship between clinical and MRI results reported by the reviewed studies was limited. The divergent results can be attributed to the various criteria, study designs, and samples used. While some samples[18,22,24] included symptomatic and asymptomatic individuals, others comprised various spectrums of patients. This heterogeneity indicates a varied prevalence of disc displacement or internal derangement, the MRI diagnoses most frequently studied. Furthermore, study group and control group characteristics varied. For example, in the analysis of the relation between pain and effusion, one sample was characterized by an MRI finding, patients with and without effusion,[20] and other samples by clinical findings, patients with and without bruxing behavior[21] or joints with and without pain.[26,28,31,32]

Some studies reported pain to be significantly related to the MRI diagnosis of internal derangements,[23,27,29,32] while other studies found no relationship.[22,31] But sensitivity, specificity, predictive values, and ORs are common measures for reporting the efficacy of diagnostic examinations. These measures help quantify the condition so that patients can be separated into groups with varying probabilities of disease or a specific diagnosis. Calculation of these measures requires a criterion standard. Some studies[12,16–18] used MRI as the criterion standard, as in the present study's calculations of predictive values and ORs. Some might question the use of this criterion standard. But when analyzing whether the patient history and clinical examination give sufficient information for an accurate TMD diagnosis, it can be argued that it is appropriate to calculate ORs of the clinical diagnosis or findings and use the MRI diagnosis as a criterion standard.

In two studies, the odds favoring the occurrence of the MRI diagnosis disc displacement in individuals with symptomatic TMD[18] (12.2) and in joints with provoked pain[24] (2.02–4.82) were rather high. But both samples included asymptomatic individuals. Most diagnostic tests can accurately distinguish healthy from affected patients, but the pragmatic value of a test is only established in a study that closely resembles clinical practice.[9] Since the most common reason for patients to seek treatment for TMD is pain,[57] a more appropriate study sample would comprise patients with different orofacial pain conditions. For joints with pain, the odds favoring the occurrence of disc displacement or internal derangement were low as reported in three studies[23,31,32] (OR 1.54–2.04). However, the results of one study presented an OR of about 5 for joints with disc displacement without reduction.[24] Low ORs were also reported for pain and osteoarthrosis[23,28] (OR 1.36–1.57). That ORs of effusion in joints with pain ranged between 1.22 and 3.8[26,28,31–33] illustrates the difficulty in interpreting this finding.

Besides the varying spectrum of samples examined by the reviewed studies, the divergent results could also be due to the techniques and criteria used to measure pain. Most studies in the present review included manual palpation in the clinical examination, but descriptions of the clinical examination were often inadequately described. Pain intensity was measured with the visual analog scale (VAS),[21,33] pain scores,[23,24] or verbal rating scales.[25] Several scales are reliable in the measurement of pain, and those most commonly used are the VAS and the numerical rating scale.[64] Although manual palpation of the TMJ has acceptable reliability,[60] the degree of TMJ pain is difficult to assess with this method. So the algometer is commonly used to measure pain thresholds in the orofacial region.[65,66] Only one of the reviewed studies used this methodology.[33]

Some studies[23,27,28,32] expressed the relation between pain and MRI findings in κ values. But κ is a statistical expression for agreement of identical findings such as disc displacement diagnosed clinically and with MRI. Because pain and internal derangements are different variables, low κ values should be the outcome.

Overall, the relationship between joint sounds and MRI findings was low. TMJ sounds are reported to be common in population-based studies with a prevalence of 14% and 30% in adolescents and adults, respectively.[67,68] Longitudinal studies have found joint sounds to fluctuate considerably in the same individuals.[69] In addition, TMJ sounds increase with age as a sign of degenerative changes.[69,70] Therefore, since TMJ sounds are prevalent in asymptomatic populations this symptom reflects the biologic variability of the TMJ and is questionable as an indicator of disease. Many consider MRI to be indicated when patients may have disc displacement without reduction. This condition is associated with a substantial history of limited jaw opening and reduced opening capacity measured in millimeters. It was therefore unexpected that only two studies[20,34] reported data on opening capacity or tried to correlate opening capacity with MRI findings.

Conclusions

The studies included in this review give no clear evidence of a relationship between a clinical diagnosis and an MRI diagnosis. And consistency concerning a relationship between clinical findings and MRI findings was limited. Some studies reported a relationship between pain and internal derangement, but ORs were generally low.

Study quality was less than optimal, mainly because the clinical examination and the criteria for clinical diagnoses and findings were incompletely described. The present review highlights the need for studies to use standardized and well-described diagnostic criteria with detailed examination specifications. Examination results should be analyzed with standardized methods. Authors should describe methods in sufficient detail to allow other researchers to replicate the study or to allow readers to judge the feasibility of the methods in their own settings. Furthermore, if the authors defined several categories of results, the readers need to know how and when the category boundaries were made. Several studies evaluating the reliability of clinical findings have pointed out that examiner calibration is crucial for reducing bias. An article detailing a diagnostic test should report the test's reliability. This is especially important when expertise is required to perform and interpret the test. Because the relationship between painful joints and internal derangements as diagnosed with MRI had low sensitivity, high specificity, and low ORs, pain cannot be considered an accurate indicator of disc displacement and internal derangement and an MRI should be performed when disc position must be determined for diagnosis and treatment planning.

The following are recommended:

- Further research, in view of the serious limitations and inconsistencies in this review's studies. The results of future research are likely to broaden understanding of the relationship between clinical and MRI diagnoses and findings. This understanding should encourage clinicians to use selection criteria for deciding which methods to use to examine patients with TMD.
- Adoption of the RCD/TMD[1] in future study designs so that results can be compared. To improve the accuracy and completeness of reports of examination and diagnostic methods, the Standards for Reporting of Diagnostic Accuracy (STARD) statement[71] should be applied. STARD consists of a checklist and a flow diagram, comparable to the essential elements in the Consolidated Standards of Reporting Trials (CONSORT),[72] which authors use to ensure that relevant information is included when reporting randomized controlled trials.

References

1. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: Review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6:301–355.
2. Liedberg J, Panmekiate S, Petersson A, Rohlin M. Evidence-based evaluation of three imaging methods for the temporomandibular disc. Dentomaxillofac Radiol 1996;25:234–241.
3. Tasaki MM, Westesson PL. Temporomandibular joint: Diagnostic accuracy with sagittal and coronal MR imaging. Radiology 1993;186:723–729.
4. Limchaichana N, Petersson A, Rohlin M. The efficacy of magnetic resonance imaging in the diagnosis of degenerative and inflammatory temporomandibular joint disorders: A systematic literature review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:521–536.
5. Müller-Leisse C, Augthun M, Bauer W, Roth A, Günther R. Anterior disc displacement without reduction in the temporomandibular joint: MRI and associated clinical findings. Magn Reson Imaging 1996;6:769–774.
6. Emshoff R, Rudisch A, Bösch R, Gassner R. Effect of arthrocentesis and hydraulic distension on the temporomandibular joint disk position. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:271–277.
7. Goodman C. Literature Searching and Evidence Interpretation for Assessing Health Care Practices. Stockholm: The Swedish council on technology assessment in health care, 1996.
8. CEBM-Centre for Evidence-based Medicine. Diagnostic critical appraisal sheet. Available at: http://www.cebm.net/index.aspx?o=1157. Accessed February 7, 2008.
9. Jaeschke R, Guyatt G, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. A. Are the results of the study valid? Evidence-based medicine working group. JAMA 1994;271:389–391.
10. Jaeschke R, Guyatt G, Sackett DL. Users' guides to the medical literatue. III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? Evidence-based medicine working group. JAMA 1994;271:703–707.
11. Whiting P, Rutjes AWS, Reitsma JB, Bossuyt PMM, Kleijnen J. The development of QUADAS: A tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. BMC Med Res Methodol 2003;3:25–37.
12. Barclay P, Hollender LG, Maravilla KR, Truelove EL. Comparison of clinical and magnetic resonance imaging diagnoses in patients with disk displacement in the temporomandibular joint. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;88:37–43.
13. Emshoff R, Rudisch A. Validity of clinical diagnostic criteria for temporomandibular disorders: Clinical versus magnetic resonance imaging diagnosis of temporomandibular joint internal derangement and osteoarthrosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:50–55.
14. Huddleston Slater JJ, Lobbezoo F, Chen YJ, Naeije M. A comparative study between clinical and instrumental methods for the recognition of internal derangements with a clicking sound on condylar movement. J Orofac Pain 2004;18:138–147.
15. Limchaichana N, Nilsson H, Ekberg EC, Nilner M, Petersson A. Clinical diagnoses and MRI findings in patients with TMD pain. J Oral Rehabil 2007;34:237–245.
16. Marguelles-Bonnet RE, Carpentier P, Yung JP, Defrennes D, Pharaboz C. Clinical diagnosis compared with findings of magnetic resonance imaging in 242 patients with internal derangement of the TMJ. J Orofac Pain 1995;9:244–253.
17. Paesani D, Westesson PL, Hatala MP, Tallents RH, Brooks SL. Accuracy of clinical diagnosis for TMJ internal derangement and arthrosis. Oral Surg Oral Med Oral Pathol 1992;73:360–363.
18. Ribeiro RF, Tallents RH, Katzberg RW, et al. The prevalence of disk displacement in symptomatic and asymptomatic volunteers aged 6 to 25 years. J Orofac Pain 1997;11:37–47.
19. Üşümez S, Öz F, Güray E. Comparison of clinical and magnetic resonance imaging diagnoses in patients with TMD history. J Oral Rehabil 2004;31:52–56.
20. Adame CG, Monje F, Muñoz M, Martin-Granizo R. Effusion in magnetic resonance imaging of the temporomandibular joint: A study of 123 joints. J Oral Maxillofac Surg 1998;56:314–318.
21. Güler N, Yatmaz PI, Ataoglu H, Emlik D, Uckan S. Temporomandibular internal derangement: Correlation of MRI findings with clinical symptoms of pain and joint sounds in patients with bruxing behaviour. Dentomaxillofac Radiol 2003;32:304–310.
22. Katzberg RW, Westesson PL, Tallents RH, Drake CM. Anatomic disorders of the temporomandibular joint disk in asymptomatic subjects. J Oral Maxillofac Surg 1996;54:147–153.
23. Bertram S, Rudisch A, Innerhofer K, Pümpel E, Grubwieser G, Emshoff R. Diagnosing TMJ internal derangement and osteoarthritis with magnetic resonance imaging. J Am Dental Assoc 2001;132:753–761.

24. Orsini MG, Kuboki T, Terada S, Matsuka Y, Yatani H, Yamashita A. Clinical predictability of temporomandibular joint disk displacement. J Dent Res 1999;78:650–660.
25. Sano T, Westesson PL. Magnetic resonance imaging of the temporomandibular joint. Increased T2 signal in the retrodiskal tissue of painful joints. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:511–516.
26. Takahashi T, Nagai H, Seki H, Fukuda M. Relationship between joint effusion, joint pain, and protein levels in joint lavage fluid of patients with internal derangement and osteoarthritis of the temporomandibular joint. J Oral Maxillofac Surg 1999;57:1187–1193.
27. Emshoff R, Innerhofer K, Rudisch A, Bertram S. Relationship between temporomandibular joint pain and magnetic resonance imaging findings of internal derangement. Int J Oral Maxillofac Surg 2001;30:118–122.
28. Emshoff R, Brandlmaier I, Bertram S, Rudisch A. Magnetic resonance imaging finding of osteoarthrosis and effusion in patients with unilateral temporomandibular joint pain. Int J Oral Maxillofac Surg 2002;31:598–602.
29. Emshoff R, Brandlmaier I, Bertram S, Rudisch A. Relative odds of temporomandibular joint pain as a function of magnetic resonance imaging findings of internal derangement, osteoarthrosis, effusion, and bone marrow edema. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;95:437–445.
30. Emshoff R, Brandlmaier I, Gerhard S, Strobl H, Bertram S, Rudisch A. Magnetic resonance imaging predictors of temporomandibular joint pain. J Am Dental Assoc 2003;134:705–714.
31. Haley DP, Schiffman EL, Lindgren BR, Anderson Q, Andreasen K. The relationship between clinical and MRI findings in patients with unilateral temporomandibular joint pain. J Am Dent Assoc 2001;132:476–481.
32. Rudisch A, Innerhofer K, Bertram S, Emshoff R. Magnetic resonance imaging findings of internal derangement and effusion in patients with unilateral temporomandibular joint pain. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:566–571.
33. Shaefer JR, Jackson DL, Schiffman EL, Anderson QN. Pressure-pain thresholds and MRI effusions in TMJ arthralgia. J Dent Res 2001;80:1935–1939.
34. Rammelsberg P, Pospiech PR, Jäger L, Pho Duc JM, Böhm AO, Gernet W. Variability of disk position in asymptomatic volunteers and patients with internal derangements of the TMJ. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:393–399.
35. Aoyama S, Kino K, Amagasa T, et al. Clinical and magnetic resonance imaging study of unilateral sideways disc displacements of the temporomandibular joint. J Med Dent Sci 2002;49:89–94.
36. de Laat A, Horvath M, Bossuyt M, Fossion E, Baert AL. Myogenous or arthrogenous limitation of mouth opening: Correlations between clinical findings, MRI, and clinical outcome. J Orofac Pain 1993;7:150–155.
37. Emshoff R, Rudisch A, Innerhofer K, Bösch R, Bertram S. Temporomandibular joint internal derangement type III: Relationship to magnetic resonance imaging findings of internal derangement and osteoarthrosis. An intraindividual approach. Int J Oral Maxillofac Surg 2001;30:390–396.
38. Emshoff R, Innerhofer K, Rudisch A, Bertram S. Clinical versus magnetic resonance imaging findings with internal derangement of the temporomandibular joint: An evaluation of anterior disc displacement without reduction. J Oral Maxillofac Surg 2002;60:36–41.
39. Hans MG, Lieberman J, Goldberg J, Rozencweig G, Bellon E. A comparison of clinical examination, history, and magnetic resonance imaging for identifying orthodontic patients with temporomandibular joint disorders. Am J Orthod Dentofacial Orthop1992;101:54–59.
40. Imirzalioglu P, Biler N, Agildere AM. Clinical and radiological follow-up results of patients with untreated TMJ closed lock. J Oral Rehabil 2005;32:326–331.
41. Kurita H, Kurashina K, Baba H, Ohtsuka A, Kotani A, Kopp S. Evaluation of disk capture with a splint repositioning appliance: Clinical and critical assessment with MR imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:377–380.
42. Larheim TA, Katzberg RW, Westesson PL, Tallents RH, Moss ME. MR evidence of temporomandibular joint fluid and condyle marrow alterations: Occurrence in asymptomatic volunteers and symptomatic patients. Int J Oral Maxillofac Surg 2001;30:113–117.
43. Murakami K, Nishida M, Bessho K, Iizuka T, Tsuda Y, Konishi J. MRI evidence of high signal intensity and temporomandibular arthralgia and relating pain. Does the high signal correlate to the pain? Br J Oral Maxillofac Surg 1996;34:220–224.
44. Ohnuki T, Fukuda M, Iino M, Takahashi T. Magnetic resonance evaluation of the disk before and after arthroscopic surgery for temporomandibular joint disorders. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96: 141–148.
45. Raustia AM, Pyhtinen J, Pernu H. Clinical, magnetic-resonance imaging, and surgical findings in patients with temporomandibular joint disorder: A survey of 47 patients. Rofo 1994;160:406–411.
46. Sanchez-Woodworth RE, Tallents RH, Katzberg RW, Guay JA. Bilateral internal derangements of temporomandibular joint: Evaluation by magnetic resonance imaging. Oral Surg Oral Med Oral Pathol 1988;65:281–285.
47. Sano T, Westesson PL, Larheim TA, Takagi R. The association of temporomandibular joint pain with abnormal bone marrow in the mandibular condyle. J Oral Maxillofac Surg 2000;58:254–257.
48. Sato S, Sakamoto M, Kawamura H, Motegi K. Long-term changes in clinical signs and symptoms and disc position and morphology in patients with nonreducing disc displacement in the temporomandibular joint. J Oral Maxillofac Surg 1999;57:23–29.
49. Schellhas KP, Wilkes CH. Temporomandibular joint inflammation: Comparison of MR fast scanning with T1- and T2-weighted imaging techniques. AJR Am J Roentgenol 1989;153:93–98.
50. Segami N, Nishimura M, Kaneyama K, Miyamaru M, Sato J, Murakami K1. Does joint effusion on T2 magnetic resonance images reflect synovitis? Comparison of arthroscopic findings in internal derangements of the temporomandibular joint. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:341–345.
51. Tallents RH, Katzberg RW, Murphy W, Proskin H. Magnetic resonance imaging findings in asymptomatic volunteers and symptomatic patients with temporomandibular disorders. J Prosthet Dent 1996;75:529–533.
52. Westesson PL, Brooks SL. Temporomandibular joint: Relationship between MR evidence of effusion and the presence of pain and disk displacement. AJR Am J Roentgenol 1992;159:559–563.

53. Whiting P, Harbord R, Kleijnen J. No role for quality scores in systematic reviews of diagnostic accuracy studies. BMC Med Res Methodol 2005;5:19–29.
54. John MT, Dworkin SF, Mancl LA. Reliability of clinical temporomandibular disorder diagnoses. Pain 2005;118:61–69.
55. List T, John MT, Dworkin SF, Svensson P. Recalibration improves inter-examiner reliability of TMD examination. Acta Odontol Scand 2006;64:146–152.
56. Wahlund K, List T, Dworkin SF. Temporomandibular disorders in children and adolescents: Reliability of a questionnaire, clinical examination, and diagnosis. J Orofac Pain 1998;12:42–51.
57. List T, Dworkin SF. Comparing TMD diagnoses and clinical findings at Swedish and US TMD centers using research diagnostic criteria for temporomandibular disorders. J Orofac Pain 1996;10:240–253.
58. Dworkin SF, LeResche L, deRouen T. Reliability of clinical measurement in temporomandibular disorders. Clin J Pain 1988;4:89–99.
59. Nilsson IM, List T, Drangsholt M. The reliability and validity of self-reported temporomandibular disorder pain in adolescents. J Orofac Pain 2006;20:138–144.
60. Dworkin SF, LeResche L, deRouen T, von Korff M. Assessing clinical signs of temporomandibular disorders: Reliability of clinical examiners. J Prosthet Dent 1990;63:547–549.
61. Drace JE, Enzmann DR. Defining the normal temporomandibular joint: Closed-, partially open-, and open-mouth MR imaging of asymptomatic subjects. Radiology 1990;177:67–71.
62. Tasaki MM, Westesson PL, Isberg AM, Ren YF, Tallents RH. Classification and prevalence of temporomandibular joint disk displacement in patients and symptom-free volunteers. Am J Orthod Dentofacial Orthop 1996;109:249–262.
63. Takano Y, Honda K, Kashima M, Yotsui Y, Igarashi C, Petersson A. Magnetic resonance imaging of the temporomandibular joint: A study of inter- and intraobserver agreement. Oral Radiol 2004;20:62–67.
64. McQuay H, Moore A. An Evidence-based Resource for Pain Relief. Oxford: Oxford University Press, 1998:14–31.
65. Ohrbach R, Gale EN. Pressure pain thresholds in normal muscles: Reliability, measurement effects, and topographic differences. Pain 1989;37:257–263.
66. Svensson P, Arendt-Nielsen L, Nielsen H, Larsen JK. Effect of chronic and experimental jaw muscle pain on pain-pressure thresholds and stimulus-response curves. J Orofac Pain 1995;9:347–356.
67. Dworkin SF, Huggins KH, LeResche L, von Korff M, Howard J, Truelove E et al. Epidemiology of signs and symptoms in temporomandibular disorders: Clinical signs in cases and controls. J Am Dent Assoc 1990;120:273–281.
68. List T, Wahlund K, Wenneberg B, Dworkin SF. TMD in children and adolescents: Prevalence of pain, gender differences, and perceived treatment need. J Orofac Pain 1999;13:9–20.
69. Könönen M, Waltimo A, Nyström M. Does clicking in adolescence lead to painful temporomandibular joint locking? Lancet 1996;347:1080–1081.
70. Wiese M, Svensson P, Bakke M, et al. Association between temporomandibular joint symptoms, signs, and clinical diagnosis using the RDC/TMD and radiographic findings in temporomandibular joint tomograms. J Orofac Pain 2008;22:239–251.
71. Bossuyt PM, Reitsma JB, Bruns DE, et al. Towards complete and accurate reporting of studies of diagnostic accuracy: The STARD initiative. Radiology 2003;226:24–28.
72. Moher D, Schulz KF, Altman DG. The CONSORT statement: Revised recommendations for improving the quality of reports of parallel-group randomized trials. Ann Intern Med 2001;134:657–662.