

RESEARCH

Web-based calibration of observers using MRI of the temporomandibular joint

K Hellén-Halme^{*1}, L Hollender², M Janda³ and A Petersson¹

¹Department of Oral and Maxillofacial Radiology, Faculty of Odontology, Malmö University, Malmö, Sweden; ²Department of Oral Medicine, School of Dentistry, University of Washington, Seattle, WA, USA; ³Public Dental Health Service of Skåne, Lund, Sweden

Objectives: Research diagnostic criteria for temporomandibular disorders (RDC/TMDs) were proposed in 1992 with the aim of standardizing and testing methods for diagnosing TMDs. RDC/TMDs have so far been lacking standardized methods for imaging and criteria for imaging diagnosis of disorders of the temporomandibular joint (TMJ). Criteria for disorders of the TMJ have recently been proposed for MRI. The aim of this study was to publish MR images of the TMJ on the web and to test the agreement of five observers using the criteria.

Methods: 20 cases of MRI of the TMJ were published on the web together with the criteria. The MR images were taken in closed and open mouth positions, and sagittal and coronal views. Five observers diagnosed disc position, disc shape, joint effusion and loose calcified bodies in the TMJ.

Results: In all cases except one, three or more observers agreed upon the diagnosis. All agreed on whether a loose calcified body was present or not. The second best agreement was obtained for disc position in the sagittal view, where all observers agreed in 16 of the 20 cases. For disc position in the coronal view and the evaluation of the disc shape, observer agreement was lower.

Conclusion: Criteria were useful in order to standardize and simplify evaluation and thereby probably increase the diagnostic outcome among different observers for MRI of the TMJ. We recommend that the criteria be used internationally to facilitate comparisons between different studies.

Dentomaxillofacial Radiology (2012) **41**, 656–661. doi: 10.1259/dmfr/82622690

Keywords: magnetic resonance imaging; observer variation; temporomandibular disorders; temporomandibular joint

Introduction

Evaluation of research depends on complete and accurate reporting. The Standards for Reporting of Diagnostic Accuracy (STARD) steering committee has taken an initiative to improve reporting of studies of diagnostic accuracy, and a checklist for reporting diagnostic accuracy studies has been published.¹ The list includes methods to test the reproducibility of observers.

Research diagnostic criteria for temporomandibular disorders (RDC/TMDs) were proposed by Dworkin

and LeResche² in 1992 with the aim of standardizing and testing methods for diagnosing TMDs. Today the RDC/TMD is an international consortium with the goal of advancing the scientific knowledge of TMDs and related pain conditions through authenticated tools for international use, multisite and cross-cultural research studies based on standardized assessment, annual meetings and international consensus workshops (<http://www.rdc-tmdinternational.org/>). RDC/TMD has so far been lacking standardized methods for imaging and imaging diagnosis of disorders of the temporomandibular joint (TMJ). Recent reviews have concluded that there is a lack of consistency in diagnostic criteria and the classification system for MRI of the TMJ.^{3,4} Criteria have been proposed for

*Correspondence to: Dr Kristina Hellén-Halme, Department of Oral and Maxillofacial Radiology, Faculty of Odontology, Malmö University, SE-205 06 Malmö, Sweden. E-mail: kristina.hellen-halme@mah.se

Received 24 October 2011; revised 29 December 2011; accepted 30 December 2011

CT and MRI within the framework of RDC/TMD, and a high reliability was found for assessing osteoarthritis (OA) using CT and for disc position and effusion using MRI.⁵ Previously it has been shown that interobserver agreement was increased with the aid of reference films.⁶ Publishing reference images and creating a calibration program on the web could provide a way of increasing the coherence among observers using MRI of the TMJ.

The aim was therefore to test if the criteria proposed by Ahmad *et al*⁵ could be useful when applied by several observers using MR images of the TMJ published on the web. A future aim is to use the images as reference images in calibration of observers using MRI of the TMJ. The hypothesis was that criteria could be a way to facilitate and increase observer agreement for MRI of the TMJ.

Materials and methods

The images in this study were obtained during 2008 and the first 6 months of 2009 at the Department of Radiology, Skåne University Hospital, Malmö, Sweden. All examinations were made in a Siemens Magnetom Vision 1.5 T machine (Siemens, Erlangen, Germany) with a bilateral TMJ surface coil. For the closed mouth position, the patients were instructed to close their mouth with their teeth in maximal contact. In the open mouth position, a stepped plastic bite block was placed between the upper and lower incisors. Use of the bite block was practised before the examination. The patients were asked to open their mouths as much as they could without experiencing unbearable pain. The examination included sagittal and coronal imaging of the TMJ in the closed mouth position, and sagittal images in the open mouth position. Sagittal sections were orientated perpendicular to the long axis of the condyle, and coronal sections were taken parallel to the long axis. The orientation was determined using axial localizers, one for the closed mouth position and one for the open mouth position. Proton density (PD) and T_2 weighted images were acquired using a double-echo turbo-spin echo sequence [echo time (TE), 15/105 ms; repetition time (TR), 2400 ms (sagittal) or 2000 ms (coronal); turbo factor, 7; field of view (FOV), $160 \times 160 \text{ mm}^2$; matrix, 255×512 ; and slice thickness, 3 mm]. Each sequence yielded 8–10 sections.

Selection and evaluation of images

The criteria for the non-osseous components of the TMJ described by Ahmad *et al*⁵ were used for selection of MR images in order to create samples of different scenarios relative to disc position, disc shape, effusion and presence of loose calcified bodies in the TMJ. The aim was to select five cases of each scenario, but for loose calcified bodies only one case was found. The different criteria are listed in Table 1. Disc diagnoses for the TMJ using MRI according to Ahmad *et al*⁵ are given in Table 2. 25 samples of MR images exemplifying the

different criteria were published on the internet. All cases had previously been evaluated and regarded as acceptable examinations at the hospital. Images from different examinations were included with differences in image quality. The images shown were PD sagittal images, closed and open mouth, T_2 sagittal images closed mouth and PD coronal image closed mouth (Figure 1). Five observers evaluated the images from the web, four of whom had more than 15 years' experience in evaluating MRI of the TMJ; the fifth observer was a post-graduate student. In five cases, one or more of the observers thought that the image quality was unacceptable when the cases were evaluated, and these five cases were excluded. The remaining 20 cases were used in the evaluation of the criteria and they are presently published on the internet together with instructions on how to use the program (<http://www.mah.se/od/rad/tmj>).

The diagnoses in Table 2 were used for determining the disc position in the sagittal plane. In all other evaluations the criteria shown in Table 1 were used. The observer had the opportunity to read the criteria at any time when observing the images (Figure 1).

Results

The results of the assessments of the five observers are shown in Table 3. The agreements of the observers for the 20 cases are shown in Table 4. In all cases except one, three or more observers agreed upon the diagnosis. In one case of joint effusion, two observers agreed that there was no effusion; two observers indicated slight effusion, while one thought it was frank. All observers agreed on whether a loose calcified body was present or not. However, the presence of a loose calcified body was shown only in one case. The second best agreement was obtained for diagnosis of the disc position in the sagittal view, where all 5 observers agreed in 16 of the 20 cases. For disc position in the coronal view and the evaluation of the disc shape, the agreement was lower. Total agreement for the evaluation of disc shape was achieved in only 6 of the 20 cases.

Discussion

Diagnostic radiology is part of a larger system where the goal is to treat patients with efficacy and efficiency.⁷ The accuracy of a diagnostic method can be defined in many different ways. Sensitivity and specificity are two measures that are often used to describe the diagnostic accuracy. Another important measure is observer agreement, *i.e.* how different observers agree when reading the same images. A systematic literature review of the efficacy of MRI of the TMJ in diagnosing degenerative and inflammatory joint diseases showed that no conclusion concerning the diagnostic efficacy could be reached.³ One problem was that diagnostic criteria varied between publications. In order to

Table 1 Non-osseous component assessment criteria using MRI of the temporomandibular joint from Ahmad *et al*⁵*Disc position: closed mouth sagittal and axially corrected coronal views***Normal disc position**

- i. In the sagittal plane, relative to the superior aspect of the condyle, the border between the low signal of the disc and the high signal of the retrodiscal tissue is located between the 11:30 and 12:30 clock positions
- ii. In the sagittal plane, the intermediate zone is located between the anterosuperior aspect of the condyle and the posteroinferior aspect of the articular eminence
- iii. In the oblique coronal plane, the disc is centred between the condyle and eminence in the medial, central and lateral parts

Indeterminate

- i. In the sagittal plane, relative to the superior aspect of the condyle, the low signal of the disc and the high signal of the retrodiscal tissue are located anterior to the 11:30 position, but the condyle contacts the intermediate zone located between the anterosuperior aspect of the condyle and the posteroinferior aspect of the articular eminence, or
- ii. In the sagittal plane, relative to the superior aspect of the condyle, the low signal of the disc and the high signal of the retrodiscal tissue are located between the 11:30 and 12:30 clock positions, but the intermediate zone of the disc is located anterior to the condyle, and
- iii. In the axially corrected coronal plane, the disc is positioned between the condyle and eminence in the medial, central and lateral parts

Disc displacement

- i. In the sagittal plane, relative to the superior aspect of the condyle, the low signal of the disc and the high signal of the retrodiscal tissue are located anterior to the 11:30 clock position, and
- ii. In the sagittal plane, the intermediate zone of the disc is located anterior to the condyle, or
- iii. In the axially corrected coronal plane, the disc is not centred between the condyle and eminence in either the medial or the lateral parts

Disc not visible: Neither signal intensity nor outline make it possible to define a structure as the disc*Disc position: open mouth sagittal views***Normal disc position:** The intermediate zone is located between the condyle and the articular eminence**Persistent disc displacement:** The intermediate zone is located anterior to the condylar head**Disc not visible:** Neither signal intensity nor outlines make it possible to define a structure as the disc*Disc shape: closed mouth sagittal views***Normal:** The disc in the sagittal plane is biconcave**Deformed:** All shapes other than biconcave in the sagittal plane**Disc not visible:** Neither signal intensity nor outlines make it possible to define a shape of the disc*Effusion: open or closed mouth sagittal views***None:** No bright signal in either joint space in the T_2 weighted images**Slight effusion:** A bright signal in either joint space that conforms to the contours of the disc, fossa/articular eminence and/or condyle**Frank effusion:** A bright signal in either joint space that extends beyond the osseous contours of the fossa/articular eminence and/or condyle and has a convex configuration in the anterior or posterior recesses*Loose calcified bodies: closed mouth sagittal views*

Single or multiple discrete low-signal intensity objects are present in the joint spaces, and are not attached to the condyle, fossa or eminence in any plane

improve the diagnostic accuracy for MR images of the TMJ, specific imaging criteria have been developed by Ahmad *et al*.⁵ The criteria are intended to be used in the RDC/TMD classification system. This system is used in many countries in order to simplify and guide how an examination of a patient with TMD should be performed. The criteria can also serve as a base when calibrating different clinicians. This aim of this study was to evaluate whether the guidelines for MRI of the TMJ could be used as a way to calibrate observers for better diagnostic accuracy. The reliability of the criteria in the study by Ahmad *et al*⁵ was examined with observers who were calibrated in an extensive training programme. The mean kappa values in the study by Ahmad *et al*⁵ reached a value of 0.84 for any disc displacement and 0.64 for effusion. The kappa value as a statistical measurement is calculated from data which form a square table from two observers with different options to choose from. In this study, we chose therefore to report the observer agreement in percentage figures.

The internet has made it possible to reach out to many people. Its use for the purpose of this study is, however, rather new. The attempt was to make a website with the purpose of presenting different scenarios of TMJ conditions in order to evaluate if criteria such as those published by Ahmad *et al*⁵ can be

helpful to increase the observer agreement for MR images of the TMJ. In order to represent a clinical situation, the images chosen were not optimized with regard to image quality. All MR examinations had been used for diagnosing patients with TMD and approved by the radiologist who made the initial report. Further, the five observers agreed upon using the images in this investigation. It has been reported that higher quality MR images lead to a better interobserver agreement,⁸ and therefore the procedure used in this investigation can be subject to discussion. If, in the future, a website for calibration and learning to diagnose different conditions of the TMJ is published on the internet, the highest quality MR images should be chosen and revised continuously as the MRI technique develops.

All observers in our study except one were experienced in the use of MRI of the TMJ. They had several years of clinical experience and extensive research in the area. The post-graduate student, however, had substantial experience of oral radiography, and the decisions made by the student did not affect the final results. This fact could indicate that MR images of the TMJ can be evaluated with the aid of written criteria if the observer has previous knowledge of radiological interpretation. The MRI technique could further be refined for obtaining the coronal images of the disc,⁹ as this technique was used in the article by Ahmad *et al*.⁵

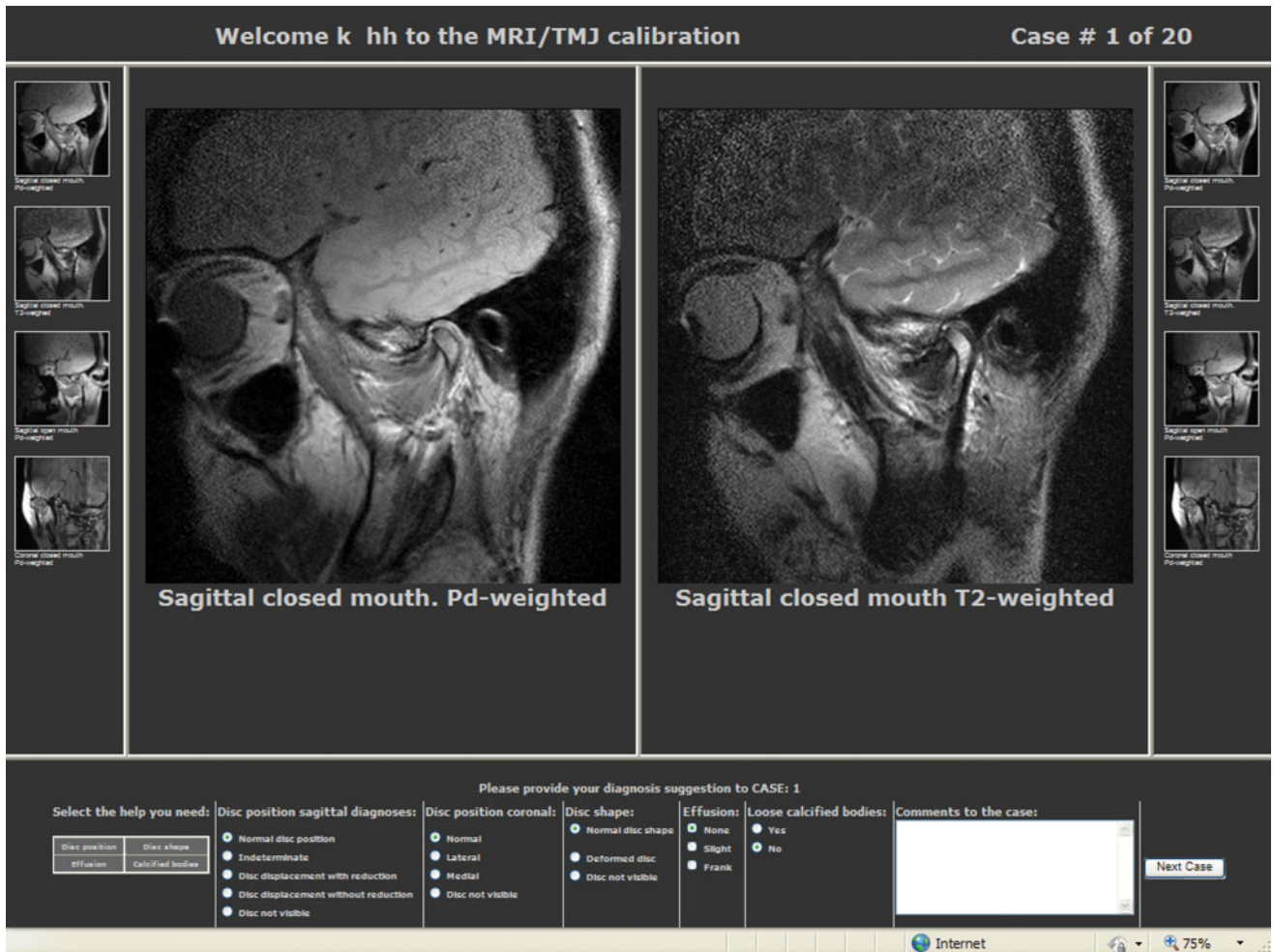


Figure 1 Page on the internet showing, in the left and right columns, MR images of the temporomandibular joint (TMJ) in the closed mouth position [proton density (PD) and T_2], open mouth position (PD) and coronal view (PD). Images can be shown in larger magnification in the middle fields. In the row in the bottom, alternative diagnoses can be chosen. In the corner to the left, it is possible to click on the different buttons and the written criteria will be shown

Several studies of observer agreement at MRI of the TMJ have been published.^{10–17} It is difficult to compare the studies as different criteria were used, for instance for disc position. Widmalm *et al*¹⁶ concluded that a diagnosis of TMD based on MRI examination protocols made by a single examiner should not be accepted, as the diagnosis may be misleading. A recent publication concluded that examiners do not demonstrate reproducibility in the interpretation of MRI of the TMJ.¹⁷ It seems that the diagnosis “anterior disc displacement without reduction” reached the highest kappa values and agreements between observers in different publications.^{8,13,15–17} In 80% of the cases the five observers agreed on the diagnosis of the disc in the sagittal plane, a finding that is similar to our results.

The observations of disc position in the coronal plane, joint effusion and disc shape reached much lower agreement between the observers. This is consistent with the findings of Takano *et al*,¹⁵ Widmalm *et al*,¹⁶

Butzke *et al*¹⁷ and Schmitter *et al*.⁸ However, better agreement of the disc shape was found by Tasaki *et al*.¹⁰ One way of increasing the agreement between observers is to reduce the number of categories. This was proposed by Takano *et al*¹⁵ regarding the finding of joint effusion, and in our study, if the finding of joint fluid was dichotomized to “yes” or “no”, the observer agreement would increase to 80%. Therefore, we propose that the criteria described by Ahmad *et al*⁵ are changed for joint effusion to be stated as present or not. Regarding the judgement of disc deformity, a better definition would perhaps be in case of a disc displacement with reduction that the shape of the disc is judged in the open (reduced) position. If the shape of the disc is normal in the open position then the judgement should be that of a normal disc shape, since the deformity seen in the closed was only “temporary”. This was also suggested by Ahmad *et al*,⁵ and it will be used in the future presentation of the criteria.

Table 2 Disc diagnosis in the sagittal plane for the temporomandibular joint using MRI according to Ahmad *et al*⁵

A. Normal: disc location is normal on closed and open mouth images
 B. Disc displacement with reduction: disc location is displaced on closed mouth images but normal in open mouth images
 C. Disc displacement without reduction: disc location is displaced on closed mouth and open mouth images
 D. Indeterminate: disc location is not clearly normal or displaced in the closed mouth position
 E. Disc not visible: neither signal intensity nor outlines make it possible to define a structure as the disc in the closed mouth and open mouth view

Table 3 Results of the five assessments for Observers a–e

| Case number | Disc position sagittal | | | | | Disc position coronal | | | | | Disc shape | | | | | Effusion | | | | | Loose calcified body | | | | |
|-------------|------------------------|---|---|---|---|-----------------------|---|---|---|---|------------|---|---|---|---|----------|---|---|---|---|----------------------|---|---|---|---|
| | a | b | c | d | e | a | b | c | d | e | a | b | c | d | e | a | b | c | d | e | a | b | c | d | e |
| 1 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 2 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 5 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| 6 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 8 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 9 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 |
| 10 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 11 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 13 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 14 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15 | 2 | 2 | 4 | 4 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 16 | 2 | 2 | 3 | 3 | 2 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 17 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 18 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 19 | 2 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| 20 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |

Disc position sagittal (diagnoses): 1, normal; 2, indeterminate; 3, disc displacement with reduction; 4, disc displacement without reduction; 5, disc not visible.

Disc position coronal: 1, normal; 2, lateral; 3, medial; 4, disc not visible.

Disc shape: 1, normal; 2, deformed; 3, disc not visible.

Effusion: 1, none; 2, slight; 3, frank.

Loose calcified body: 1, yes; 2, no.

Table 4 Agreements between the five observers

| Diagnosis | Cases | | | | | | | | | | | | | | | | | | | | All (%) |
|-----------|-------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|---------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |
| A | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 3 | 3 | 5 | 5 | 4 | 5 | 80 |
| B | 3 | 5 | 5 | 3 | 4 | 5 | 3 | 3 | 5 | 3 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 30 |
| C | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 5 | 3 | 4 | 3 | 4 | 4 | 5 | 30 |
| D | 3 | 4 | 5 | 3 | 3 | 3 | 5 | 4 | 3 | 2 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 55 |
| E | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 |

Number indicates how many observers agreed.

Diagnosis: A, disc position sagittal; B, disc position coronal; C, disc shape; D, effusion; E, loose calcified body.

The total agreement of all five observers is given in the column “all”.

The MR images in the sagittal plane showed closed and open mouth positions of the TMJ. The images formed the bases for giving diagnoses such as disc displacement with or without reduction. The coronal images could only be used for identifying the disc position in the closed mouth position. This limits the number of possible diagnoses of the disc position in the coronal plane and a combination of diagnoses in the sagittal and coronal plane. However, this decision was taken by the RDC/TMD consortium, as more

emphasis was put on disc displacement in the anteroposterior direction than in the mediolateral direction. A diagnostic examination should ideally lead to different treatment options.⁷ Today there are no such possibilities in RDC/TMD, and this might be a suggestion for future development of the system.

The criteria proposed by Ahmad *et al*⁵ are important to follow in order to standardize the reporting of TMD in MRI of the TMJ. We suggest that the criteria are used internationally following the intentions of RDC/

TMD. Our internet page can be used in order to train and calibrate observers, as in the majority of cases more than three of five trained observers agreed upon the diagnosis. On the website it will be possible to reach our conclusions after the evaluations are made on a separate page.

The conclusion of this study was that the use of criteria was useful in order to standardize and simplify the evaluation and thereby probably increase the

diagnostic outcome among different observers for MRI of the TMJ. We recommend that the criteria are used internationally to be able to compare different studies.

Acknowledgments

We want to thank Professor Per-Lennart Westesson and Senior Consultant Lars-Göran Hansson for acting as observers.

References

1. Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig LM, et al. Towards complete and accurate reporting of studies of diagnostic accuracy: the STARD initiative. *BMJ* 2003; **326**: 41–44.
2. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord* 1992; **6**: 301–355.
3. 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.
4. Koh KJ, List T, Petersson A, Rohlin M. Relationship between clinical and magnetic resonance imaging diagnoses and findings in degenerative and inflammatory temporomandibular joint diseases: a systematic literature review. *J Orofac Pain* 2009; **23**: 123–139.
5. Ahmad M, Hollender L, Anderson Q, Kartha K, Ohrbach R, Truelove EL, John MT, Schiffman EL. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **107**: 844–860.
6. Rohlin M, Petersson A. Rheumatoid arthritis of the temporomandibular joint: radiologic evaluation based on standard reference films. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1989; **67**: 594–99.
7. Fryback DG, Thornbury JR. The efficacy of diagnostic imaging. *Med Decis Making* 1991; **11**: 88–94.
8. Schmitter M, Kress B, Hähnel S, Rammelsberg P. The effect of quality of temporomandibular joint MR images on interrater agreement. *Dentomaxillofac Radiol* 2004; **33**: 253–258.
9. Hollender L, Barclay P, Maravilla K, Terry V. A new coronal imaging plane for magnetic resonance imaging of the temporomandibular joint. *Dentomaxillofac Radiol* 1998; **27**: 48–50.
10. Tasaki MM, Westesson P-L, Raubertas RF. Observer variation in interpretation of magnetic resonance images of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol* 1993; **76**: 231–234.
11. Nebbe B, Brooks SL, Hatcher D, Hollender LG, Prasad NGN, Major PW. Interobserver reliability in quantitative MRI assessment of temporomandibular joint disk status. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; **86**: 746–750.
12. Orsini MG, Kuboki T, Terada S, Matsuka Y, Yamashita A, Clark GT. Diagnostic value of 4 criteria to interpret temporomandibular joint normal disk position on magnetic resonance images. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; **86**: 489–497.
13. Nebbe B, Brooks SL, Hatcher D, Hollender LG, Prasad NGN, Major PW. Magnetic resonance imaging of the temporomandibular joint: interobserver agreement in subjective classification of disk status. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **90**: 102–107.
14. Vahlensieck M, Okweschokwu S, Greven M. Magnetresonanztomographie (MRT) des Kiefergelenkes: Einfluss auf Therapieentscheidung und Übereinstimmung zweier Auswerten. English abstract. *Fortschr Röntgenstr* 2002; **174**: 1415–1421.
15. 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.
16. Widmalm SE, Brooks SL, Sano T, Upton LG, McKay DC. Limitation of the diagnostic value of MR images for diagnosing temporomandibular joint disorders. *Dentomaxillofac Radiol* 2006; **35**: 334–338.
17. Butzke KW, Batista Chaves KD, Dias da Silveira HE, Dias da Silveira HL. Evaluation of the reproducibility in the interpretation of magnetic resonance images of the temporomandibular joint. *Dentomaxillofac Radiol* 2010; **39**: 157–161.