Recognition, prevalence, and risk factors of internal derangements of the temporomandibular joint

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Chapter 5

A comparative study between clinical and instrumental techniques for the recognition of internal derangements

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submitted for publication
Abstract

The aim was to examine the concurrent validity of clinical criteria, as suggested in this study, for the recognition of various types of internal derangements within the temporomandibular joint (TMJ). The results of a clinical examination were compared with those of condylar movement recordings and MR imaging. To test the recognition of an anterior or posterior disc displacement with reduction and of hypermobility within the TMJ, forty-two participants underwent a clinical examination, an opto-electronic movement recording, and a MRI scan. The examinations were executed in a single-blind design, by different examiners for each technique. For 10 randomly chosen participants, the condylar movement recordings and the MRI's were recorded twice. The data of these second recordings were added to the other data, while the examiners were unaware of their presence. The intra-observer reliability for the recognition of internal derangements was "almost perfect" for the condylar movement recordings (Kappa value K=0.86) and for the MRI's (K=0.73). The inter-method reliability was substantial (K=0.59) between the two function-based techniques, i.e. between the clinical examination and the condylar movement recordings. However, the inter-method reliability was poor between the anatomy-based MRI technique and either of the two function-based techniques (for the condylar movement recordings, K=0.15 and for the clinical examination, K=0.12). For the achievement of a function-based diagnosis of an internal derangement, a clinical examination, which is based upon clearly defined sets of criteria, is sufficient.
Introduction

An internal derangement (ID) of the temporomandibular joint (TMJ) can anatomically be described as a deviation in position or form of the tissues within the capsule of the joint (The glossary of prostodontic terms, 1999) whereas functionally, it is manifest by interferences with smooth TMJ movements (McNeill, 1993). Disc displacements with or without reduction within the TMJ, and hypermobility of the TM condyle are examples of frequently occurring internal derangements. The displacement of the disc is usually into an anterior direction (ADD), but posterior disc displacements (PDD) have also been described (Blankestijn and Boering 1985; Lückerath et al., 1989; Westesson et al., 1998). In most cases, the disturbed structural relationship of the disc with the condyle restores during mandibular movement, with clicking sounds during movement as its main clinical manifestation. However, in rare cases, the disc stays permanently displaced with respect to the condyle and the patient has difficulty in either full opening or closing the mouth. This condition is known as a “closed lock” or “open lock”, respectively. Hypermobility in the TMJ is regarded as a sign of an increased laxity within the joint. During wide opening and closing, jerky lateral mandibular movements and clicking sounds are noted when the condyle snaps over the apex of the eminence. The prevalence rates of ADDs, PDD’s and hypermobility are still largely unknown. So far, studies to internal derangements have mainly been focused on the “TMJ clicking” phenomenon as such and less on the underlying causes.

Although most forms of internal derangements are considered harmless and cause no or only little discomfort to the patients, the disc displacements with reduction may occasionally develop into a more serious clinical condition, the non-reducing disc displacement. Unfortunately, it is unknown which disc displacements show this development, and under which conditions. To gain more insight into the possible long-term clinical implications of internal derangements, research should focus on the prevalence rates and risk factors of the internal derangements themselves rather than on those of the clicking phenomenon. Large population samples are then needed and one is, for practical reasons, limited to clinical examination techniques.

This study focuses upon the most frequently occurring internal derangements: those associated with a clicking sound during movement. To recognize the various internal derangements, clinical criteria are needed. For the recognition of ADD’s, widely accepted criteria are formulated by the research diagnostic criteria (RDC) for temporomandibular disorders (Dworkin and LeResche, 1992). However, for the recognition of posteriorly dis-
placed discs and hypermobility, no clinical criteria are available yet. In this paper, clinical
criteria are suggested for the recognition of the various types of internal derangements that
are associated with a clicking sound during movement. The aim was to study the concur-
rent validity of these criteria by comparing the results of the clinical examination with those
of condylar movement recordings and MR imaging.
Materials and methods

Suggestions for clinical criteria for the recognition of internal derangements:

**Anterior disc displacement with reduction:**

The criteria for the recognition of an ADD were modified from the criteria suggested by the Research Diagnostic Criteria (RDC) for temporomandibular disorders (Dworkin and LeResche, 1992). One of the RDC criteria is that the interincisal distance at the time of the opening click should be at least 5 mm greater than the distance at the time of the closing click. However, a recent study has indicated that this 5 mm criterion is not very specific for an ADD (Huddleston Slater et al., 2002a) and for that reason, this criterion was not included in our set of clinical ADD criteria. As an alternative, clicking should be present on opening and on closing. However, it is a clinical experience that the opening click is usually louder than the closing click. Manual loading of the mandible during closing reduces the intra-articular distance within the TMJ (Huddleston Slater et al., 1999) and as a result, it enhances the closing click. Further, the closing click, which is due to the dislocation of the disc from the condyle, usually occurs just before the condyle re-enters the fossa (Huddleston Slater et al., 2002a). Protrusive opening and closing prevents the return of the condyle into the fossa and thus should eliminate the clicking due to an ADD.

Therefore, the clinical ADD criteria used in this study were:
- Reproducible TMJ clicking on opening and on (loaded) closing on at least two of three opening-closing trials; and
- Elimination of the TMJ clicking on protrusive opening and closing.

**Posterior disc displacement with reduction:**

Some studies suggest that in a PDD, the disc gets posteriorly displaced during maximal mouth opening, and restores its structural relationship with the condyle during mouth closing (Wise et al., 1993; Yoda et al., 2002). Therefore, disc dislocation is not eliminated on protrusive opening, but on submaximal mouth opening, i.e., mandibular opening and closing movements up to about half the maximum possible excursion.

The clinical PDD criteria for the recognition of a posterior disc displacement were:
- Reproducible TMJ clicking on opening and/or on (loaded) closing on at least two of three trials; and
- Elimination of TMJ clicking on submaximal mouth opening.
**Hypermobility:**

As a clinical condition, hypermobility in the TM joint can only be noted when it interferes with smooth mandibular movements. Often jerky mandibular movements and clicking sounds are then noted when the condyle snaps over the apex of the eminence during opening. The observations are not eliminated during protrusive opening, because condylar subluxation is then not prevented.

Therefore, the clinical criteria for the recognition of hypermobility were:

- Reproducible TMJ clicking on opening and on (loaded) closing on at least two of three trials; and
- TMJ clicking occurring in the last part of the opening and the first part of the closing movement, often in combination with characteristic jerky lateral movements of the mandible; and
- No elimination of TMJ clicking on protrusive opening.

**“Other” internal derangements:**

When the TMJ clicks, noted during mouth opening and closing, did not meet one of the above described sets of criteria, the internal derangement underlying the clicks was classified as “other”.

The interrater reliability of the clinical protocol had been tested (Huddleston Slater et al., 2002b). Cohen's kappa for the clinical assessment of the presence of an internal derangement as such was 0.58; for the classification to type, Cohen's kappa was 0.90.
Validity study of the clinical protocol:

Participants

Fourty-two participants, 22 women and 20 men (mean ± SD = 30.0 yrs ± 9.9 yrs), participated in the validity study. They were recruited from among patients referred to the CMD clinic of our department and from among students from the dental school. All gave informed consent to the procedures approved by the review board of the Netherlands Institute for Dental Sciences and the Committee for Scientific Research on Humans of the Utrecht University.

To ensure that various forms of internal derangements were present in the group of participants, each participant was clinically screened by an independent examiner (J.H.S) prior to participation. During this screening, ten participants showed no signs of an internal derangement. The remaining 32 participants showed clinical signs of an internal derangement in one of their TM joints. Anterior disc displacement without reduction (closed lock) was clinically excluded during the screening.

Protocol

Each participant underwent a clinical examination, an opto-electronic movement recording, and a MRI scan, all performed within one month. The examinations were executed according to the below-described protocols and were performed, in a single blind design, by different experienced examiners for each technique. The examiners were unaware of the results of the preceding clinical screening and were blind to the results of the other examiners.

Clinical Examination

One examiner (F.L.) clinically examined the presence of an internal derangement according to the above described criteria, using palpation and auscultation with a stethoscope. The participants performed, in a fixed order, at least three maximal opening and closing movements, three submaximal opening movements, and three protrusive opening movements that started from and ended in a protruded end-to-end position. Three closing movements were also performed while the mandible was loaded with a manually applied, downward directed force (about 30 N) on the chin, which was calibrated beforehand using a weight scale.

For the auscultation technique, the bell of an infant stethoscope (3M Littmann, St. Paul,
MN U.S.A.) was placed over the lateral pole of the TMJ. Palpation was performed with the index and middle fingers placed over the participant's lateral poles of the TMJ. The pressure was about 5 N (Dworkin and LeResche, 1992), which was calibrated using a weight scale. Both joints were palpated simultaneously. Clicks were denoted when they were observed with either of the two techniques.

**Opto-Electronic Movement Recordings**

Mandibular movements were recorded by means of the OKAS-3D system, which is an opto-electronic device capable of accurately recording mandibular motion with six degrees of freedom at a sampling frequency of 300 Hz per coordinate (Naeije et al., 1995). Small microphones (condenser type) were placed over the palpated lateral pole of the TMJ's to simultaneously record joint sounds. Off-line, all recordings were interpreted by a single investigator (M.N.). Specialized software graphically visualized the movement traces of the incisal point and those of the kinematic centers of the condyles (Yatabe et al., 1995; Naeije et al., 1999) in a sagittal, horizontal or frontal plane, and depicted the occurrence of a joint sound on these traces with the use of an asterix.

The presence of an ADD was recognized when:

- the kinematic condylar movement traces showed the characteristic and reproducible deflections from smooth traces during opening and (loaded) closing as shown in fig. 1; and
- the deflections coincided with the occurrence of the clicks; and
- the deflections and clicks were eliminated during protrusive opening.

The presence of a PDD was recognized when:

- the sagittal kinematic condylar movement traces showed the characteristic and reproducible deflections in the opening and (loaded) closing movement traces, as shown in fig. 2; and
- the deflections coincided with the occurrence of the clicks; and
- the deviations and clicks were eliminated with submaximal mouth opening.

The presence of hypermobility was recognized when:

- the sagittal kinematic condylar movement traces showed characteristic and reproducible decelerations/accelerations in the last part of the opening movement and/or the first part of the (loaded) closing movement, as shown in fig. 3; and
- the decelerations/accelerations coincided with the occurrence of the clicks; and
- the incisal point showed reproducible and characteristic (jerky) lateral movements coinciding with the occurrence of the clicks, as shown in fig. 3; and
- the decelerations/accelerations were not eliminated with protrusive opening.

When the movement recordings and observed clicks did not meet one of the above described sets of criteria, the internal derangement was classified as "other" (see fig. 4).

Figure 1. Superimposed sagittal kinematic movement traces of a joint with an opening and closing deflection at the time of clicking, which is characteristic for an ADD. Clicks are indicated with an asterisk (*). During free closing, no closing sounds could be detected (A). During free opening and loaded closing, also closing sounds were detected. Note that those parts of the opening and closing movement traces with a restored condyle-disc complex coincided (B). During protrusive opening and closing, a sound was detected only on the first opening movement (which started at the intercuspal position). Thereafter, all clicks were eliminated, while the condyle moved beyond the former position of the opening click (C). The top-left point of each trace is the condylar position with the mandible in the intercuspal position.
Figure 2. Superimposed sagittal kinematic condylar movement traces of a joint with a PDD. Clicks are indicated with an asterisk (*). Opening clicks are located at the end of the opening movements. During closing, an upward deflection at the time of clicking is noted. (A) During submaximal opening and loaded closing, no clicks were recorded, while the condyle moved beyond the former position of the closing click (B). Note the differences between a PDD and an ADD. The top-left point of each trace is the condylar position with the mandible in the intercuspal position.
Figure 3. Movements of the incisal point (frontal view) that show characteristic jerky mandibular movements during closing, characteristic for hypermobility (A). Clicks are indicated with an asterisk (*). The superimposed sagittal kinematic condylar movement traces show sudden accelerations and decelerations at the time of clicking both in free opening and (loaded) closing (B). During protrusive opening and closing, the clicks and accelerations and decelerations could not be eliminated (C).
Figure 4. Superimposed sagittal kinematic movements traces of an internal derangement which was classified as "other". Clicks are indicated with an asterisk (*). During free opening and closing, opening sounds were detected. Note that no deflections were present in the movement traces (A). Also, loaded closing shows no deflections (B). During protrusive opening and closing, the sounds could not be eliminated (C). The top-left point of each trace is the condylar position with the mandible in the intercuspal position.
MRI

$T_1$-weighted MR images were performed with a 1.5 T MR imaging system (Gyroscan NT Intera, Philips Medical Systems, Eindhoven, The Netherlands) with a surface coil used as receiver. The patient's head was placed in a headrest in the MR imager. The repetition time (TR) was 530 msec; the echo time (TE), 18 msec. Imaging was performed in a closed mouth position with nine interleaved 3-mm sagittal planes (perpendicular to the mediolateral pole of the condyle) obtained from lateral to medial, followed by nine interleaved 3-mm coronal planes. Thereafter, imaging was performed in the maximally opened mouth position, controlled with a resin bite block, with nine interleaved 3-mm sagittal planes obtained lateral to medial. For all images made, the data matrix was 205x256 pixels, and the imaging time 4 minutes and 21 seconds.

MRI's were interpreted by a single investigator (Y-J. C.), who was blind to the results of the clinical examination and the opto-electronic movement recordings. The criteria, described by Katzberg and Westesson (1993), were used to interpret the disc position. Anterior disc displacement with reduction was diagnosed when:

- the inferior surface of the intermediate zone was anterior to the anterior prominence of the condyle and the inferior surface of the intermediate zone was not in contact with the condyle when the mouth was closed; and
- the condyle was underneath the intermediate zone of the disc when the mouth was opened.

Although anterior disc displacement without reduction (closed lock) was excluded during the clinical screening, MRI could still suggest the presence of a closed lock. It was diagnosed when the inferior surface of the intermediate zone stayed in front of the condyle when the mouth was opened.

For posterior disc displacement with reduction, no scoring criteria are described in the literature. Posterior disc displacement with reduction was diagnosed when:

- the condyle was underneath the intermediate zone of the disc when the mouth was closed; and
- the inferior surface of the intermediate zone was posterior to the condyle and the inferior surface of the intermediate zone was not in contact with the condyle when the mouth was maximally opened.

For hypermobility, no scoring criteria are described in the literature either. In order to diagnose hypermobility, criteria were used that were based on the anterior-posterior relationship between condyle and eminence. Hypermobility was diagnosed when:
• at maximal mouth opening, the posterior condylar surface goes in front of the lowest part of the articular eminence.

Intra-observer reliability

To test the intra-observer reliability of the instrumental techniques (opto-electronic movement recordings and MRI), 10 randomly chosen participants were recorded twice. The data of these “double” participants were added to the other data, while the blinded examiners were unaware of the presence of these “double” participants.

For the MRI, the second recordings were made within 1 hour of the first recording, for the opto-electronic movement recordings they were made within 10 weeks of the first recording.

Statistical analysis

Cohen’s kappa was used as an estimation of the intra-observer reliability using the data of the 10 “double” participants. For the inter-method reliability, for each combination of two techniques (e.g., clinical examination vs. movement recordings; clinical examination vs. MRI; MRI vs. movement recordings), kappa values were calculated. The kappa values were interpreted according to Landis & Koch (1977).
Results

The intra-observer reliability for the recognition of internal derangements was “almost perfect” for both the movement recordings (Kappa value K=0.86) and the MRI’s (K=0.73). The inter-method reliability for the recognition of the internal derangements was substantial (K=0.59) for the clinical examination versus the movement recordings, and poor for both the clinical examination versus the MRI’s (K=0.12) and the movement recordings versus the MRI’s (K=0.15).

Table 1 shows the assessments of clinical examinations and movement recordings (OKAS) of the 84 joints. In 61 cases (73%), both techniques agreed upon the diagnosis. Disagreement was most often found in those cases where the clinical examination found an internal derangement (in 6 cases an ADD and in 5 cases hypermobility) and the movement recordings scored none (NIL). In 11 cases, the movement recordings also found “other” internal derangements, where in 6 of these cases the clinical examination scored an ADD.

In table 2, the assessments of clinical examinations and MRI’s are given. In only 27 cases (32%), both techniques showed agreement. Disagreement was mostly found in the 40 cases in which the clinical examination scored “no internal derangement”. Of those cases, MRI’s had 12 NIL’s, 11 ADDs, 7 hypermobilities, 4 CL’s (closed locks), 5 ADDs in combination with hypermobility and 1 unknown case. Of the 23 cases that the MRI’s scored no internal derangement, the clinical examination scored 5 ADDs, 4 hypermobilities, and 2 “others”.

The assessments of the movement recordings and MRI’s are given in table 3. In only 28 cases (33%), both techniques showed agreement. Also in this comparison, disagreement was most often found in the 48 cases in which the movement recordings scored “no internal derangement”. Of these cases, MRI’s had 15 NIL’s, 11 ADDs, 7 hypermobilities, 5 CL’s (closed locks) and 9 ADDs in combination with hypermobility. Of the 23 cases in which MRI scored “no internal derangement”, the movement recordings scored 15 NIL’s, 1 ADD, 2 hypermobilities and 5 “others”.

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**Table 1.** Number of TM joints with an internal derangement recognized by the methods of clinical examination and condylar movement recordings (OKAS).

NIL = No internal derangement, ADD = Anterior Disc Displacement, Hyp = Hypermobility, PDD = Posterior Disc Displacement, Other = Other Internal derangements, CL = Closed Lock, A+H = combined score of Anterior Disc Displacement and Hypermobility, ? = not interpretable

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**Table 2.** Number of TM joints with an internal derangement recognized by the methods of clinical examination and MRI’s.

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Table 3. Number of TM joints with an internal derangement recognized by the methods of condylar movement recordings (OKAS) and MRI’s.

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Discussion

Validated clinical criteria for the recognition of the various subtypes of internal derangements within the temporomandibular joint may play an important role in a better understanding of the long term clinical implications of these internal derangements. In this study, clinical criteria for the recognition of subtypes of internal derangements were formulated and validated. These criteria were partly modifications from suggestions from the literature (Dworkin and LeResche, 1992) and partly based upon intellectual inferences from the functional anatomy of the different tissues within the temporomandibular joint. In a validity study to these criteria, it is important that the various subtypes of internal derangements are more or less equally represented within the study sample. Although strong efforts were made to accomplish this, the posteriorly displaced disc displacements were underrepresented. The difficulty encountered in finding PDD’s may partly be due to difficulties recognizing them clinically and partly be due to their suspected low prevalence rate (Obwegeser and Aarnes, 1973; Westesson et al., 1998).

In this study the internal derangements were classified into anterior or posterior disc displacements, hypermobility, and “others”. When TMJ clicking sounds were notable on movement, but when the clicks and the associated movement patterns of the mandible did
not meet one of the described sets of criteria, the internal derangement was classified as "other". Apart from disc displacements and hypermobility, snapping of the condyle along the joint capsula (Freesmeyer, 1993), and passing of the condyle of an irregularity in the form of the soft and hard articular tissues (a deviation in form) are among the mechanisms suggested to cause a clicking sound from the joint. However, these suggestions are not widely accepted. As an illustration, the deviation in form is mentioned in the 1993 version of the guidelines of the American Academy of orofacial pain (McNeill, 1993), but is not mentioned in the 1996 version (Okeson, 1996). For this reason, no attempts were made to further specify the internal derangements within the "other" group.

Six degrees of freedom movement recordings have shown great potential for the study of mandibular motion (Naeije et al., 1999). They enable the reconstruction of the movement traces of any point of the mandible relative to the skull. Observations of specific characteristics of single point condylar movement traces, such as limited length, crossing of opening and closing traces, a substantial distance between opening and closing traces, and irregularities in traces, are suggested in the diagnosis of internal derangements (Farrar, 1978; van Willigen, 1979; Klett, 1982; Ozawa and Tanne, 1997). When false positive diagnoses are to be avoided, it is crucial that the single point condylar movement traces of asymptomatic joints show none of these characteristics. The movement traces of the condylar kinematic center meet these criteria (Morneburg and Pröschel, 1998, Naeije et al., 1999). The kinematic center movement characteristics are mainly determined by the contour of the articular eminence and are insensitive to variations in the rotational component of mandibular movement between opening and closing and also between consecutive movements.

So far, no universally accepted criteria are available for the recognition of TMJ internal derangements with the use of a clinical examination, condylar movement recordings or MRI's. The criteria of the condylar movement traces used in this study are partly based upon inferences from the functional anatomy of TMJ's with an internal derangement, and are also a further elaboration of criteria suggested by Mauderli et al. (1988) and Ozawa and Tanne (1997). The interpretation of the MRI's was based upon an anatomical/morphological evaluation of the position and form of the tissues within the capsule. For the recognition of ADDs, the criteria suggested by Katzberg and Westesson (1993) were used. However, for the recognition of a PDD or of hypermobility, no MRI criteria were available.

The "almost perfect" Kappa values for the intra-observer reliability of the movement recordings and of the MRI's indicated that these techniques can reliably be used in the
evaluation of internal derangements. The inter-method reliability between the clinical examination and movement recordings was substantial. However, the reliability between MRI's on the one hand and the clinical examination and the movement recordings on the other hand, was poor. In a study comparing three methods of internal derangement assessment (clinical examination, condylar movement recordings, and MRI) to arthrography as “the gold standard”, Romanelli et al. (1993) concluded that the clinical examination and the movement recordings agreed most often with arthrographically detected internal derangements, but that MRI’s often failed to detect the presence of an internal derangement. Parlett et al. (1993) and Ozawa and Tanne (1997) who compared the results of axiographic recordings with those of MRI findings, also reported great discrepancies between the two techniques. Misdiagnosis of disc displacements on MRI’s is a known problem (Kircos et al., 1987; Ribeiro et al., 1997; Barclay et al., 1999). This is probably related to the uncertainty in the interpretation of an MRI finding as an internal derangement. The wide biological variance of the temporomandibular joint structures between subjects is also a complicating factor in this respect.

It was striking that the MRI examiner in this study quite often recognized a disc displacement with or without reduction in joints which were, according to the clinical examination and the movement recordings, completely free of symptoms of an internal derangement, and vice versa. This underlines the discrepancy which exists between a function-based and an anatomy-based diagnosis of internal derangements within the TMJ. It is worthwhile to see whether suggestions for newer MRI techniques, such as dynamic MR imaging (Chen et al., 2000) and the individualized oblique-axial MRI technique (Chen et al., 2000; Chen et al., 2002) will improve the concordance between function-based and anatomy-based diagnoses of internal derangements within the TMJ.

The use of movement recordings has the advantage that the detailed condylar movements deflections, often associated with an internal derangement, can be analyzed off-line, from different view points and also at a lower speed than is possible during a clinical examination. Notwithstanding these advantages, the substantial agreement between the results of the clinical examination and the condylar movement recordings found in this study suggests that an experienced clinical examiner is capable of achieving acceptable results in recognizing internal derangements. Disagreement between clinical examination and movement recordings was most often found in those cases where the clinical examination found an internal derangement and the movement recordings did not. This may be due to “cross talk” from the contralateral joint. The left and the right TM condyles are rigidly connected
by a bony segment, the mandible. This may obscure the determination whether observed clicking sounds originated from the joint under investigation or from the contralateral joint.

In conclusion, for the achievement of a function-based diagnosis of an internal derangement, a clinical examination based upon clearly defined sets of criteria, is sufficient.