Temporomandibular joint internal derangements: Diagnosis, mechanisms and risk factors, and prognosis

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Chapter 3

Is condylar position a predictor for functional signs of TMJ hypermobility?

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Abstract

Temporomandibular joint hypermobility is only noted when it interferes with smooth mandibular movements. These interferences (viz., clicking sounds and jerky mandibular movements) result from condylar dislocation in front of the eminence at wide mouth opening, or alternatively in front of the articular disc (posterior disc displacement). The aim of this study was to test the hypothesis that condyles of hypermobile persons are positioned more anterosuperiorly to the crest of the eminence during maximum mouth opening than those of persons without TMJ hypermobility. Possible posterior disc displacement was also evaluated. Nine persons with symptomatic hypermobility and nine control persons free of internal derangements were included, their diagnoses being based upon opto-electronic movement recordings. Condylar positions during maximum mouth opening were analyzed on magnetic resonance images with two slightly different methods, showing the degree to which the condyles are displaced around the eminence. No posterior disc displacements were found on any of the magnetic resonance images. After excluding an outlier and using both measurement methods, a small difference in condylar position was found between the two groups of subjects. The condyles of all hypermobile persons traveled beyond the eminence. However, so did the condyles of nearly half of the non-hypermobiles. The large overlap between both groups suggests that condylar position alone is not a good predictor for symptomatic TMJ hypermobility. It is probably the combination of condylar location in front of the eminence with a particular line of action of the masticatory muscles, which gives rise to functional signs of hypermobility.

Keywords: internal derangement, temporomandibular joint, hypermobility, mandibular movement recordings, magnetic resonance imaging.

Introduction

Internal derangements (IDs) of the temporomandibular joint (TMJ) are, from an anatomical point of view, defined as a deviation in position or form of the tissues within the capsule of the joint (The glossary of prosthodontic terms, 1999). Clinically, IDs are only manifest when they interfere with normal, smooth mandibular movements (McNeill, 1993). In the literature, the most commonly described IDs are disc displacements (mostly in an anterior direction, but also posterior, sideways, and rotational) (Foucart *et al.*, 1998; Westesson *et al.*, 1998) and hypermobility. Considering the definitions of IDs, there are two ways for setting a diagnosis: by observing the morphology or by exploring the TMJ function. The first approach aims at visualizing the joint, and includes techniques such as TMJ arthrography, arthroscopy, computer tomography, and MRI (Hellsing, 1986). To the second approach belong clinical examination and mandibular movement recordings (Mauderli *et al.*, 1988; Dworkin and Le Resche, 1992; Airoldi *et al.*, 1994; Naeije *et al.*, 1995). These latter techniques set their diagnosis according to observed functional interferences during mandibular movements.

The literature reports a great discrepancy between the diagnoses of IDs, based upon anatomical TMJ characteristics and on functional characteristics. The anatomical picture may show a deviation, while the joint is free of functional interferences, and vice versa (Marguelles-Bonnet *et al.*, 1995; Emshoff *et al.*, 2002; Huddleston Slater *et al.*, 2004). In this study, differences between the outcomes of the two diagnostic methods for hypermobility are further explored. TMJ hypermobility is usually only noted when it interferes with smooth mandibular movements (McNeill, 1993). In this case, clicking sounds at the end of opening and/or at the beginning of closing, and jerky lateral mandibular movements are observed. These interferences may be due to a condylar dislocation at wide opening in front of, and superior to, the crest of the eminence (Okeson, 1996; The glossary of prosthodontic terms, 1999; Shorey and Campbell, 2000). It has also been reported that the interferences may alternatively result from the disc being dislocated posteriorly to the condyle (Kai *et al.*, 1992; Wise *et al.*, 1993; Nitzan, 2002). Snapping of the condyle over the crest of the eminence or over the anterior band of the disc would then be responsible for the interferences with smooth mandibular movements. Usually, symptomatic hypermobility is not associated with complaints, except when it is accompanied by myogenous pain, secondary to the dislocations, or when the mandibular condyle has such great difficulty passing the crest of the eminence or the anterior band of the disc that the mouth cannot close properly (Okeson, 1996).

The aim of the study is to test the hypothesis that at wide opening, the condyles of patients with symptomatic hypermobility are positioned more anteriorly or anterosuperiorly to the crest of the articular eminence than those of patients without hypermobility. To that end, the condylar position was quantified using MRI's taken at wide opening. The MRI's were also screened for the presence of a posteriorly displaced disc at wide opening. The diagnosis of symptomatic hypermobility was based upon mandibular movement characteristics recorded with an opto-electronic movement recording device.

Materials and methods

Participants and protocol

This study is a further analysis of data obtained in a previous study (Huddleston Slater *et al.*, 2004). In that study, a comparison was made between three methods for recognizing internal derangements within the TMJ. The 42 participants were recruited from patients referred to the clinic for Temporomandibular Disorders of our department, and from students at the Academic Centre for Dentistry Amsterdam (ACTA). Each participant underwent a clinical examination, an opto-electronic mandibular movement recording, and an MRI scan, all performed within one month. The examinations were performed in a "single-blind" design by different experienced examiners for each technique. The presence of an internal derangement, such as an anteriorly or posteriorly displaced disc, hypermobility, or other interferences, was determined for the three techniques, using specifically described criteria.

In the present study, MRI data was further analyzed only for those participants, who were either diagnosed with symptomatic hypermobility, or as having no internal derangements (i.e., ID-free). The diagnoses were based upon analysis of the opto-electronic movement recordings. Nine participants were assigned to the hypermobile group (4 males and 5 females, mean age 25.3 ± 3.6 years, ranging from 20 to 32 years), and nine to the ID-free control group (5 males and 4 females, mean age 26.1 ± 2.8 years, ranging from 20 to 29 years).

Opto-electronic movement recordings

Functional signs of hypermobility were diagnosed in the previous study, using the Oral Kinesiology Analysis System (OKAS-3D) (Naeije *et al.*, 1995). Mandibular movements were recorded with six degrees of freedom at a sampling frequency of 300 Hz per coordinate. Small condenser type microphones were placed over the palpated lateral pole of

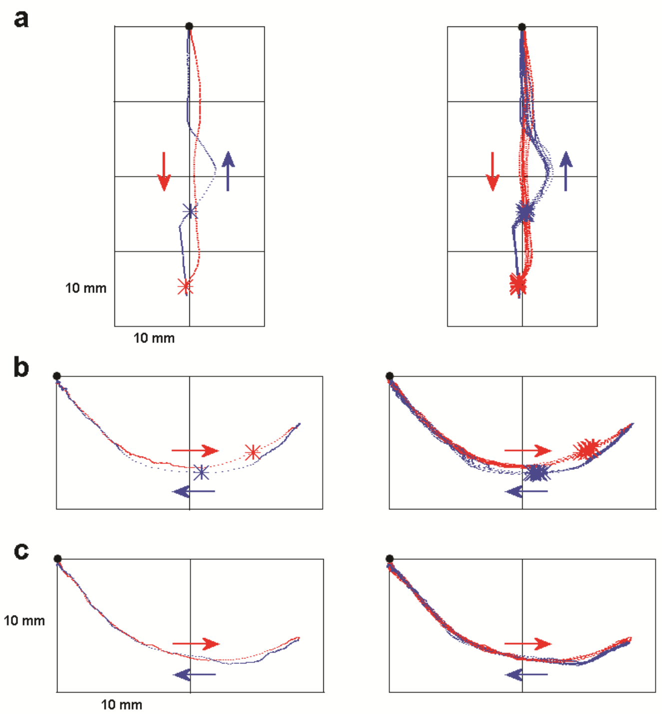

Figure 1. Typical example of single (left) and superimposed (right) open-close movement traces of a participant with symptomatic TMJ hypermobility. The frontal recordings of the incisal point (a) and the sagittal recordings of the kinematic centre of the right (b) and the left (c) TMJ condyle are shown. Clicking sounds are indicated with an asterisk. The movement traces of the incisal point illustrate the jerky mandibular movements, especially during closing. The rapid changes in spacing between subsequent positions of the right condyle illustrate the sudden accelerations and decelerations experienced by that condyle at the time of clicking. The superimposed movement traces illustrate the reproducibility of the movement recordings. The top midpoint of the plots of the incisal point and the top-left points of the plots of the condyles indicate their positions with the mandible in the intercuspal position. Opening traces are in red, closing traces in blue.

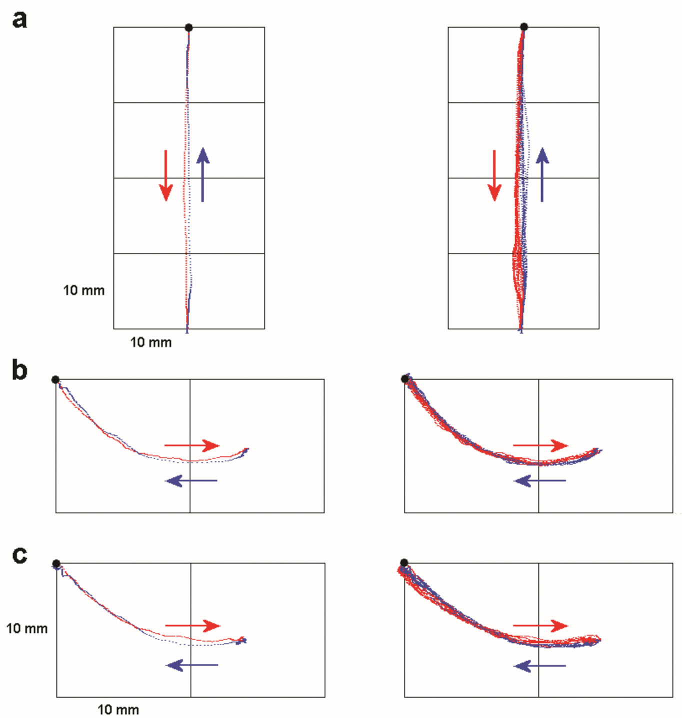

Figure 2. Typical example of single (left) and superimposed (right) open-close movement traces of a participant without internal derangements. The frontal recordings of the incisal point (a) and the sagittal recordings of the kinematic centre of the right (b) and the left (c) TMJ condyle are shown. The incisal point and the condyles performed smooth movements and no clicking sounds were noted. The superimposed movement traces illustrate the reproducibility of the movement recordings. The top midpoint of the plots of the incisal point and the top-left points of the plots of the condyles indicate their positions with the mandible in the intercuspal position. Opening traces are in red, closing traces in blue.

the TMJs to record joint sounds. Specialized software graphically visualized the movement traces of the incisal point and those of the kinematic centres of the condyles (Yatabe *et al.*, 1995; Naeije, 2003) in a sagittal, horizontal, and frontal plane. It also depicted the occurrence of a joint sound on these traces by an asterisk. Off-line, the recordings were interpreted blindly by a single investigator.

The participants performed, during 20-second recordings, free jaw opening and closing, free opening and loaded closing, submaximal open-close movements to about half the maximum mouth opening, and protrusive opening and closing. The loaded closing movements were performed while the mandible was loaded with a manually applied, downward directed force (about 30 N) on the chin, which had been calibrated beforehand using a weight scale (Huddleston Slater *et al.*, 1999).

The criteria for the recognition of symptomatic hypermobility were as follows (Huddleston Slater *et al.*, 2004) (fig. 1).

- The sagittal condylar movement traces showed characteristic and reproducible decelerations/accelerations in the last part of opening and/or the first part of (loaded) closing.
- The decelerations/accelerations coincided with the occurrence of the clicks.
- The incisal point showed reproducible and characteristic jerky lateral movements coinciding with the occurrence of clicks.
- No elimination of the clicks and decelerations/accelerations was noted during protrusive opening and closing.

When the TMJs showed smooth condylar movements with no clicking sounds, they were diagnosed to be free of internal derangements (fig. 2).

Magnetic resonance imaging

The intra-articular relations of the TMJ were studied with the use of MR-imaging of the joint. T1-weighted MR images were made 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 repetition time (TR) was 530 msec; the echo time (TE), 18 msec. During the recording, the participants had their heads in a head rest with the Frankfort plane as perpendicular as possible to the horizontal plane of the imager. Imaging was performed in closed mouth position, with nine interleaved 3-mm sagittal planes (perpendicular to the mediolateral pole of the condyle), and nine interleaved 3-mm coronal planes. Thereafter, imaging was performed in the maximally opened mouth position, controlled with a resin

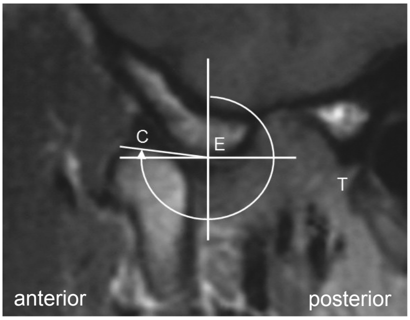

Figure 3. Sagittal MRI slice of a temporomandibular joint in maximum mouth opening position. A coordinate system is centred on point E with its x-axis parallel to the horizontal plane of the MRI. The angle between the line EC and the vertical axis was measured to quantify the condylar position relative to the articular eminence. E - summit lowest point of the articular eminence point; T – lowest point of the postglenoid tubercle; C- top condylar point.

bite block, with nine interleaved 3-mm sagittal planes. For all images made, the data matrix was 205 x 256 pixels, and the imaging time 4 minutes and 21 seconds.

In this study, the condylar position relative to the eminence was quantified, using two slightly different methods. First, for both methods, the sagittal MRI slice in open-mouth position in which both condyle and eminence are best visible was chosen. After that, two points were determined: the summit lowest point of the eminence marked as point E, and the postglenoid tubercle marked as point T. In the first method, a coordinate system, centred on point E with its x-axis parallel to the horizontal plane of the MRI, was superimposed over the slice. Then, the top condylar point, respective to the horizontal plane, was marked as point C. Finally, the angle between the line EC and the vertical axis was measured (fig. 3). In the second method, the x-axis was also drawn through point E, but parallel to the line ET. A new top condylar point with respect to this x-axis was determined, and the angle between the line EC and the vertical axis of this coordinate system was measured.

All MRI's were screened by a single investigator for the presence of a posteriorly displaced disc. These interpretations were done unaware of the results of the opto-electronic movement recordings. For the recognition of a posteriorly displaced disc at mouth opening, the following MRI criteria were used (Huddleston Slater *et al.*, 2004).

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

Statistical analysis

First, the linear correlation between the condylar angles of the left and right joints was calculated with the Pearson's correlation test. Second, the condylar angles of the participants with symptomatic hypermobility were compared with those of the ID-free participants, using the average of the left and right values for each person. To that end, the non-parametric Mann-Whitney U test, with a 95% confidence interval, was applied.

Results

Figures 4a and b show the condylar angles of the left and the right temporomandibular joint for the hypermobile and ID-free participants, as calculated by the two analysis methods. There is a significant correlation between the condylar angles of the left and right TMJ for the hypermobile and the ID-free group, and also for the group of participants as a whole (table 1). The condylar angles for the ID-free group range from about 100º (with the condyle situated before the articular eminence) to about 290º (with the condyle beyond and above the crest of the articular eminence). Apart from one outlier at about 100º, all condylar

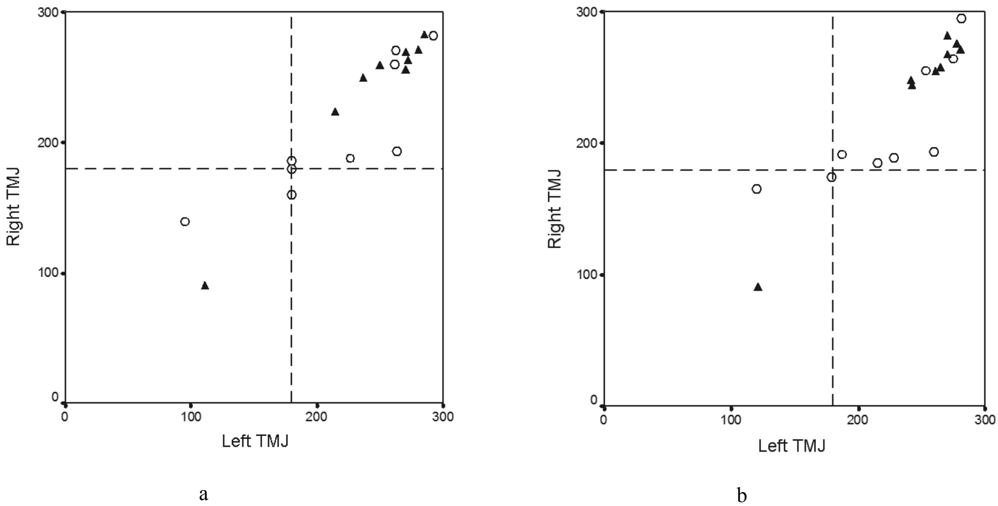

Figure 4. Scatter plot of the condylar angles of the left and the right TMJ for the hypermobile (▲) and ID-free participants (○), as measured with the first (a) and the second (b) condylar angle measuring method. Reference lines are set at 180º, indicating a condylar position right below the articular eminence at maximum mouth opening.

Table 1. Correlation coefficients and (in parenthesis) their p-values for the condylar angles of the left and the right joint for the hypermobile participants, the ID-free participants and for all the participants.

	Hypermobile group (n=9)	**ID-free group (n=9)**	**All participants (n=18)**
Method 1	.981 (.000)	.859 (.003)	.916 (.000)
Method 2	.990 (.000)	.792 (.011)	.897 (.000)

angles of the hypermobile group lie beyond and some of them above the crest of the articular eminence (ranging from approximately 230º to 280º), see fig. 4. No significant difference between the condylar angles of the participants with symptomatic hypermobility and those of the ID-free participants was found (P = .171 and .145 for both analysis methods). However, when the hypermobility outlier at about 100º was excluded, a small difference between the two groups was found (P = .054 and .043, respectively).

The MRI screening for posteriorly displaced discs at wide opening gave no positive diagnosis for any of the hypermobility or ID-free participants.

Discussion

This study has shown that the condyles of symptomatically hypermobile patients are positioned anteriorly and superiorly to the crest of the articular eminence at maximum mouth opening. However, the same is true for about half of the non-hypermobile ID-free participants.

The functional diagnosis of hypermobility was based upon the results of OKAS-3D opto-electronic movement recordings. These recordings permit an objective documentation of the jaw movements for further off-line analysis. The mandibular movements can be observed from different viewpoints, with finer details and at a lower speed than is possible during a clinical examination. It also enables the electronic recording of joint sounds at a high sensitivity, as well as the assessment of possible links between the occurrences of joint sounds and possible interferences in condylar movement traces.

A question about the angulation of the participants' heads during the MRI taking arose during our study. During the MRI procedure, the participants had their heads in a head rest with the Frankfort plane as perpendicular as possible to the horizontal plane of the

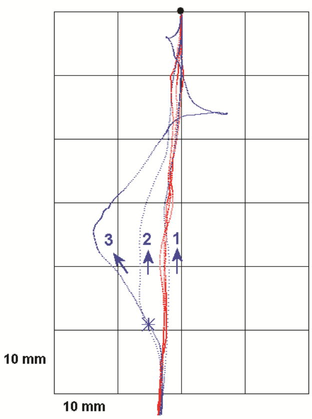

Figure 5. The superimposed frontal open-close movement traces of the incisal point of a participant with occasional symptomatic TMJ hypermobility. Within this 10-second recording, two smooth mandibular movements free from joint sounds were followed by a jerky mandibular movement with a joint click (see asterisk). The top midpoint of the plot of the incisal point indicates its position with the mandible in the intercuspal position. Opening traces are in red, closing traces in blue.

imager. This enables the horizontal plane of the sagittal MRI slices to be used as a line of reference in the first condylar analysis method. However, inevitably there remains some uncertainty regarding the exact angulation of the participant's head in the MRI scan. To overcome this, we also used a second condylar analysis method with a reference line, which was independent of the orientation of the participant's head in the MRI scan and solely depended upon anatomical points within the MRI scan itself. Similar methods have already been used before (Taskaya-Yylmaz and Ogutcen-Toller, 2002; Seligman and Pullinger, 2004). Analysis of the condylar positions relative to the articular eminence arrived at the same conclusions for both measuring methods, indicating that these conclusions are relatively robust and independent of the analysis method used.

There is a strong correlation between the condylar angles of the right and left TMJs, not only for all the participants as a group but also for the subgroups of symptomatic hypermobility and ID-free participants. This is in line with the high left-right anatomical symmetry of the masticatory system. The high correlation in the hypermobile group suggests that hypermobility is not a feature of a left or right temporomandibular joint alone, but more a feature of the masticatory system as a whole. In this respect, it might be better to talk about a hypermobile masticatory system than about a particular hypermobile temporomandibular joint.

As already mentioned in the results section, the condylar angles of all, except one, of our hypermobile participants were far greater than 180º. The outlier, however, showed condylar angles of about 100º, which indicates that the condyles did not reach further than the posterior slope of the articular eminence at wide opening. Nevertheless, the mandibular movements showed all the signs of a hypermobile masticatory system. If it was not the crest of the eminence which hampered condylar movements, then it could have been the disc that was posteriorly displaced in respect to the condyle at wide opening. However, on the MRI of this person there were no visible signs of a posteriorly displaced disc. Re-evaluation of the clinical examination of this patient showed that the patient has a tendency to restrict her jaw movements, fearing a possible dislocation. Therefore, it is likely that this participant had not opened maximally wide during the MRI recording, despite clear instructions to do so. This is the most plausible explanation for the small condylar angles found in this patient.

Four or five of our participants (depending upon the analysis method used) without any functional sign of hypermobility also had large angles, showing that the condyles of these ID-free joints passed beyond, and were sometimes situated above the crest of the eminence at wide opening. Similar findings have also been reported earlier

(Nevakari, 1960; Obwegeser *et al.*, 1987). In a study by Nevakari (1960), 70% of the subjects of an unselected sample moved their condyles beyond the articular eminence during maximal mouth opening. In another study (Obwegeser *et al.*, 1987), 41 of the 51 symptom-free participants showed the same movement characteristics. However, in contrast to our study, in these studies no subjects with symptoms of hypermobility were specifically included.

The fact that not only our participants with symptomatic TMJ hypermobility, but also about half of the ID-free control subjects had large condylar angles, shows that displacement of the condyle out of the glenoid fossa, anterosuperiorly to the articular eminence, is not a sufficient condition for functional signs of hypermobility to become apparent. Maybe it is only when a condylar position beyond the eminence is combined with an unfavorable line of action of the jaw opening and closing muscles, that functional interferences appear. The role of the jaw muscles is further illustrated in the movement recordings of one of our hypermobile participants, see fig. 5. Within a 10-second recording, two smooth mandibular movements free from joint sounds were followed by a jerky mandibular movement with a joint click. This suggests that the symptomatic hypermobility in this participant is also dependent upon the way the jaw muscles are activated.

In conclusion, condylar position alone is not a good predictor for functional signs of hypermobility. It is probably the location of the condyle in front of the articular eminence, combined with a particular line of action of the masticatory muscles, which gives rise to functional signs of hypermobility.

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