Clinical Predictability of Temporomandibular Joint Disc Displacement
M.G. Orsini, T. Kuboki, S. Terada, Y. Matsuka, H. Yatani and A. Yamashita

J DENT RES 1999 78: 650
DOI: 10.1177/00220345990780020401

The online version of this article can be found at:
http://jdr.sagepub.com/content/78/2/650
Clinical Predictability of Temporomandibular Joint Disc Displacement

M.G. Orsini*, T. Kuboki, S. Terada, Y. Matsuka, H. Yatani, and A. Yamashita

Department of Fixed Prosthodontics, Okayama University Dental School, Okayama, Japan; *corresponding author

Abstract. Single items from a typical clinical examination have proved disappointing in their predictive value for temporomandibular joint (TMJ) disc displacement. Only one criterion (the 12 o’clock) is used to diagnose normal disc position. According to this criterion, the posterior band of the disc should be located at the top of the condyle, at the 12 o’clock position. The purpose of this study was to determine which signs and symptoms provide a valid prediction of the condition of the joint based on 4 magnetic resonance imaging (MRI) criteria used to define normal disc position. Sagittal MRI and clinical findings of 137 temporomandibular disorder patients and 23 normal asymptomatic volunteers were used. Three calibrated and blinded observers interpreted the images. Disc position with the mouth closed was evaluated based on 4 MRI criteria: 12, 11, 10 o’clock, and the intermediate zone. Disc position with the mouth open was determined based on one criterion. It was considered normal if the intermediate zone of the disc was located between the condyle and the articular eminence. Joints were classified as normal or as having disc displacement with or without reduction. The sensitivity and specificity of multiple clinical parameters for predicting the condition of the joint established by each of these 4 gold-standard MRI criteria were then determined. Regarding disc displacement with reduction, significant differences were observed in the sensitivity and specificity of all of the clinical parameters used to predict the imaging diagnosis established by each of the criteria. Concerning disc displacement without reduction, no significant differences were observed. The intermediate zone criterion was the criterion that most accurately reflected the condition of the joint. The clinical predictability of the disorder diagnosed according to this criterion suggests that clinical findings alone are too often nonspecific as predictors of the imaging stage of disc displacement. However, we found that combining the most sensitive clinical items to predict the disorder and using an overall criterion for positivity to interpret the results led to an impressive increase in the specificity of the combination, enabling false-positive diagnoses to be excluded.

Key words: temporomandibular disorders, disc displacement, internal derangements, magnetic resonance imaging.

Received August 18, 1997; Last Revision May 11, 1998; Accepted May 12, 1998

Introduction

Internal derangement of the temporomandibular joint (TMJ) is one of the most common temporomandibular disorders (Wilkes, 1978; Farrar and McCarty, 1979; Katzberg et al., 1980). The term refers to any abnormality within the TM joint but is generally used to denote an abnormal positional relationship of the articular disc to the mandibular condyle and the articular eminence; the term has thus been used synonymously with disc displacement (Adams, 1981). The disorder has been associated with characteristic clinical findings that have been recognized by many clinicians (Ireland, 1953; Farrar and McCarty, 1979; Eriksson and Westesson, 1983).

Magnetic resonance imaging (MRI) and arthrography accurately depict abnormalities of disc position and morphology and have therefore been used to substantiate the clinically suspected existence of disc displacement (Katzberg et al., 1980; Eriksson et al., 1985; Katzberg, 1989; Tasaki and Westesson, 1993). However, such radiologic evaluation of the soft tissue components of the TMJ may not always be available. Arthrography is an invasive technique, and cost and availability often limit the use of MRI; most of the management approaches for these patients are thus symptom-based. For this reason, several studies have been conducted to determine the accuracy of clinical diagnoses of the different stages of disc displacement. There is some controversy in the literature over this topic. The accuracy rates obtained for different stages of disc displacement have ranged from 43% to 90% (Roberts et al., 1985, 1986, 1987a,b,c, 1988, 1991; Kozeniauskas, 1988; Kozeniauskas and Ralph, 1988; Schiffman et al., 1989; Anderson et al., 1989; Paesani et al., 1992).

It is noteworthy that, in these studies, the 12 o’clock criterion was used to define the normal disc position (Shannon et al., 1990). In a previous study, we evaluated the 12 o’clock criterion as well as three other criteria (the 11 and 10 o’clock and the intermediate zone) to determine which would be the best suited to identify disc position abnormalities. We found a higher prevalence of false-positive diagnoses when using the 12 and the 11 o’clock criteria and a higher prevalence of false-negative diagnoses when using the other two criteria (10 o’clock and intermediate zone) (Orsini et al., 1998).

False-positive diagnoses are related to over-classification of the disease, which might lead to over-treatment, while
false-negative diagnoses are related to under-classification and consequently under-treatment (Griner et al., 1981). A more accurate diagnostic operational criterion to define TMJ disc displacement that is closely related to the clinical signs and symptoms of the disorder is needed, to avoid over- and under-treatment and to obtain a more cost-effective outcome.

In the present study, we used the aforementioned 4 criteria to diagnose normal disc position on MRI of a group of temporomandibular disorder patients and a group of normal asymptomatic volunteers. We compared the patients’ and volunteers’ TMJ signs and symptoms with their imaging diagnoses established according to each of these 4 criteria to determine: (1) which criterion was associated with the fewest false-positive and false-negative diagnoses, and (2) which signs and symptoms provided a valid prediction of the condition of the joint established by this criterion. It was assumed that if single items were not accurate enough to predict the condition of the joint, a combination of items would provide incremental information that would aid the decision-maker regarding patient management.

Two null hypotheses were tested in this study. One was that there is no difference in the sensitivity and specificity of the clinical parameters to predict the MRI diagnostic stage established according to each of the 4 criteria. The other was that there is no difference in the diagnostic sensitivity and specificity obtained by single and multiple clinical item combinations.

**Materials and methods**

**Subjects**

One hundred and forty-six patients who consecutively attended the TMJ and Craniofacial Pain Clinic at Okayama University Dental School between April, 1994, and March, 1995, were studied. Seventy-nine percent were female, and 21% were male, with mean ages (± SD) of 33.0 ± 15.4 and 34.4 ± 18.2 yrs, respectively. All of the patients presented with signs and symptoms of temporomandibular disorders, including TMJ joint pain, clicking and/or crepitation of the joint, masticatory muscle pain, and limitation of opening of the mandible. There were also 23 asymptomatic healthy volunteers (88% females and 22% males, mean ages ± SD 19.6 ± 0.5 and 25.4 ± 0.8 yrs, respectively) who were selected from students at Okayama University Dental School. The inclusion criteria for volunteers were: no significant medical history, no history of temporomandibular disorders such as joint pain, joint noise or masticatory muscle pain, and range of opening over 45 mm. The exclusion criterion was radiographic evidence of structural changes in the TMJ.

Nine TMJ patients were excluded because their clinical examination was incomplete, leaving 137 TMJ patients and 23 volunteers. The protocol of this experiment was approved by the appropriate committee in our department. Informed consent was obtained from each patient and volunteer before commencement of the study.

**Clinical examination**

The physical examination of all subjects and volunteers was performed by a single clinician who was not included among the observers, and was performed following a structured protocol of known reliability (Matsuka et al., 1997). The inter-examiner reliability was reported to be satisfactory (kappa index > 0.75) for almost all of the clinical features assessed. Agreement between the examiners regarding pain during palpation was lower than for other clinical items but was still acceptable (kappa index = 0.52).

The presence and absence of the following 8 clinical parameters were assessed as predictors for disc displacement with and without reduction:

**Clicking**: Its presence or absence was recorded by the examiner through bilateral manual palpation of the lateral aspect of the TMJ. Clicking was defined as a single distinct snapping, popping, or cracking sound of short duration emanating from the TMJ during jaw movement (opening and/or closing) that was audible to or palpable by the examiner. Patients were asked to execute three maximum voluntary jaw openings while the clinician recorded joint sounds. If a click was present on two (opening and/or closing) mandibular movements, it was recorded as positive. If the subject was diagnosed as having clicking, the elimination or persistence of the sound after repositioning of the mandible 3 mm anterior from the intercuspal position was also recorded (Dworkin and LeResche, 1992).

**Muscle pain on palpation**: Pain of the muscles that move and stabilize the mandible was assessed as positive or negative by a bilateral manual palpation technique (Krough-Poulson, 1969). First, the distinct muscle band was located and then palpated by the examiner with firm pressure (approximately 2 lb per square inch) (Dworkin and LeResche, 1992). The following sites were palpated extra-orally: the anterior, posterior, and middle temporalis, the superficial and deep masseters, the insertion of the medial pterygoid muscle, the anterior and posterior digastric, the superior, middle, and inferior sternocleidomastoid, and the trapezius muscle. A positive score was assigned if palpation produced a clear reaction from the patient, i.e., a palpbral response or if the patient experienced a distinctively tender or painful sensation in more than 3 of the muscles palpated (Clark et al., 1993). The sensation was carefully confirmed by repeated palpation of the relevant sites.

**TMJ pain on palpation**: This parameter was assessed as positive or negative through bilateral manual palpation of the lateral aspect of the joint by means of firm pressure (approximately 1 lb per square inch) (Dworkin and LeResche, 1992). A positive score was recorded by the examiner if palpation produced a clear reaction from the patient, i.e., a palpbral response or if the patient experienced a distinctively tender or painful sensation.

**Limitation of mandibular movement**: Maximum voluntary mandibular opening was determined by the examiner using a plastic ruler graduated in millimeters to measure the distance between the upper and lower incisal edges added to the amount of vertical overlap. Less than 40 mm was considered a limitation of opening (Fricton and Schuffman, 1986).

**Restriction of condylar movement**: The subjects were asked to perform their maximum voluntary opening, and restriction of condylar movement was assessed as positive or negative.
through bilateral manual palpation of the lateral aspect of the joint via the subjective opinion of the examiner that restriction existed for that joint.

**TMJ pain on assisted opening:** Assisted opening was performed by the application of 2 to 3 lbs of force to the lower and upper incisors with the middle finger and thumb. TMJ pain was assessed as present or absent. A positive score was recorded by the examiner if a patient experienced a distinctly painful sensation in the TMJ during the procedure.

**Crepitus:** The presence or absence of crepitus was recorded by the examiner through bilateral manual palpation of the lateral aspect of the TMJ. Crepitus was defined as a multiple gravel-like sound of long duration described as grating emanating from the TMJ during jaw movement that was audible to or palpable by the examiner. Patients were asked to execute 3 voluntary jaw openings while the clinician recorded joint sounds.

**Mandibular deviation at the end of opening:** This was estimated from an anterior view as a horizontal difference between the midlines of the upper and lower central incisors.

**Imaging**

The patients underwent MRI scanning of the TMJs with the jaws in closed and maximally open positions, with a 1.5-T MR imaging system (Signa, GE Medical Systems, Milwaukee, WI, USA) at Okayama Kyokuto Hospital, Japan. Sagittal proton density-weighted images were taken with a fast spin echo technique (TR, 2300 ms; TE, 19.0 ms; slice thickness, 3 mm; field of view, 12 cm; matrix, 256 x 192; number of excitations, 4), with the use of a unilateral surface coil (127 mm). Each subject’s head was placed with the Frankfort plane parallel to the opening of the scanner. The head was fixed with adhesive tape onto a foam rubber support.

**Image interpretation**

For each TMJ, representative lateral, central, and medial images were identified by one of the investigators not included among the observers (S.T.). After these 3 slices were identified, the images were randomly numbered and identifiers were covered. The random numbers were used to ensure that all observers were blinded to the identity, age, sex, and prior diagnosis of the subjects.

Three observers with 4 to 7 yrs of experience at reading TMJ MRI, and who had been previously calibrated (according to the criteria to be evaluated), individually interpreted the images, which were randomly ordered. Each observer was blinded to the other observers’ results.

**Criteria for interpreting disc position**

The disc position in the closed-mouth position was evaluated by two approaches. One approach involved a description of the posterior band location in terms of hours on a clock face, and the other involved a description of the location of the intermediate zone of the disc in relation to the condyle and the articular eminence. The observers evaluated the images on two different occasions. On each occasion, one of these two methods was followed.

For the clock face analysis, the observers used a custom-made acetate template on which a clock face was drawn. Superimposing this template on the image and using the condylar outline as the face of a clock, the observers described the posterior band location in terms of clock hours.

Three criteria were used: 12, 11, and 10 o’clock (Fig. 1). For the 12 o’clock criterion, the disc position in the closed-mouth position was considered normal if the thickest part of the posterior band was located at the top of the condyle between the 12 and 1 o’clock positions. Regarding the 11 o’clock and 10 o’clock criteria, the disc postion was considered normal if the thickest part of the posterior band was situated between the 11 and 1 o’clock positions for the 11 o’clock criterion and between the 10 and 1 o’clock positions for the 10 o’clock criterion. A disc with the thickest part of the posterior band located anterior to its criterion zone was considered displaced for the criterion being judged (Shannon et al., 1990).

Concerning the description of the intermediate zone location, the position of the disc was considered normal if the intermediate zone was located between the anterior-superior aspect of the condyle and the posterior-inferior aspect of the articular eminence in the middle or above a line that joined the centers of 2 imaginary circles fitted to these structures (intermediate
between the
by
within the bone boundary
between the
rior-inferior aspect of the articular eminence in the
disc was identified.
relation to the condyle and the articular eminence
criterion,
zone
were:
structures,
the
line that
2.
Figure
was
d slices.
observers
images.
The
x 3 x
3
image
independently,
findings
to a
open
redundant
were
how the
intermediate zone was located
anterior-superior aspect of the condyle and the poste-
rerior-inferior aspect of the articular eminence in the middle or above
line that joined the centers of 2 imaginary circles fitted to these
structures, the position of the disc was considered normal. These
circles were positioned to approximate the condyle and the emi-
rence outlines. The upper limit of the eminence circle was set to be
within the bone boundary to the cranial cavity.

zone criterion). These circles were positioned to approximate
the condyle and the eminence outlines. Discs with the interme-
diate zone located anterior to this position were considered dis-
placed according to this criterion (Fig. 2). This criterion is based
on the assumption that the aforementioned line is the line of
action of TMJ loading (Osborn, 1995).
Finally, disc position with the mouth open was determined
by a single criterion. Disc position during opening was consid-
ered normal if the intermediate zone of the disc was located
between the condyle and the articular eminence when the jaw
was wide open (Fig. 3).

For each joint, each of the 3 slices was scored by the three
observers independently, using the 2 types of criteria for the
closed-mouth image (clock face and intermediate zone) and
one for the open-mouth image. In total, there were 8640 (320 x
3 x 3 x 3) judgments made on the position of the disc in this
data set. The redundant three-slice data (judgments on disc
position in the medial, central, and lateral slides) were reduced
to a single datum point (displaced or not), based on a positive
finding being present in any of the 3 images. Finally, the open-
and closed-mouth diagnoses were combined, and a final diag-
osis was formulated for each joint. The expected 3 diagnostic
options which were available from these data were: (1) normal,
(2) disc displacement with reduction, and (3) disc displacement
without reduction. To be given a final diagnosis, at least two of
the three observers had to have the same diagnostic result for
the joint. An additional diagnostic category was utilized in this
study. A diagnosis of “other” was used for an obvious poste-
rior displacement of the disc, when the position of the disc
could not be determined from the image, and in those situa-
tions where each observer selected a different diagnostic option
for the joint.

Comparison of imaging and clinical findings
The clinical and MRI findings of each TMJ were subsequently
compared ipsilaterally. The data were arranged in 2 x 2 tables
with the MRI diagnosis according to each criterion used as the
gold standard and each of the clinical parameters assessed for
disc displacement with and without reduction as the predictor
variable. The sensitivity and specificity of each clinical variable
for predicting the joint diagnosis according to each of the crite-
reria were then calculated. A one-way ANOVA for repeated
measurements was used to evaluate the differences in the sensitivity
and specificity values of the clinical parameters regarding all of
the criteria. Least-mean-squares analyses were then used for

Figure 2. Description of the location of the disc intermediate zone in
relation to the condyle and the articular eminence (intermediate
zone criterion, closed-mouth position). The thin central portion of
the disc was identified. When the intermediate zone was located
between the anterior-superior aspect of the condyle and the poste-
rrior-inferior aspect of the articular eminence in the middle or above
a line that joined the centers of 2 imaginary circles fitted to these
structures, the position of the disc was considered normal. These
circles were positioned to approximate the condyle and the emi-
rence outlines. The upper limit of the eminence circle was set to be
within the bone boundary to the cranial cavity.

Figure 3. Method for analyzing disc position in the open-mouth
position. The disc position with the mouth open was considered
normal if the intermediate zone of the disc was located between the
condyle and the articular eminence when the jaw was wide open in
the middle of a line that joined the centers of 2 imaginary circles fit-
ted to these structures. These circles were positioned to approxi-
mate the condyle and the eminence outlines. The upper limit of the
eminence circle was set to be within the bone boundary to the cranial
cavity.
as assessing mean differences among the criteria. The level of significance was set at \( \alpha = 0.01 \).

### Selection of the predictors

Data regarding the criterion for which the clinical variables showed the highest sensitivity and specificity values were selected for further analysis. A cut-off point was then established for selecting the clinical variables that would be more useful to screen as well as to confirm the presence of the suspected diagnosis. All variables with less than 20% sensitivity or specificity were excluded from the analysis. When the same parameter (presence and absence) was included in the analysis, that with the highest sensitivity was selected (Griner et al., 1981).

### Two-test and multiple-test combinations

Because few tests are both highly sensitive and specific, two or more tests were used for evaluation of a diagnostic possibility. Chi-square tests were then used to assess differences in the distribution of true- and false-positive and true- and false-negative diagnoses established by each combination of tests selected to diagnose disc displacement both with and without reduction. The level of significance was set at \( \alpha = 0.05 \).

### Reproducibility of the imaging interpretation

Inter-observer performance was calculated as a kappa index for each of the aforementioned criteria. It was assessed among the examiners (A,B,C) two by two (AB, BC, CA). Data were analyzed with the SPSS-X statistical package (SPSS, Inc., Chicago, IL, USA) on a Macintosh computer. The six-point scale proposed by Landis and Koch (1977) was used to interpret the kappa index. Values less than zero were termed poor agreement, 0.00 to 0.20 slight, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, 0.61 to 0.80 substantial, and values higher than 0.81 indicated almost perfect agreement.

### Results

#### Distribution of imaging diagnoses

The diagnoses assigned according to the specified criteria are shown in Table 1. Note that as the number of normal disc position diagnoses increases, the percent of joints with disc displacement with reduction declines. Conversely, the percent of joints with disc displacement without reduction does not appear to be substantially affected by the 4 closed-mouth disc position criteria.

One joint (for the 12 o’clock criterion) and 3 joints (for each of the other 3 criteria — 10 o’clock, 11 o’clock, and IZ) were excluded from among the total of 320 because the diagnostic choice data never achieved majority agreement. Another 4 joints were excluded because the MRI could not be interpreted, and 1 was excluded because the disc was unusually positioned (posterior displacement).

#### Inter-observer agreement in joint basis

On the basis of the kappa index, the agreement between the different pairs of observers was substantial for the 4 criteria evaluated (mean kappa index = 0.70).

### Sensitivity and specificity values of the clinical variables

The sensitivity and specificity values of the 8 clinical variables for predicting the diagnostic imaging stage of disc displacement with and without reduction according to the 4 criteria are given in Tables 2 and 3, respectively. A one-way ANOVA for repeated measurements performed on these values revealed significant main effects for the criterion regarding diagnosis of disc displacement with reduction (sensitivity, \( p = 0.0034 \); specificity, \( p = 0.0002 \)). Least-mean-squares analyses showed significant mean differences between the 12 o’clock and intermediate zone criteria (sensitivity, \( p = 0.0006 \); specificity, \( p = 0.0001 \)), and between the 11 o’clock and intermediate zone criteria (sensitivity, \( p = 0.0064 \); specificity, \( p = 0.0099 \)). In contrast, no significant mean differences were observed between the 12 and 11 o’clock criteria (sensitivity, \( p = 0.3312 \); specificity, \( p = 0.0292 \)), between the 11 and 10 o’clock criteria (sensitivity, \( p = 0.1319 \); specificity, \( p = 0.0438 \)), or between the 10 o’clock and intermediate zone criteria (sensitivity, \( p = 0.15925 \); specificity, \( p = 0.4964 \)). No significant main effects were observed for the criteria regarding the diagnosis of disc displacement without reduction (sensitivity, \( p = 1.00 \); specificity, \( p = 1.00 \)).

### Criterion to define disc displacement

Because the sensitivity and specificity values of the clinical parameters for predicting disc displacement without reduction were not significantly different among the 4 criteria, and those of the intermediate zone criterion were higher than those of the 3 other criteria regarding the diagnosis of disc displacement with reduction, we used the data concerning the intermediate zone criterion for the further analysis of the clinical predictability of the disorder.

### Selection of the predictors

After a cut-off point was set, the clinical variables that would be more useful to screen as well as to confirm the presence of the suspected diagnosis were selected as predictors for the disorder. As shown in Tables 4 and 5, six and five clinical parameters were selected as predictors for disc displacement with and without reduction, respectively. The clinical items with the highest sensitivity were clicking and no deviation of the mandible on maximum opening for disc displacement with reduction, and restriction of condylar translation as assessed by palpation and absence of clicking for disc displacement without reduction.

### Combinations of tests

The combinations of clicking and no deviation of the mandible on maximum opening, and restriction of condylar translation and TMJ pain during assisted opening showed the highest specificity to predict disc displacement with (84.7%) and without reduction (93.3%), respectively. When all the selected clinical items were combined to predict disc
displacement with or without reduction, as the number of tests increased in each combination, the aggregate sensitivity of the combination was substantially reduced compared with that of each test alone (p < 0.0001), while the specificity increased (p < 0.0001) (Tables 4 and 5).

**Discussion**

Although the presence of the posterior band of the articular disc anterior to the traditional 12 o'clock position has been used to define anterior disc displacement (Helsing et al., 1986; Shannon et al., 1990), displacement according to this criterion has been observed in normal asymptomatic volunteers, raising the question of what should be considered an abnormal disc position (Kaplan et al., 1986; Kirkos et al., 1987; Westesson et al., 1989; Hatala et al., 1991).

In the present study, 4 gold-standard MRI criteria (12, 11, 10 o'clock, and the intermediate zone) were used to define the normal disc position, and the sensitivity and specificity of 8 clinical parameters for predicting the condition of the joint established by each of these criteria were determined.

The overall data obtained showed higher sensitivity and specificity values for almost all of the clinical parameters regarding the imaging diagnosis established according to the intermediate zone criterion (due to fewer false-positive and -negative results), and therefore this criterion was used for the further analysis of the predictability of disc displacement.

### Table 1. Distribution of the magnetic resonance imaging diagnoses according to the four criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Normal</th>
<th>Disc Displacement with Reduction</th>
<th>Disc Displacement without Reduction</th>
<th>Other</th>
<th>Number of Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 o'clock</td>
<td>57</td>
<td>181</td>
<td>76</td>
<td>6</td>
<td>320</td>
</tr>
<tr>
<td>11 o'clock</td>
<td>100</td>
<td>137</td>
<td>75</td>
<td>8</td>
<td>320</td>
</tr>
<tr>
<td>10 o'clock</td>
<td>164</td>
<td>75</td>
<td>73</td>
<td>8</td>
<td>320</td>
</tr>
<tr>
<td>Intermediate zone</td>
<td>175</td>
<td>63</td>
<td>74</td>
<td>8</td>
<td>320</td>
</tr>
</tbody>
</table>

* A diagnosis of “other” was used for: a posterior disc displacement, when the position of the disc could not be determined from the image, and when each observer selected a different diagnostic option for the joint.

### Table 2. Sensitivity and specificity of the clinical parameters for predicting disc displacement with reduction

<table>
<thead>
<tr>
<th>Clinical Parameter</th>
<th>Disc Displacement with Reduction</th>
<th>Disc Displacement without Reduction</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 o'clock presence</td>
<td>11 o'clock absence</td>
<td>10 o'clock presence</td>
</tr>
<tr>
<td>Clicking</td>
<td>28.2</td>
<td>71.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Temporomandibular joint pain</td>
<td>3.9</td>
<td>96.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Elimination of the clicking*</td>
<td>21.0</td>
<td>79.0</td>
<td>24.8</td>
</tr>
<tr>
<td>Muscle pain</td>
<td>7.7</td>
<td>92.3</td>
<td>8.0</td>
</tr>
<tr>
<td>TMJ pain during assisted opening</td>
<td>11.0</td>
<td>89.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Deviation of the mandible on maximum opening</td>
<td>12.7</td>
<td>87.3</td>
<td>15.3</td>
</tr>
<tr>
<td>Limitation of opening dimension</td>
<td>17.7</td>
<td>82.3</td>
<td>19.7</td>
</tr>
<tr>
<td>Restriction of condylar translation</td>
<td>19.9</td>
<td>80.1</td>
<td>24.1</td>
</tr>
</tbody>
</table>

**Sensitivity**

<table>
<thead>
<tr>
<th>Clinical Parameter</th>
<th>Disc Displacement with Reduction</th>
<th>Disc Displacement without Reduction</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 o'clock presence</td>
<td>11 o'clock absence</td>
<td>10 o'clock presence</td>
</tr>
<tr>
<td>Clicking</td>
<td>81.2</td>
<td>18.8</td>
<td>82.3</td>
</tr>
<tr>
<td>Temporomandibular joint pain</td>
<td>90.2</td>
<td>9.8</td>
<td>91.4</td>
</tr>
<tr>
<td>Elimination of the clicking*</td>
<td>83.5</td>
<td>16.5</td>
<td>85.7</td>
</tr>
<tr>
<td>Muscle pain</td>
<td>90.2</td>
<td>9.8</td>
<td>90.9</td>
</tr>
<tr>
<td>TMJ pain during assisted opening</td>
<td>66.9</td>
<td>33.1</td>
<td>72.6</td>
</tr>
<tr>
<td>Deviation of the mandible on maximum opening</td>
<td>75.2</td>
<td>24.8</td>
<td>80.6</td>
</tr>
<tr>
<td>Limitation of opening dimension</td>
<td>75.3</td>
<td>24.8</td>
<td>78.9</td>
</tr>
<tr>
<td>Restriction of condylar translation</td>
<td>54.1</td>
<td>45.9</td>
<td>57.0</td>
</tr>
</tbody>
</table>

**Specificity**

- Recorded after repositioning of the mandible 3 mm from the intercuspal position.
- Significant differences were observed between the 12 o'clock and intermediate zone criteria and between the 11 o'clock and intermediate zone criteria (least-mean-squares analyses, p < 0.01).
Disease classification is a necessary part of diagnosis. Diagnostic tests are considered important for the process of diagnosis. In this process, diagnostic tests can be considered at 3 levels: screening, exclusionary, and confirmatory. The first level denotes wide screening in a community to detect the subpopulation in which a disease is likely to be present. Screening tests should have high sensitivity, but not necessarily high specificity. Exclusionary tests should take this procedure further; they require high specificity to minimize the number of false-positives so that those who do not have the disease are excluded. Confirmatory tests should have the highest possible sensitivity and specificity to eliminate both false-positive and -negative results, although, unfortunately, these criteria can rarely be simultaneously met in any single test (Griner et al., 1981; Johnson, 1991).

After selecting the clinical variables that would be more useful to screen as well as to confirm the presence of the suspected diagnosis, we followed the first step of the diagnostic process and selected the clinical tests with the highest sensitivity to predict disc displacement with and without reduction.

For disc displacement with reduction, clicking was one of the strongest predictors. However, it should be noted that it was not present in all of the joints with this diagnosis. In addition, clicking was also observed in a small percentage of joints without disc displacement (14.3%) and in a small percentage of joints with disc displacement without reduction (22.0%). Other possible explanations for clicks include deviations in condylar form (remodeling), muscular incoordination, or adhesions (Schiffman et al., 1989).

With regard to disc displacement without reduction, restriction of condylar translation as assessed by palpation was the best predictor. This does not mean that all joints that exhibited restriction of condylar translation would present disc displacement without reduction, or that all joints with disc displacement without reduction would always present restricted motion. In fact, false-positives and false-negatives were observed. It should be noted that in this study we included consecutive TMJ cases, some of which were restricted in motion for reasons other than an acutely displaced disc. Likewise, it is known that, given time, the degree of mandibular opening in patients with disc displacement without reduction begins to increase and probably returns to a normal range (Roberts et al., 1985; Anderson et al., 1989; Schiffman et al., 1989; Kurita et al., 1998).

We found that none of the clinical parameters assessed independently could predict the specific imaging stage of disc displacement with complete accuracy, as has been re-

<table>
<thead>
<tr>
<th>Table 3. Sensitivity and specificity of the clinical parameters for predicting disc displacement without reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical Parameter</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Restriction of condylar translation</td>
</tr>
<tr>
<td>TMJ pain during assisted opening</td>
</tr>
<tr>
<td>Limitation of opening dimension</td>
</tr>
<tr>
<td>Deviation of the mandible on maximum opening</td>
</tr>
<tr>
<td>TMJ pain</td>
</tr>
<tr>
<td>Muscle pain</td>
</tr>
<tr>
<td>Clicking</td>
</tr>
<tr>
<td>Elimination of the clicking&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crepitus</td>
</tr>
</tbody>
</table>

<sup>a</sup> Recorded after repositioning of the mandible 3 mm from the intercuspal position. No significant differences were observed among the four criteria (ANOVA, p > 0.01).
ported previously (Roberts et al., 1985, 1986, 1987a,b,c, 1988, 1991; Schiffman et al., 1989). A combination of these clinical tests may thus be useful to increase the diagnostic information available regarding patient management problems that cannot be resolved by a single test (Griner et al., 1981; Cebul et al., 1982; Hershey et al., 1986).

Questions thus arise as to which additional tests should be selected and how the tests’ combination results should be interpreted.

The intelligent selection of any test combination depends upon a choice that is appropriate for the purpose intended. For combined testing, the ideal is to select individual tests that measure different characteristics of the suspected pathologic condition. However, it should be noted that trade-offs exist in the decision to perform multiple tests instead of just one. Among these are the additional complexities involved in the interpretation of tests in combination (Griner et al., 1981; Cebul et al., 1982).

For multiple-test combinations, a “positive” combination might be considered one in which all tests’ results are positive or one in which any test result is positive. The more severe “positive-if all-tests-positive criterion” serves to increase the combination’s specificity (resulting in fewer false-positive classifications) at the cost of decreased sensitivity, whereas use of the “positive-if-one-test-positive criterion” improves the combination’s sensitivity (resulting in fewer false-negative classifications) at the expense of decreased specificity (Cebul et al., 1982; Hershey et al., 1986).

The choice of criterion for

| Table 4. Sensitivity, specificity, and diagnostic accuracy of various tests’ combinations for predicting disc displacement with reduction |
|---------------------------------|---------------|---------------|---------------|
| **Single Clinical Tests**       | Sensitivity   | Specificity   |
| No deviation of the mandible on maximum opening | 84.1          | 20.1          |
| No TMJ pain during assisted opening | 82.5          | 20.9          |
| No limitation of opening dimension | 81.0          | 20.9          |
| No restriction of condylar translation | 76.2          | 32.9          |
| Clicking                        | 50.8          | 83.1          |
| Elimination of clicking in an anterior jaw position | 44.4          | 88.0          |
| **Two-test Combinations**       | Sensitivity   | Specificity   |
| No deviation of the mandible/No TMJ pain during assisted opening | 76.2          | 30.5          |
| No deviation of the mandible/No limitation of opening dimension | 76.2          | 27.3          |
| No deviation of the mandible/No restriction of condylar translation | 74.6          | 36.5          |
| No deviation of the mandible/Clicking | 50.8          | 84.7          |
| No deviation of the mandible/Elimination of clicking | 44.4          | 89.2          |
| **Multiple-test Combinations**  | Sensitivity   | Specificity   | Diagnostic Accuracy |
| No deviation of the mandible/No TMJ pain during assisted opening | 76.2          | 30.5          | 39.7          |
| No deviation of the mandible/No TMJ pain during assisted opening/No limitation of opening dimension | 71.4          | 34.9          | 42.3          |
| No deviation of the mandible/No TMJ pain during assisted opening/No limitation of opening dimension/No restriction of condylar translation | 68.3          | 38.6          | 44.6          |
| No deviation of the mandible/No TMJ pain during assisted opening/No limitation of opening dimension/No restriction of condylar translation/Clicking | 44.4          | 86.3          | 77.9          |
| No deviation of the mandible/No TMJ pain during assisted opening/No limitation of opening dimension/No restriction of condylar translation/Clicking/Elimination of clicking | 38.1          | 90.0          | 79.5          |

As the number of tests increased in each combination, the aggregate sensitivity of the combination was reduced, while the specificity increased (Chi square, p < 0.0001).
Table 5. Sensitivity, specificity, and diagnostic accuracy of various tests' combinations for predicting disc displacement without reduction

<table>
<thead>
<tr>
<th>Single Clinical Tests</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restriction of condylar translation</td>
<td>68.9</td>
<td>80.7</td>
</tr>
<tr>
<td>TMJ pain during assisted opening</td>
<td>55.4</td>
<td>90.8</td>
</tr>
<tr>
<td>Deviation of the mandible</td>
<td>32.4</td>
<td>87.0</td>
</tr>
<tr>
<td>Limitation of opening dimension</td>
<td>32.4</td>
<td>83.2</td>
</tr>
<tr>
<td>No clicking</td>
<td>77.0</td>
<td>23.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Two-test Combinations</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restriction/No clicking</td>
<td>60.8</td>
<td>81.9</td>
</tr>
<tr>
<td>Restriction/TMJ pain during assisted opening</td>
<td>54.1</td>
<td>93.3</td>
</tr>
<tr>
<td>Restriction/Limitation of opening dimension</td>
<td>31.1</td>
<td>86.6</td>
</tr>
<tr>
<td>Restriction/Deviation of the mandible</td>
<td>29.7</td>
<td>90.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiple-test Combinations</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Diagnostic Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restriction</td>
<td>68.9</td>
<td>80.7</td>
<td>77.9</td>
</tr>
<tr>
<td>Restriction/No clicking</td>
<td>60.8</td>
<td>81.9</td>
<td>76.9</td>
</tr>
<tr>
<td>Restriction/No clicking/TMJ pain during assisted opening</td>
<td>45.9</td>
<td>94.1</td>
<td>82.7</td>
</tr>
<tr>
<td>Restriction/No clicking/TMJ pain during assisted opening/Limitation of opening dimension</td>
<td>21.6</td>
<td>96.2</td>
<td>78.5</td>
</tr>
<tr>
<td>Restriction/No clicking/TMJ pain during assisted opening/Limitation of opening dimension/Deviation of the mandible</td>
<td>10.8</td>
<td>97.9</td>
<td>77.2</td>
</tr>
</tbody>
</table>

a As the number of tests increased in each combination, the aggregate sensitivity of the combination was reduced, while the specificity increased (Chi square, p < 0.0001).

A positive combination will depend on two things. One is the relative values the decision-maker places on making false-positive and false-negative classifications and management of errors. The other is changes in treatment benefits and risks. Lower benefits and higher risks of treatment favor the positive-if-all-tests-positive criterion, while higher benefits and lower risks of treatment favor the positive-if-one-test-positive criterion (Cebul et al., 1982; Hershey et al., 1986).

It has been reported that since just a low percentage of the general population seeks treatment for symptoms of disc displacement, and because the patients' lives are not at risk, lower levels of sensitivity can be used for this disorder. However, the asymptomatic patient who is incorrectly diagnosed as having the disorder can incur substantial human and financial cost and may be subjected to unnecessary and potentially damaging treatment (Wismer et al., 1990).

It thus seems reasonable to select, for the disorder under study, the "positive-if-all-tests-positive criterion" to interpret the tests combination's results so that false-positive diagnoses can be avoided. In this way, the combination of multiple tests serves as a single exclusionary test, which is the test recommended for making a diagnosis after performing a screening test (Griner et al., 1981; Johnson, 1991).

Here, 6 tests were combined to diagnose disc displacement with reduction and 5 to diagnose disc displacement without reduction. High sensitivity guided the choices of combinations of tests. As the number of tests increased in each combination, the aggregate sensitivity of the combination was substantially reduced compared with that of each test alone, while the specificity increased. Therefore, by combining the tests with highest sensitivity and treating the combination as a single test using an overall criterion for positivity, we accepted a decreased sensitivity for an increase in diagnostic specificity up to 90% and 97.9% for disc displacement with and without reduction, respectively, which allows for the exclusion of false-positive diagnoses.

Since observer variations are well-known to exist and could significantly influence the evaluation of disease (Rohlin and Petersson, 1989), the degree of observer consistency was investigated. Reliability, on a joint-by-joint basis, regarding each of the criteria studied was substantial for the 3 pairs of observers (mean kappa index, 0.70). Calibration of the observers by collective discussion of the way to interpret the images according to the criteria appears to have been effective (Orsini et al., 1997).

There are some inherent weaknesses regarding the experimental design of the present study that we would like to address.

First, it should be noted that a potential bilateral disorder presents a problem in data analysis. With TMJ disc displacement, it is likely that the stage of the disease in one TMJ can influence the condition and the clinical presentation of the contralateral side, since the mandible is bi-articular, neither joint moving independently of its opposite. This situation is sometimes also complicated by the indirect effect of the musculature on movements of the mandible. It should be noted that in this study we included consecutive cases, some of which presented with a muscle disorder. This could have significant impact on the diagnosis of TMJ disc position (Anderson et al., 1989; Schiffman et al., 1989). We admit that
these represent problems in diagnosis and data analysis, but these are problems inevitably faced by every clinician in the diagnosis of TMJ disc displacement. We believe that this heterogeneous patient population provided a good test ground for the clinical diagnostic process.

Second, we recognize that temporomandibular disorders’ signs and symptoms fluctuate, and that they may come and go in an unpredictable pattern (Könnönen and Nyström, 1993; Onizawa and Yoshida, 1996). It would be desirable to record all of the clinical variables on several occasions over time to confirm the reliability of these data. Third, we recognize that if a TMJ MRI were available, all views would be utilized to make the judgment of the disc position’s normalcy. However, in this study, we restricted judgments about disc position to those made using the sagittal plane views only. This was done because the position of the disc on a sagittal view is the most commonly used, and often the only, stated criterion. The use of only sagittal views will produce slightly higher numbers of false-negative and false-positive diagnoses compared with the additional use of coronal views (Brooks and Westesson, 1993; Tasaki and Westesson, 1993). Finally, the current clinical and research literature suggests that the gold standard for the diagnosis of TMJ disc displacement is expert examiners’ decisions based on all clinical and imaging data. However, since the purpose of this study was to investigate the predictability of the clinical findings, the imaging findings were used as the gold standard. The aim of future studies will be to investigate the predictive power of the MR images and the clinical findings based on this new gold standard.

In conclusion, the sensitivity and specificity of 8 clinical parameters for predicting the imaging diagnosis of TMJ disc displacement established by 4 criteria were assessed. The prevalence of false-positive and false-negative diagnoses was closely related to the operational criteria used. The intermediate zone criterion was the one that most accurately reflected the condition of the joint, with the fewest false-positive and false-negative diagnoses. The clinical predictability of the disorder diagnosed according to this criterion suggests that clinical findings alone are too often nonspecific as predictors of the imaging stage of disc displacement. Even though some of the clinical parameters by themselves were closely related to the disorder, caution should be exercised in using them as absolute indicators of the status of the joint. However, we found that combining the most sensitive parameters and using an overall criterion for positivity to interpret the results of the combination led to an impressive increase in the specificity of the combination, allowing false-positive diagnoses to be excluded.

Acknowledgments
This study was supported by a Grant-in-Aid for the Encouragement of Young Scientists (No. 057716484) from the Ministry of Education, Science and Culture of Japan. The authors gratefully acknowledge Dr. Glenn T. Clark, Professor and Chairman, Section of Diagnostic Sciences and Orofacial Pain, UCLA School of Dentistry, for his helpful comments on the manuscript.

References


