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# Adolescent TMJ Tomography and Magnetic Resonance Imaging: A Comparative Analysis

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*The predictive value of radiographic tomography was assessed using magnetic resonance imaging as a definitive test of TMJ soft-tissue status in a predominantly asymptomatic adolescent sample. Eighty-two TMJs in 41 subjects (mean age = 12.5 years, range = 10 to 17 years) were independently evaluated using axially corrected tomography and magnetic resonance imaging. Tests of comparison and correlation were performed. Correspondence of tomographic classification to magnetic resonance imaging classification of nondisplacement (55%), reducing internal derangement (35%), or nonreducing internal derangement (10%) showed a significant relationship ( $P < .05$ ). Tomography as a diagnostic test of abnormal disc position had a sensitivity of 0.43, a specificity of 0.80, a positive predictive value of 0.64, and a negative predictive value of 0.63. Tomography is inappropriate as a diagnostic test for TMJ internal derangement.*

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**key words:** tomography, magnetic resonance imaging, adolescent, temporomandibular joint

A test is said to have sensitivity if it can correctly identify a disease parameter and if it addresses the question, "if disease is present, how often is the test positive?"<sup>1</sup> Conversely, a test is said to have specificity if it can correctly identify absence of disease and if it addresses the question, "if disease is absent, how often is the test negative?"<sup>1</sup> Within any given population, sensitivity and specificity are independent of disease frequency and thus provide a measure of the discriminative power of a test. Disease prevalence, however, does influence the absolute number of individuals falsely identified, either positively or negatively, as a result of testing. For example, a highly sensitive (but imperfect) test for a prevalent disease will identify numerous true positives, but it will also indicate false negatives that, as a proportion of population size, may represent a significant number of people. The prevalence-dependent frequency with which a positive test result actually signifies disease is calculated as the positive predictive value of the diagnostic test. Conversely, negative predictive value is the frequency with which a negative test identifies people without disease. Table 1 illustrates, with a  $2 \times 2$  stratification of data, the relationship between sensitivity, specificity, positive predictive value, and negative predictive value.<sup>2</sup>

Temporomandibular internal derangement (ID) is defined as an abnormal relationship of the disc to the mandibular condyle and related articular eminence<sup>3</sup>; however, radiographic findings suggest that condylar position and analysis of joint space may not be

**Table 1** Relationship Between Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value for a 2 × 2 Distribution

| Diagnostic test | Standard test      |                    |
|-----------------|--------------------|--------------------|
|                 | Disease present    | Disease absent     |
| Disease present | A (true positive)  | B (false positive) |
| Disease absent  | C (false negative) | D (true negative)  |

True positive = (A); false positive = (B); false negative = (C); true negative = (D); sensitivity = (A)/(A+C); specificity = (D)/(D+B); positive predictive value = (A)/(A+B); negative predictive value = (D)/(D+C).

reliable indicators of ID. Although Ronquillo et al<sup>4</sup> report that posteriorly positioned condyles indicate anterior disc displacement with reduction, while concentric condyle position indicates either nonreducing anterior disc displacement or no displacement, Katzberg<sup>5</sup> found no significant relationship of posterior condylar position to ID. In addition, Brand et al<sup>6</sup> found disc position prediction, based on condylar positioning, to be accurate in only 63% of 243 subjects; they concluded that anterior disc displacement failed to alter the apparent condylar position more frequently than condylar repositioning occurred in the absence of anterior disc displacement. Furthermore, condylar morphology often does not duplicate the frequently irregular shape of the fossa,<sup>7</sup> and may appear radiographically to have different spatially related positions in medial and lateral aspects of the same joint.<sup>8-10</sup> Interarticular joint space may be of limited value in predicting soft tissue relationships.

Magnetic resonance imaging (MRI) makes it possible to achieve high-resolution tissue contrast with direct imaging of the temporomandibular disc, including changes in its placement subsequent to motion of the condyle.<sup>11</sup> In sagittal views, the normal disc has a characteristic biconcave shape.<sup>12</sup> The junction of the posterior band of the disc and the bilaminar zone should fall within 10 degrees of vertical to be within the 95th percentile of normal.<sup>13</sup> Correlation of MRI and surgical findings reveals a sensitivity of 0.86 to 0.98, a specificity of 0.87 to 1.00, a positive predictive value of 0.89 to 1.00, and a negative predictive value of 0.78 to 0.89 for correctly identifying disc position.<sup>14-17</sup> Tasaki and Westesson<sup>18</sup> report high intraobserver (95%) and interobserver reliability (91%). Thus, MRI represents the current "gold standard" for identification of temporomandibular soft tissue detail and disc position.

The purpose of this study was to determine the diagnostic sensitivity, specificity, positive predic-

tive value, and negative predictive value of tomography in diagnosing temporomandibular joint internal derangement in a series of adolescents using magnetic resonance imaging as a definitive test.

## Materials and Methods

Data were obtained from 41 adolescent patients (mean age 12.5; range 10 to 17 years) selected sequentially from a private clinical practice (PM) upon presenting for assessment of possible orthodontic treatment. Informed consent was obtained and verified with parents/guardians. Temporomandibular joint imaging was obtained using both tomography and MRI. Maximum dental intercuspation and maximum unassisted vertical mandibular opening were the positions selected for all TMJ imaging. Maximum intercuspation was registered with a polyvinyl siloxane impression material to ensure a comparable intercuspation position during imaging.

Multidirectional, axially corrected tomography was obtained with a Tomax (Incubation Industries, Warring, PA) using hypocycloidal plane localization. Before tomography, the mediolateral long axis and center of each condyle was estimated from a flat plane submentovertex projection.<sup>19,20</sup> Three 2-mm tomographic slices, perpendicular to the mediolateral long axis of the condyle, were obtained from each joint with patients registered in maximum intercuspation. Medial and lateral tomographic slices were spaced 3 to 4 mm apart depending on the medial-lateral condylar width. A single central slice, corrected for condylar translation, was obtained with patients postured in maximum unassisted vertical opening. With the patient upright during imaging, static head position was maintained with a cephalostat.

T<sub>1</sub>-weighted magnetic resonance images were obtained with a Shimadzu magnetic resonance scanner (Shimadzu, Tokyo, Japan) producing a 1 T magnetic field. Horizontal (transverse plane) scout scans, spaced at 5-mm intervals, were used to localize the mediolateral long axis and center of each condyle. Multiple 3-mm thick imaging slices, spaced on 3-mm intervals and perpendicular to the mediolateral long axis of the condyle, were obtained from each joint with patients registered in maximum intercuspation. The series was repeated on each joint, with patients postured in maximum unassisted vertical opening. During imaging of each joint, and with the patient supine, a surface coil was fixed to the para-auricular region, and static head position was maintained with a nonferromagnetic restraining device.

**Table 2** Tomographic Categorization: Assessment Criteria Suggestive of Altered Joint Dynamics

| Tomographic category             | Condyle position          |                        | Joint space               |                          |
|----------------------------------|---------------------------|------------------------|---------------------------|--------------------------|
|                                  | At maximal intercuspation | At maximal translation | At maximal intercuspation | At maximal translation   |
| Normal                           | Concentric                | Normal                 | Equidistant               | Maintained               |
| Displaced disc with reduction    | Nonconcentric             | Normal                 | Reduced                   | Increased                |
| Displaced disc without reduction | Nonconcentric             | Abnormal               | Reduced                   | Maintained               |
| Equivocal (unknown)              | Concentric/nonconcentric  | Normal/abnormal        | Equidistant/reduced       | Maintained/<br>increased |

**Table 3** MRI Categorization: Assessment Criteria Relative to Disc Position

| MRI category                                      | Intermediate zone of disc   |
|---|---|
| Normal  | Interposed between condyle and posterior slope of articular eminence. Normal disc morphology.                           |
| Displaced disc with reduction (normal meniscus)   | Anteriorly displaced (normal disc morphology) relative to condyle with normal relationship re-established on opening.   |
| Displaced disc with reduction (abnormal meniscus) | Anteriorly displaced (abnormal disc morphology) relative to condyle with normal relationship re-established on opening. |
| Displaced disc without reduction                  | Anteriorly displaced relative to condyle without normal disc relationship established on opening.                       |

Tomograms were assessed on three separate occasions by two investigators (LK/BN) to radiographically classify each joint image as suggestive of (a) nondisplaced disc, (b) disc displacement with reduction, (c) disc displacement without reduction, or (d) unknown. Condyle position at maximum intercuspation and maximum translation was evaluated on the premise that condyle concentricity relative to the fossa, in combination with translation to a point approximating the height of the articular eminence, represented normality. Normality of interarticular joint space was defined as equidistant anterior, superior, and posterior joint space at maximum intercuspation maintained at maximum unassisted vertical opening. Consensus of the investigators was required to categorize each joint. Radiographic assessment criteria are summarized in Table 2.

Magnetic resonance images were assessed independently by a medical radiologist and a maxillofacial radiologist blinded to patient identity and imaging side. Evaluation of disc position was based on the premise that a normally reduced disc was one in which the intermediate zone was interposed between the condylar head and the articular eminence. Further, evaluation of disc morphology was based on the premise that a normal disc had posterior and anterior bands distinguishable from

a thinner intermediate zone. Consensus of the investigators was required to categorize each joint. Magnetic resonance imaging assessment criteria are summarized in Table 3. In this study, reducing disc displacement (normal disc morphology) was combined with reducing disc displacement (abnormal disc morphology) to form a single group.

Tomographic joint classification, using magnetic resonance as a standard for comparison, was measured by the sensitivity, specificity, positive predictive value, and negative predictive value of each tomographic classification. Diagnostic subgroups ("normal," "internal derangement with reduction," and "internal derangement without reduction") were individually isolated from the sample for comparison with the balance of the sample. Sensitivity and specificity were calculated as conditional probabilities estimating the likelihood of correctly identifying true positive and true negative tissue status using tomography as a discriminator. Positive predictive value was calculated as the frequency with which presence of tissue status in question, irrespective of the number of false negatives, was correctly identified. Negative predictive value was calculated as the frequency with which absence of tissue status in question, irrespective of the number of false positives, was correctly identified.

**Table 4** Contingency Table of Tomography Relative to Magnetic Resonance Imaging Categorization

| Tomography                       | Magnetic resonance imaging |                                  |                                | Total     |
|----------------------------------|----------------------------|----------------------------------|--------------------------------|-----------|
|                                  | Normal                     | Disc displacement with reduction | Displacement without reduction |           |
| Normal                           | 36                         | 18                               | 3                              | 57 (70%)  |
| Disc displacement with reduction | 3                          | 9                                | 0                              | 12 (15%)  |
| Displacement without reduction   | 2                          | 2                                | 3                              | 7 (9%)    |
| Equivocal finding                | 4                          | 0                                | 2                              | 6 (7%)    |
| Total                            | 45 (55%)                   | 29 (35%)                         | 8 (10%)                        | 82 (100%) |

**Table 5** Categorization of Diagnoses of Internal Derangement and Normal by Magnetic Resonance Imaging and Tomography

| Tomography                      | Magnetic resonance imaging      |                    | Total |
|---------------------------------|---------------------------------|--------------------|-------|
|                                 | Abnormal (internal derangement) | Normal             |       |
| Abnormal (internal derangement) | 16 (true positive)              | 9 (false positive) | 25    |
| Normal                          | 21 (false negative)             | 36 (true negative) | 57    |
| Total                           | 37                              | 45                 | 82    |

## Results

Table 4 provides cross-tabulation of the tomographic classification with the MRI findings. The investigators were not able to categorize tomograms from six joints. A chi-square analysis showed a significant relationship ( $P < .05$ ) between the tomographic and MRI classifications, implying that the two diagnostic techniques showed overall agreement.

To assess the diagnostic sensitivity and specificity of tomographically classifying joint status as abnormal, the diagnoses of "internal derangement with reduction," "displacement without reduction," and "equivocal" were pooled to allow binary stratification of "abnormal" versus "normal" (Table 5). The six joints that were categorized as unknown by tomography were included with abnormal as a worst-case scenario. This approach was weighted against the alternative of exclusion, and the decision was made to function on the worst-case scenario. Thirty-six joints were correctly identified as normal, 16 joints were correctly identified as abnormal, 21 joints were falsely diagnosed as normal, and 9 joints were falsely diagnosed as abnormal. Tomographic sensitivity was 0.43, specificity was 0.80, positive

predictive value was 0.64, and negative predictive value was 0.63.

To assess the diagnostic sensitivity and specificity of tomographically classifying joint status as internally deranged with reduction, the diagnoses of "normal," "displacement without reduction," and "equivocal" were pooled to allow binary stratification of "internal derangement with reduction" versus all other diagnoses (Table 6). Nine joints were correctly identified as internally deranged with reduction, 50 joints were correctly categorized collectively under other diagnoses, 3 joints were falsely categorized as internally deranged with reduction, and 20 joints were falsely categorized under other diagnoses. Tomographic sensitivity was 0.31, specificity was 0.94, positive predictive value was 0.75, and negative predictive value was 0.71.

To assess the diagnostic sensitivity and specificity of tomographically classifying joint status as displaced without reduction, the diagnoses of "normal," "internal derangement with reduction," and "equivocal" were pooled to allow binary stratification of "displacement without reduction" versus all other diagnoses (Table 7). Three joints were correctly identified as displaced without reduction, 70 joints were correctly categorized collectively under

**Table 6** Categorization of Diagnoses of Disc Displacement With Reduction and Other Diagnoses by Magnetic Resonance Imaging and Tomography

| Tomography                       | Magnetic resonance imaging       |                    | Total |
|----------------------------------|----------------------------------|--------------------|-------|
|                                  | Disc displacement with reduction | Other diagnoses    |       |
| Disc displacement with reduction | 9 (true positive)                | 3 (false positive) | 12    |
| Other diagnoses                  | 20 (false negative)              | 50 (true negative) | 70    |
| Total                            | 29                               | 53                 | 82    |

**Table 7** Categorization of Diagnoses of Disc Displacement Without Reduction and Other Diagnoses by Magnetic Resonance Imaging and Tomography

| Tomography                          | Magnetic resonance imaging          |                    | Total |
|-------------------------------------|-------------------------------------|--------------------|-------|
|                                     | Disc displacement without reduction | Other diagnoses    |       |
| Disc displacement without reduction | 3 (true positive)                   | 4 (false positive) | 7     |
| Other diagnoses                     | 5 (false negative)                  | 70 (true negative) | 75    |
| Total                               | 8                                   | 74                 | 82    |

other diagnoses, 4 joints were falsely categorized as displacement without reduction, and 5 joints were falsely categorized under other diagnoses. Tomographic sensitivity was 0.38, specificity was 0.95, positive predictive value was 0.43, and negative predictive value was 0.93.

## Discussion

In our sample, tomographic diagnoses of ID were collectively established with low sensitivity (0.43) and relatively low positive predictive value (0.64), meaning that the probability of tomography correctly identifying ID when present was 43% and the probability of ID existing in a joint identified by tomography as internally deranged was 64%. Tomographic specificity was relatively high (0.80) and negative predictive value was moderately low (0.63), meaning that the probability of tomography correctly identifying absence of ID was 80% and the probability of normal tissue status existing in a joint identified by tomography as normal was 63%. These data produce positive and negative likelihood ratios of 2.15 and 0.71, respectively, indicating that a tomography result of ID is slightly more than twice as likely (2.15 times) to come from a joint with ID than from a normal joint, and that a tomography result of

normal is only slightly less likely (0.71 times) to come from a joint with ID than from a joint without ID. The likelihood ratios, combined with low ID diagnostic accuracy (0.63), indicate that tomography is poorly discriminative for the presence or absence of nonspecific temporomandibular ID as identified by MRI.

Tomographic diagnoses of ID *with* reduction were established with a sensitivity of only 0.31, a positive predictive value of 0.75, a specificity of 0.94, and a negative predictive value of 0.71. In our sample, the probability of correctly identifying absence of reducing ID was 94%, but the probability of correctly discriminating reducing ID was only 31%. The predictive values can be interpreted to mean that the probability of the presence of reducing ID in a joint tomographically suspected as such was 75% and the probability of the absence of reducing ID in a joint tomographically suspected as such was 71%. Positive and negative likelihood ratios were 5.5 and 0.73, respectively, indicating that a tomography result of reducing ID is 5.5 times more likely to come from a joint with reducing ID than from all other joints but that other diagnoses combined are only slightly less likely (0.73 times) to come from a joint with reducing ID than from any other joints. In practical terms, this means that if tomography is used to discriminate reducing ID from the sample as

a whole, it is likely to produce numerous false negative results and exhibit a bias towards underdiagnosis. In our sample, more than twice as many joints with reducing ID were unidentified than were identified, and one-third of those identified were incorrect.

Similarly, tomographic diagnoses of ID *without* reduction were established with a sensitivity of 0.38, a positive predictive value of 0.43, a specificity of 0.95, and a negative predictive value of 0.93. In our sample, the probability of correctly identifying absence of nonreducing ID was 95%, but the probability of correctly discriminating nonreducing ID was only 38%. The predictive values can be interpreted to mean that the probability of the presence of nonreducing ID in a joint tomographically suspected as such was 43% and the probability of the absence of nonreducing ID in a joint tomographically suspected as such was 93%. Positive and negative likelihood ratios were 6.9 and 0.66, respectively, indicating that a tomography result of nonreducing ID is nearly seven (6.9) times more likely to come from a joint with nonreducing ID than from all other joints, but that other diagnoses combined are only slightly less likely (0.66 times) to come from a joint with nonreducing ID than from any other joints. In practical terms, this means that if tomography is used to discriminate low-prevalence (0.10) nonreducing ID from the sample as a whole, it is likely to produce more errors than correct diagnoses. In our sample, nearly twice as many joints with nonreducing ID were unidentified than were identified, and less than half of those identified were correct (ie, three times more errors than correct diagnoses were made).

Although MRI joint classification was determined by independent and blinded examiners, it remained subjective. Despite assessment criteria relative to disc position being categorically defined, no consideration was given to the mediolateral component of disc displacement observed in some of the MRIs. A number of joints demonstrated varied degrees of antero-medial disc displacement, which, when viewed in the sagittal plane, appeared medially to be reduced but laterally to be displaced. It became apparent in the MRI analysis that a purely anteroposterior approach to classifying internal derangement was overly simplistic.

The authors recognize that caution should be exercised in interpreting the frequency of temporomandibular ID found in this study as representative of a typical adolescent population. Although our sample revealed a high proportion of positive soft tissue findings (0.45) compared with prevalence estimated in adult populations,<sup>21,22</sup> subjects were serially selected from an orthodontic practice in which referrals were biased toward patients having dento-

facial abnormality. Patient selection may have been further biased as a result of the practitioner's (PM) affiliation with a university-based TMD clinic.

## Conclusion

Although soft tissue structures are not clearly discernible with noncontrast tomography,<sup>23</sup> clinicians have shown an association of width of joint space with ID, suggesting that condylar concentricity in the glenoid fossa represents normality while decreased posterior joint space suggests disc displacement. In addition, separate studies defining the ideal condyle-fossa spatial relationship<sup>24,25</sup> describe different "ideals" theoretically possessing different diagnostic criteria. Subjective interpretation of a testing procedure may disable a diagnostic test's ability to minimize false-positive and false-negative test results. In our sample, noncontrast tomographic evaluation of adolescent TMJ status significantly underestimated positive soft tissue findings discernible with MRI. Our results indicate that tomography is inappropriate as a diagnostic test for TMJ internal derangement.

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## Resumen

Análisis Comparativo sobre la Tomografía de la Articulación Temporomandibular (ATM) y las Imágenes de Resonancia Magnética en Adolescentes

El valor de predicción de la tomografía radiográfica fue evaluada utilizando las imágenes de resonancia magnética como un examen definitivo del estado del tejido blando de la ATM en una muestra de adolescentes asintomáticos predominantemente. Se evaluaron independientemente a 82 personas (edad media = 12.5 años, escala = 10 a 17 años), utilizando una tomografía corregida axialmente e imágenes de resonancia magnética. Se efectuaron exámenes de comparación y correlación. La correspondencia de la clasificación tomográfica a la clasificación de las imágenes de resonancia magnética de los casos sin desplazamiento (55%), malfuncionamiento interno en vía de reducción (35%), o malfuncionamiento interno sin estar en el proceso de reducción (10%) mostraron una relación significativa ( $P < 0,05$ ). La tomografía como un examen de diagnóstico de la posición anormal del disco presentó una sensibilidad de 0,43, una especificidad de 0,80, un valor de predicción positivo de 0,64, y un valor de predicción negativo de 0,63. La tomografía es inapropiada como examen de diagnóstico en los malfuncionamientos internos de la ATM.

## Zusammenfassung

Kiefergelenkstomographie und Magnetresonanz bei Jugendlichen: eine vergleichende Analyse

Der voraussagbare Wert der radiographischen Tomographie wurde mittels Magnetresonanz als entscheidender Test des Weichteilstatus des Kiefergelenkes in einer überwiegend asymptomatischen jugendlichen Auswahl beurteilt. Zweiundachtzig Personen (Durschnittsalter = 12.5 Jahre, Breite = 10 bis 17 Jahre) wurden mittels axial korrigierter Tomographie und Magnetresonanz unabhängig ausgewertet. Vergleichstests und Korrelationstests wurden durchgeführt. die Gegenüberstellung zwischen tomographischer Klassifikation und Magnetresonanz-Klassifikation von Nichtverlagerung (55%), internal derangement mit Reduktion (35%) oder internal derangement ohne Reduktion (10%) zeigte eine signifikante Verbindung ( $P < .05$ ). Die Tomographie als diagnostischer Test für eine abnormale Diskusposition hat eine Sensitivität von 0.43, eine Spezifität von 0.80, einen positiv voraussagbaren Wert von 0.64 und einen negativ voraussagbaren Wert von 0.63. Die Tomographie ist ungeeignet als diagnostischer Test für internal derangement des Kiefergelenkes.