CONTINUING EDUCATION ARTICLE

Mandibular articular disk position changes during Herbst treatment: A prospective longitudinal MRI study

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The aim of this prospective longitudinal study of 15 consecutively treated Class II malocclusions was to assess any possible changes in the relative position of the articular disk to the condyle during different phases of Herbst therapy. Using a disk position index, parasagittal MRIs (central, medial and lateral slices) of the right and left TMJ were analyzed at five occasions: before Herbst treatment (T1), at start of treatment when the appliance was placed (T2), after 6 weeks of treatment (T3), after 13 weeks of treatment (T4), and after 7 months of treatment when the appliance was removed (T5). In all subjects Herbst treatment resulted in Class I or overcorrected Class I dental arch relationships. Condyle position was on average unchanged during Herbst treatment (T1 to T5). Before treatment (T1) the articular disk was in a slight protrusive position relative to the condyle. At start of treatment (T2) the mandible was advanced to an incisal edge to edge position. Because of the physiologic relative movement of disk and condyle on mandibular protrusion the disk attained a pronounced retrusive position. At the end of treatment (T5), the disk had almost returned to its original pretreatment position. In several cases, however, a slight retrusive disk position prevailed. In conclusion, Herbst treatment did not result in any adverse changes in articular disk position. On the contrary, the Herbst appliance could possibly be useful in the therapy of patients with anterior disk displacement. (Am J Orthod Dentofacial Orthop 1999;116:207-14)

In the physiologic temporomandibular joint (TMJ), the articular disk is positioned between the condylar head and the glenoid fossa and follows the condyle during mandibular opening and closing movements. Disk displacement or disk adhesion result in a more or less pronounced disturbance of TMJ function. Orthodontic treatment has often been said to be associated with the development of TMJ dysfunction even though more recent studies could not find any association between orthodontics and temporomandibular disorders (TMD).

Before the introduction of magnetic resonance imaging (MRI) in medical diagnostics only invasive methods (eg, arthrography, arthroscopy) for studying the mandibular articular disk were available. Therefore, in orthodontics and/or dentofacial orthopedics, the functioning disk has received little attention and, according to our knowledge, no investigation has been published about the subject.

The purpose of this prospective longitudinal investigation with the MRI technique was to analyze possible changes in the relative position of the mandibular articular disk to the condyle during different phases of Herbst appliance treatment. The study was confined to disk position changes in the sagittal plane. An analysis of changes in the transverse plane will be considered in a forthcoming study.

SUBJECTS

Fifteen consecutively treated Herbst patients (10 males and 5 females) aged 12 years to 17 years participated in this prospective study. All subjects had a Class II malocclusion. The average treatment time with the Herbst appliance was 7 months. A casted splint Herbst appliance was used in the treatment of all subjects. Selected characteristics of the patients are presented in Table I. Clinical or MRI signs and symptoms of TMJ dysfunction before treatment were found in 2 of the 15 patients (cases 1 and 12). Case 1 had a partial anterior disk displacement with reduction in one joint that, however, was reduced during Herbst therapy. Case 12 exhibited slight osteoarthritic changes in both condyles. As a result of the remodeling processes, a normal condylar morphology was seen after treatment.

METHOD

MRIs of the TMJ were obtained by means of a Magnetom Expert 1.0 Tesla (Siemens AG, Erlangen,
Table 1. Selected characteristics in 15 Herbst patients (10 males and 5 females)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender (M/F)</th>
<th>Age before treatment (years)</th>
<th>Treatment time (months)</th>
<th>Cephalometric variables</th>
<th>Angle Class</th>
</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ANB (°)</td>
<td>ML/NSL (°)</td>
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<tr>
<td>1</td>
<td>F</td>
<td>17.5</td>
<td>11</td>
<td>4.0</td>
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<td>2</td>
<td>M</td>
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<td>6.0</td>
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<td>7.5</td>
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</tr>
<tr>
<td>4</td>
<td>M</td>
<td>12.6</td>
<td>7</td>
<td>6.5</td>
<td>32.0</td>
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<tr>
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<td>7</td>
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<tr>
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<td>F</td>
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<td>9.0</td>
<td>29.5</td>
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<td>7</td>
<td>M</td>
<td>13.2</td>
<td>7</td>
<td>5.0</td>
<td>34.0</td>
</tr>
<tr>
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<td>7.0</td>
<td>39.5</td>
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<td>M</td>
<td>12.2</td>
<td>9</td>
<td>10.0</td>
<td>44.0</td>
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<td>F</td>
<td>13.8</td>
<td>8</td>
<td>4.0</td>
<td>37.0</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>13.6</td>
<td>7</td>
<td>7.5</td>
<td>32.0</td>
</tr>
</tbody>
</table>

Germany) equipped with TMJ coils for simultaneous imaging of the left and right joint. The MRI protocol included closed mouth parasagittal proton density weighted spin echo sequences (TR 2000/TE 40/Matrix 252 x 256/FOV 150 x 150) and mouth open parasagittal T2-weighted sequences (TR 4500/TE 128 Matrix 230 x 256/FOV 201 x 230) taken perpendicular to the long axis of the condyle. Five slices of each joint were made. Slice thickness was 3 mm with no interslice gap.

The MRIs were taken at the following treatment stages:
- T1: Before Herbst treatment (mean, 28 days before start of treatment)
- T2: At start of Herbst treatment when the appliance was placed (mean, 6 days after appliance placement)
- T3: After 6 weeks (4 to 7 weeks) of treatment
- T4: After 13 weeks (8 to 18 weeks) of treatment
- T5: After 7 months (5 to 11 months) of treatment when the Herbst appliance was removed (mean, 4 days after appliance removal)

In the analysis of the closed mouth MRIs, the central, the proximal medial, and proximal lateral slice from each joint were used. In the analysis of the mouth open MRIs, the central slice from each joint was evaluated.

All MRIs were traced and analyzed twice with a 1 week interval between the two registrations. In the final evaluation, the mean value of the duplicate registrations was used. In order to be able to compare the MR images in a series, care was taken that they had the same magnification. Furthermore, to make the measuring procedure more simple and accurate, all tracings were magnified to 156% by a photocopying procedure. Articular disk position was assessed by a modified method of Bumann et al and Vargas Pereira. The following reference points and measuring variables were used (Figs 1 and 2):

Cm: Midpoint of the mandibular condylar head (assessed by visual inspection)
Tm: Midpoint of the tuberculum articolare (assessed by visual inspection)
Da: Anterior point of the articular disk
Dp: Posterior point of the articular disk
Dm: Midpoint of the articular disk (the midpoint of the line Da-Dp)

For the final assessment of the disk position a disk position index was calculated:

\[(a:b) \times 100\]

The index describes the position of the articular disk in relation to the mandibular condyle and the temporal articular eminence. In a centered disk position, the midpoint of the disk (Dm) is on the line Cm-Tm; the distance a is zero (0). In a protrusive disk position, Dm is in front of the line Cm-Tm; the distance a is positive (+). In a retrusive disk position, Dm is behind the line Cm-Tm; the distance a is negative (-).

Statistical Evaluation

For the disk position index, the arithmetic mean (mean) and the standard deviation (SD) were calculated. Student t test was used to assess the changes in the index during the different observation periods as well as to compare the three MRI slices (central, medial, and lateral). The levels of statistical signifi-
cance used were: $P < .001 (***)$, $P < .01 (**)$, and $P < .05 (*)$. $P \geq .05$ was considered not significant (NS).

**Method Error Calculation**

The method error (ME) was calculated for the disk variables $a$ and $b$. Duplicate closed mouth proton density weighted parasagittal MRIs of five untreated subjects were evaluated (untreated subjects were used to exclude the possibility of any changes in articular disk position occurring during Herbst treatment). The duplicate MRIs (registration 1 and registration 2) were made with a time interval of 14 days. For each registration, two separate tracings were made and evaluated (measurement 1 and measurement 2).

The following MEs were assessed:

1. The ME for the duplicate measurements (M1 and M2) for each of the two registrations (R1 and R2); this error includes the error in tracing the MRIs, defining the reference points, and reading the ruler.

2. The ME for the duplicate registrations (R1 and R2) using the mean value of the two measurements (M1 and M2) for each registration; this error includes the projection error of the two MRIs as well as the errors listed in point 1.

The ME calculations were performed using the formula of Dahlberg:

$$ME = \sqrt{\frac{\Sigma d^2}{2n}}$$

where $d$ is the difference between two measurements of a pair and $n$ is the number of subjects.

The MEs of the disk variables $a$ and $b$ are shown in Table II.

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**TABLE II.** Method error assessment for duplicate measurements (M1/M2) and for duplicate registrations (R1/R2). Analysis of parasagittal MRIs (medial, central, and lateral slices) from five untreated subjects. The right and left joints were evaluated.

<table>
<thead>
<tr>
<th>Slice and joint</th>
<th>Registration and measurement</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a (mm)</td>
<td>b (mm)</td>
</tr>
<tr>
<td>Medial right</td>
<td>R1 M1/M2</td>
<td>0.47</td>
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<tr>
<td></td>
<td>R2 M1/M2</td>
<td>0.55</td>
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<tr>
<td></td>
<td>R1/R2</td>
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<tr>
<td>Medial left</td>
<td>R1 M1/M2</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>R2 M1/M2</td>
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<tr>
<td></td>
<td>R1/R2</td>
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<tr>
<td>Central right</td>
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<td>0.84</td>
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<tr>
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<td>R2 M1/M2</td>
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<td></td>
<td>R1/R2</td>
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<tr>
<td>Central left</td>
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<tr>
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<td>R2 M1/M2</td>
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<td></td>
<td>R1/R2</td>
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<td></td>
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<td>R1/R2</td>
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<tr>
<td>Lateral left</td>
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</tr>
<tr>
<td></td>
<td>R1/R2</td>
<td>1.02</td>
</tr>
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</table>

**RESULTS**

All 15 subjects were treated to Class I or overcorrected Class I dental arch relationships. The results of the disk position index calculations are presented graphically in Figs 3 to 8. As no gender differences existed the findings for the males and females were pooled.

In the closed mouth MRIs, an average protrusive disk position (positive index value) was seen before treatment (T1) (Figs 3 and 4). At start of treatment when the appliance was placed (T2), a disk retrusion
Fig 3. Disk position index. Mean values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central slice) from the right TMJ in the closed and open mouth position. (T1, before treatment; T2, start of treatment when the appliance was placed; T3, after 6 weeks of treatment; T4, after 13 weeks of treatment; T5, after 7 months of treatment when the appliance was removed.)

Fig 4. Disk position index. Mean values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central slice) from the left TMJ in the closed and open mouth position (T1, before treatment; T2, start of treatment when the appliance was placed; T3, after 6 weeks of treatment; T4, after 13 weeks of treatment; T5, after 7 months of treatment when the appliance was removed.)

Fig 5. Disk position index. Individual values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central slice) from the right TMJ in the closed mouth position. (T1, before treatment; T2, start of treatment when the appliance was placed; T5, after 7 months of treatment when the appliance was removed. The mean value of the 15 subjects is shown.)

(negative index value) occurred in all subjects but one (Figs 5 and 6). During the course of treatment, the disk in both joints tended to return to its original position. After treatment (T5) a relative disk retrusion in comparison to the pretreatment values prevailed (Figs 3 and 4). A large interindividual variation existed, however (Figs 5 and 6).

In the open mouth MRIs an average disk retrusion was present at all times of examination (Figs. 3 and 4). The disk position varied insignificantly during the course of treatment.

When considering the different MRI slices of each joint the disk became retrusive (P < .01) during the period T1 to T2 for all slices of the right joint (Fig 7) and for the lateral slice of the left joint (P < .001) (Fig 8). When looking at the total examination period from before to after Herbst treatment (T1 to T5), a significant disk retrusion (P < .05) occurred only for the lateral MRI slice of the left joint. For the other MRI slices in both joints, a tendency of an average disk retrusion was noted. During the course of treatment retrusion of the disk seemed most pronounced for the medial slices of both joints (Figs 7 and 8).

Case Reports

Two patients will be presented in order to demonstrate the condyle-disk changes during the different
Fig 6. Disk position index. Individual values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central slice) from the left TMJ in the closed mouth position. (T1, before treatment; T2, start of treatment when the appliance was placed; T5, after 7 months of treatment when the appliance was removed. The mean value of the 15 subjects is shown.)

Fig 7. Disk position index. Mean values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central, medial and lateral slices) from the right TMJ in the closed mouth position. (T1, before treatment; T2, start of treatment when the appliance was placed; T3, after 6 weeks of treatment; T4, after 13 weeks of treatment; T5, after 7 months of treatment when the appliance was removed. The significance levels $P < .01$ [**] and $P < .05$ [*] are given.)

Fig 8. Disk position index. Mean values in 15 Class II subjects treated with the Herbst appliance. Analysis of MRIs (central, medial and lateral slices) from the left TMJ in the closed mouth position. (T1, before treatment; T2, start of treatment when the appliance was placed; T3, after 6 weeks of treatment; T4, after 13 weeks of treatment; T5, after 7 months of treatment when the appliance was removed. The significance level $P < .001$ [***] is given.)

phases of Herbst treatment. Case 1 (Fig 9) is a 15.3-year-old boy (patient 3 in Table I) treated with the Herbst appliance for 6 months and case 2 (Fig 10) is a 13.8-year-old girl (patient 14 in Table I) treated with the Herbst appliance for 8 months.

DISCUSSION

This is the first prospective longitudinal study to record the influence of orthodontic treatment on the disk-condyle complex. The subject material was well defined comprising consecutively treated Class II malocclusions. In the treatment, the same type of appliance (Herbst appliance) was used.

At start of Herbst treatment (T2), the mandible was advanced to an incisal edge to edge position and kept there by the telescopic mechanism. The condyle was displaced out of the glenoid fossa and positioned on the top of the articular eminence. After treatment, the condyles of the subjects had, on average, returned to their original fossa position. This was a result of adaptive dental and skeletal changes:

posterior movement of the upper dentition and anterior movement of the lower dentition, stimulation of sagittal condylar growth, and remodeling of the glenoid fossa.
Most previous MRI studies analyzing sagittal disk position are based on visual descriptive methods. According to several authors, the posterior band of the disk should normally be in a "12 o'clock" position. The disadvantage with the "12 o'clock" method is, however, that the inclination of the articular sloop is not considered, which can lead to a misinterpretation of the disk position.

Several metric methods for the analysis of sagittal disk position exist. The present method is based on that of Bumann et al. and Vargas Pereira. According to the definition used the majority of the Herbst cases exhibited a slight disk protrusion before treatment (Figs 5 and 6). This corresponds roughly with the normative index values (range +33 to -21) for physiological TMJs given by Vargas Pereira. Thus indicating a physiologic disk position in the Herbst cases. However, a slight tendency toward an anterior disk displacement was noted, a finding that has been reported to be seen more frequently in Class II malocclusions.

When placing the Herbst appliance, the mandible with its condyles was advanced to an incisal edge to edge position. The concomitant physiological change in the relative position of the articular disk to the condyle resulted in a disk retusion. As mentioned before, the condyle will return to its original fossa position during the course of Herbst therapy, and the disk will change its relative (physiological) position in relation to the condyle accordingly.

However, in several subjects, a minor disk retusion remained after Herbst treatment. In relation to the total observation period (T1 to T5), this disk retusion was seen in all MRI slices (Figs 7 and 8). A statistical significant change, however, was only seen for the lateral slice of the left joint. When comparing these findings with the normative index values given by Vargas Pereira, Herbst treatment did not result in any pathologic changes in disk position (disk displacement).

The therapeutic disk retusion found in many cases after treatment is remarkable as it was not the result of...
a change in condyle position.\textsuperscript{18} Investigations of patients with anterior disk displacement in which a disk repositioning therapy was performed and controlled by MRI\textsuperscript{25,44,45} have shown that a repositioning of the disk is possible only when the condyle was permanently displaced anteriorly. If the therapeutic condyle displacement is not maintained, a relapse in disk position will occur.\textsuperscript{46-48} Therefore, the frequent observation of a disk retrusion occurring during Herbst treatment could possibly be used as a therapeutic measure in cases with anterior disk displacement. Studies at our department are in progress to test this hypothesis and to elucidate the mechanism leading to the disk retrusion mentioned.

It should be pointed out that because of fibrotic adaptations in the retrodisksal pad\textsuperscript{49} during the observation period T4 to T5 in some patients, it was difficult to differentiate between the posterior band of the articular disk and the retrodisksal tissue.\textsuperscript{16,50} This could possibly have resulted in an overestimation of the disk length, which thus could have affected the index value for the assessment of the disk position.

When comparing the different MRI slices, the disk position varied considerably. Similar results were found by Pho Duc et al\textsuperscript{43} and Vargas Pereira.\textsuperscript{16} This variation, however, seemed to be of minor clinical importance.

In the mouth open MRIs, a constant articular disk retrusion was found. This was due to the physiologic change in relative disk-condyle position during mouth opening. These results are in accordance with those from other investigations.\textsuperscript{16,43}

**CONCLUSION**

Herbst treatment did not result in any negative or pathologic changes of articular disk position. On the contrary the appliance could possibly be useful in the treatment of patients with milder forms of anterior disk displacement.
We are indebted to Dr. Claude Faubert (radiologist and neuroradiologist in private practice) for his cooperation and for producing all MR images.

REFERENCES


