REVIEW ARTICLE

Effect of Herbst treatment on temporomandibular joint morphology: A systematic literature review

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The purpose of this systematic review was to evaluate the effect of Herbst appliance therapy on temporomandibular joint (TMJ) morphology, with special reference to glenoid fossa remodeling, condylar remodeling, condylar position, and articular disc position. Publications of controlled trials of Herbst treatment of Class II patients using magnetic resonance imaging (MRI), computerized tomography scans, or tomography to assess TMJ morphology were identified with Medline (1966-2001), Best Evidence (1991-2001), Cochrane Database of Systematic Reviews (second quarter, 2001), and Embase (1998-2001). Case reports were excluded. Based on our search, only 5 studies met the selection criteria. All studies used internal controls with pretreatment and posttreatment imaging. Four studies used MRI, and 1 used tomograms. The 4 MRI studies used overlapping patient samples and were not considered as independent evidence. The MRI studies did not provide conclusive evidence of osseous remodeling or condyle position change. The tomography study demonstrated minor condyle position change. Methodological deficiencies prevented major conclusions regarding disc position. The reviewed studies highlight the importance of further research. Prospective controlled studies using serial MRI and tomography are required to establish the effect of Herbst treatment on TMJ morphology. (Am J Orthod Dentofacial Orthop 2003;123:388-94)

Since 1979, interest has been renewed in using the Herbst appliance for treating Class II malocclusions.[1] This functional orthopedic appliance is commonly called a "bite-jumping" appliance (defined as a change in the sagittal jaw position, where the mandible is repositioned anteriorly in relation to the maxilla). It is claimed that these appliances can successfully correct Class II malocclusions.[1-5] Some studies indicate that orthodontic treatment (including the use of functional appliances) might be detrimental to the temporomandibular joint (TMJ),[6-8] but more recent studies and reviews have shown that this is not the case.[9-13] Nonetheless, there still seems to be some confusion about the long-term effects of the Herbst appliance on the TMJ. Because the Herbst appliance might affect the glenoid fossa, the condyle, the condylar position, and the disk position, it is appropriate to critically evaluate the corresponding literature examining these effects. With a systematic evidence-based review, selection bias can be limited, and any valid TMJ effects induced by the Herbst appliance can be reviewed.[14]

The purpose of this systematic review was to evaluate the effect of Herbst appliance therapy on TMJ morphology. We focused specifically on glenoid fossa remodeling, condylar remodeling, condylar position, and articular disc position.

MATERIAL AND METHODS

The following criteria were used to consider studies for this review: (1) Class II patients treated with the Herbst appliance; (2) use of magnetic resonance imaging (MRI), computerized tomography (CT) scans, or tomography (axially or horizontally corrected) to image the TMJ; (3) controlled study (minimum—internal control with preintervention and postintervention imaging); and (4) no case reports.

The design of the Herbst appliance is unique because it is nonremovable and postures the mandible protrusively.[1,3,11] Removable functional appliances allow the condyle to seat in the glenoid fossa when the appliance is removed from the mouth, including during

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Table I. Search strategy

No.	*Medline search history*	*Results*
1	exp orthodontic appliances, functional/ or "Herbst appliance" .mp.	1608
2	exp Temporomandibular joint/	6619
3	"TREATMENT EFFECTS" .mp.	3328
4	1 and 2	72
5	1 and 3	37
6	4 or 5	107
7	Limit 6 to (human and English language)	80

mastication. Because the effect on TMJ morphology can differ between fixed and removable functional appliances, this study was restricted to the Herbst appliance. To ensure morphologically accurate representation of TMJs during treatment, we limited our study to MRI, CT scans, and tomography (axially or horizontally corrected).[15-19] This eliminated transcranial and transpharyngeal TMJ radiographs, which have been shown in the literature to be inaccurate.[20,21]

To find the relevant articles appropriate for this review, we conducted a search in Medline from 1966 to the first week in October 2001. Table I shows the search history with the search terms and how they were combined.

This search strategy was also used for the following databases: Best Evidence, 1991 to March/April 2001; Cochrane Database of Systematic Reviews, second quarter of 2001; and Embase, 1988 to September 2001. The abstracts of related articles were reviewed to search for any applicable studies that might have been missed. The reference lists of the retrieved articles were hand searched.

Eligibility was determined by reading the reports identified by the search. Two authors (K.P. and P.W.M.) read all reports, and agreement was reached by discussion.

RESULTS

The Medline search identified 80 studies; no additional studies were identified by the secondary searches. Of the 80 studies identified, 12 were directly related to the review topic, but only 5 of them met the selection criteria. No randomized controlled studies were identified. All studies included in this review used internal controls with pretreatment and posttreatment imaging of each patient. One study used horizontally corrected tomograms. The remaining 4 studies used MRI. The samples reported in the 4 MRI studies overlapped; therefore, they were considered to represent a single study. The 5 studies included in the results of our review are summarized in Table II. The remaining 7 studies, with the reasons for rejection, are listed in Table III.

Glenoid fossa remodeling

Of the 5 acceptable studies, only 2 of the MRI studies evaluated the effects of the Herbst appliance on the glenoid fossa. The study sample of Ruf and Pancherz[22] in 1998 was included in the larger sample reported in their 1999 study.[23] The sample included consecutively treated patients with Class II malocclusion and full permanent dentition. Based on hand-wrist radiographs to determine skeletal maturity, the sample was subdivided into adolescents (12 girls, 13 boys) with a mean age of 12.8 years (range, 11.4-15.7) and young adults (19 girls, 4 boys) with a mean age of 16.5 years (range, 13.6-19.8). Parasagittal MRIs were obtained pretreatment, shortly after appliance placement, 6 to 12 weeks after appliance placement, and shortly after appliance removal. Average Herbst treatment time was 7 months. Slice depth of the MRI images chosen for assessment of remodeling was not stated. The MRIs were visually inspected for evidence of remodeling. There was no report of investigator blinding or method error for remodeling.

Ruf and Pancherz reported "signs of remodeling" in the TMJs of 36 of the 50 adolescents and 22 of the 28 young adults. Remodeling was described as bone apposition, being most intensive at the inferior part of the glenoid spine and less pronounced toward the top of the spine. They describe a slight anteclination of the spine. Remodeling was reported to be more pronounced in the young adult sample than in the adolescent group.

Condyle remodeling

Of the 5 studies that met the selection criteria, only 3 examined the effects of Herbst treatment on the morphology of the condyle. The study sample of Ruf and Pancherz[22] in 1998 was included in the larger sample reported in their 1999 study.[23] The sample included consecutively treated patients with Class II malocclusion and full permanent dentition. Based on hand-wrist radiographs to determine skeletal maturity, the sample was subdivided into adolescents (12 girls, 13 boys) with a mean age of 12.8 years and young adults (19 girls, 4 boys) with a mean age of 16.5 years. Parasagittal MRIs were obtained pretreatment, shortly after appliance placement, 6 to 12 weeks after appliance placement, and shortly after appliance removal. Average Herbst treatment time was 7 months. Slice depth of the MRI images chosen for assessment of remodeling was not stated. The MRIs were "visually inspected" for evidence of remodeling. There was no

Table II. Studies included for review

Authors/date	*Number of patients*	*Study design*
Croft et al[27]/1999	37	Clinical trial, horizontally corrected tomographs, internal control
Ruf and Pancherz[24]/2000	62	Prospective, longitudinal, clinical MRI study, internal control
Pancherz et al[12]/1999	15	Prospective, longitudinal MRI clinical trial, internal control
Ruf and Pancherz[23]/1999	39	Prospective, longitudinal MRI clinical trial, internal control
Ruf and Pancherz[22]/1998	15	Prospective MRI clinical trial, internal control

Table III. Excluded studies

Authors/date	*Number of patients*	*Reason for exclusion*
Paulsen and Karle[47]/2000	2 treated	Case report
Ruf and Pancherz[13]/1998	20 treated no control	No control, MRIs taken posttreatment and compared with norms in literature
Paulsen et al[48]/1998	1 treated	Case report looking at scinigraphy of TMJ
Paulsen[49]/1997	100 treated	Transpharyngeal radiographs were used to assess TMJs before, during, and after treatment
Paulsen et al[50]/1995	1 treated	Case report (using CT scan of TMJ) in late puberty
Cobo et al[51]/1993	14 patients with combined treated and control groups	Standardized transcranial oblique lateral radiographs were used
Hansen et al[9]/1990	19 treated no control	No control, only posttreatment tomographs taken and compared with norms from literature

report of investigator blinding or method error for remodeling.

At 6 to 12 weeks after appliance placement, an area of increased signal intensity in the posterosuperior region of the condyle was reported in the TMJs of 48 of the 50 adolescents and 26 of the 28 young adults.[23] A double contour described as a bone marrow demarcation line was identified in the young adults but not in the adolescents. The remodeling zone persisted at appliance removal in the MRIs of the young adult group only.

In a third study, Ruf and Pancherz[24] reported 62 consecutive Class II patients (35 girls, 27 boys) treated with the Herbst appliance. Although not stated, it appears that this study included the samples used in the previous studies. Pretreatment, immediately posttreatment, and 1-year posttreatment MRIs were used to examine the condyles. There was no report of examiner blinding, and the method error for visual examination of the films was not reported. Ruf and Pancherz reported "osteoarthritic changes or deviations in form" in 17 of 128 (13.3%) TMJs pretreatment and in only 4 of 112 (3.6%) TMJs having changes at 1 year posttreatment. "Osteoarthritic changes" and "deviations in form" were not defined.

Condylar position

Of the 5 studies that met the inclusion criteria, 3 examined the position of the condyle with Herbst treatment.

Ruf and Pancherz's 1998[22] study sample was included in the larger sample in their 2000 study.[24] Although the 2 studies included the same patient group, they will be discussed separately. The 1998 study[22] reported parasagittal MRIs obtained pretreatment, shortly after appliance placement, 6 to 12 weeks after placement, and shortly after appliance removal. They traced and analyzed the MRIs with a method described by Kamelchuk et al[25] and then used the anterior and posterior joint spaces to calculate a *joint space index*. The 2000 study[24] reported on parasagittal MRIs taken pretreatment, posttreatment, and more than 1 year posttreatment. A joint space index according to the method described by Mavreas and Athanasiou[26] was calculated. Although there was no report of examiner blinding, the method error was reported in both studies. The 1998 study[22] reported a joint space index method error of 7.5 to 9.1 and the 2000 study[24] reported a joint space index error of 7.2 to 11.5.

The 1998 Ruf and Pancherz[22] study reported only pretreatment and posttreatment condyle positions. They concluded "that condylar position was, on average, unaffected by Herbst treatment." Ruf and Pancherz's 2000 study[24] pooled the left and right joint data. They reported that the condyle was significantly more anteriorly positioned immediately posttreatment (medial and lateral MRI slices only), but, at 1 year posttreatment, the "condyle returned to its original position." There was great individual variation in joint space index values, with the SD within groups far exceeding the mean differences between groups. Furthermore, the reported method error was larger than the mean condyle position change.

In 1999, Croft et al[27] also studied condyle position in response to Herbst treatment. They evaluated 40 consecutively treated (11 months with Herbst followed by at least 6 months with a positioner appliance) Class II patients (24 girls, 16 boys) in the mixed dentition. Horizontally corrected tomographs were available for 37 of the 40 patients and were evaluated at pretreatment (T1), posttreatment (T2), and postretention (T3, average of 2.7 years posttreatment). Each tomogram was traced, and the posterior and anterior joint spaces were determined with a joint space analysis described by Pullinger and Hollender.[21] Method error for tomograph measurement was reported (0.3-0.4 mm). There was no significant change in condyle position during the treatment period (T1-T2). However, in the posttreatment period (T2-T3), there was a significant decrease in posterior joint space (0.7 mm). An overall (T1-T3) decrease in posterior joint space of 0.4 mm ($P < .05$) was reported.

Temporomandibular disc position

From the 5 studies that met inclusion criteria, 2 evaluated TMJ disc changes induced by the Herbst appliance.

The first study by Pancherz et al[12] in 1999, evaluated changes in the articular disc position by examining serial MRIs of 15 consecutively treated Class II patients. All films were evaluated with a modification of the method described by Bumann et al.[28] A disk position index based on a ratio of displacement of the intermediate zone to disc length was also calculated. There was no report of examiner blinding. Method error was reported based on 2 MRI surveys of 5 normal volunteers. Error was reported for measurement location of disc intermediate zone and disc length. Error for the disk position index, which combines disc length and disc displacement, was not reported. Study data were presented graphically. With the reference system chosen to identify disc position for this study, there was significant disc retrusion (all slices of the right joint, $P < .01$, and the lateral slice of the left joint, $P < .001$) on initial appliance placement, but, over the whole examination period (including retention), a significant disk retrusion ($P < .05$) was seen only in the lateral MRI slice of the left joint. Extreme caution should be used in interpreting the results of this study. There was large variation in disc position index scores between patients, including reports of large method error.

In 2000, Ruf and Pancherz[24] published a follow-up study of 56 patients treated with the Herbst appliance. The sample included a previously reported sample.[12] At each of the pretreatment, posttreatment, and 1-year follow-up times, 5 parasagittal MRI slices (open and closed mouth) were obtained for each TMJ. Three of the 5 MRI slices were chosen to represent the medial, central, and lateral components of the joints. Three different methods of evaluating disc position were used, consisting of the twelve-o'clock, the posterior-band, and the intermediate-zone criteria. There was no report of examiner blinding, but method error was reported for all 3 techniques. Partial disc displacement was defined as disc displacement in either the medial or the lateral MRI slice but not in the other 2. Total disc displacement was defined as disc displacement in at least 2 of 3 MRI slices. A disc was classified as displaced if at least 2 of the 3 methods of evaluating disc position indicated a displacement. The technique used to evaluate disc position in the open-mouth MRI slices was not described. It appears that disc position was determined by visual inspection and categorized as normal or displaced. Joints were categorized as partial disc displacement with reduction (PDDwR), total disc displacement with reduction (TDDwR), and total disc displacement without reduction (TDDnoR).

Twenty-two joints of 13 patients (21%) had varying severity of disc displacement (7 PDDwR, 6 TDDwR, 9 TDDnoR) before treatment. Immediately after Herbst placement and at the end of treatment, all joints with PDDwR and 3 joints with TDDwR had normal disc position. The remaining 3 joints with TDDwR progressed to TDDnoR. No disc repositioning was achieved in the joints with pretreatment TDDnoR.

One year after Herbst removal, 4 joints with pretreatment PDDwR had normal disc position, and 1 joint had progressed to TDDwR. The 1-year posttreatment MRI was unavailable for the other 2 joints. Of the 3 joints with pretreatment TDDwR, which demonstrated correct disc position after Herbst treatment, 1 had PDDwR, and 2 had TDDwR at 1-year posttreatment. All joints with TDDnoR improved during the posttreatment year.

Despite acknowledging lack of total agreement in disc classification between the 3 assessment techniques, Ruf and Pancherz detail the findings of the intermediate-zone technique. There were large variations in measured disc position between patients and between MRI slices in the same joint. From pretreatment to posttreatment, average disc position was more retrusive ($P < .001$). At 1 year posttreatment, the average disc positions for the lateral and central MRI slices were still retrusive ($P < .05$). However, the reported intermediate-zone mean differences were smaller than the reported method error.

DISCUSSION

Published cephalometric research has reported anterior and inferior relocation of the glenoid fossa, minor increased mandibular length, and posterior redirection of condylar growth associated with Herbst treatment.[1,4,22-24,27,29] These changes could occur through intra-articular osseous or soft tissue remodeling. Potential remodeling could include apposition on the posterior-superior aspect of the condyle, apposition in the superior aspect of the fossa, and inferior-posterior condylar repositioning in the fossa.

Articles reviewed for this study do not provide conclusive evidence of glenoid fossa or condylar remodeling. The difficulty in using MRI data to quantify remodeling was pointed out by Ruf and Pancherz.[22] Quantitative analysis with superimposition of MRIs was attempted but abandoned because of changes in plane orientation between imaging acquisitions. Various criteria have been suggested to critically appraise the validity of observational studies.[30-32] The qualitative assessment in the 4 MRI studies[12,22-24] does not include reports of investigator blinding or method error. Blinding could have been achieved by randomly assigning a code number to each MRI, with the examiner having access to the code after data collection was complete. Study design would have been improved through multiple observations and reporting method error (κ statistic). Use of internal control also limits the validity of these studies. Although Ruf and Pancherz[22] suggested that a true untreated control would be unethical, other prospective, randomized, controlled studies have been reported for other Class II treatment modalities.[33-35]

Croft et al[27] demonstrated only small changes in condyle position associated with Herbst treatment. In view of the large individual variability in condyle position, the average change identified in this study was not clinically significant.[36,37] The magnitude of these changes does not account for the overall cephalometric changes reported with Herbst treatment. MRI data in the 4 studies reviewed here do not provide conclusive evidence about condylar position relative to the glenoid fossa. The same methodological issues discussed for osseous remodeling apply.

Disc position and disc morphology are important considerations in establishing the clinical appropriateness of Herbst appliance therapy. The prevalence of pretreatment internal derangement (disc displacement) reported by Ruf and Pancherz[24] was less than that reported by Nebbe and Major.[38] The difference in prevalence of internal derangement might be related to different measurement approaches. Nebbe et al[39] validated a technique to objectively describe disc displacement and disc deformation related to the primary load-bearing region of the joint. Ruf and Pancherz[24] used a combination of 3 different approaches and pointed out lack of agreement among them. The first 2 approaches assessed positioning of the posterior band of the disc, which has questionable functional relevance. The intermediate-zone criterion approach uses arbitrary landmarks (condyle and tuberculum articulare midpoint) and has a large method error compared with the approach of Nebbe et al.[39]

Despite the limitations associated with the Ruf and Pancherz[24] study, it appears that Herbst treatment is not contraindicated by partial disc displacement with reduction. There was consistent improvement in disc position in these patients. This is supported in the current literature; several studies have shown anterior repositioning appliances to be somewhat effective in treating anterior disc displacement with reduction.[40-42]

There was progression in severity of internal derangement in half of the joints with total disc displacement with reduction. Without random allocation with an untreated control, it is impossible to state whether it was the result of appliance therapy or a natural progression.[7]

Use of the Herbst appliance will dramatically alter functional loading patterns. Osseous response to altered functional loading (condyle position) remains unknown. Although the Ruf and Pancherz study[24] presented data to support their conclusion that Herbst treatment "reduced structural condylar bony change," the basis for their description of "osteoarthritic changes" and "deviation in form" was not given. There were no reports of blinding to reduce bias and method errors for these observations. Kinniburgh et al[43] and Major et al[44] have not identified substantive TMJ osseous abnormalities in adolescents with disc displacement. Altered craniofacial development associated with TMJ disc status has been described.[45,46] Response to Herbst treatment in patients with disc abnormalities cannot be assumed to be the same in as patients with normal joints.

Future research should involve prospective randomly controlled clinical trials. Pretreatment and posttreatment MRI and tomography should be included to document the effect of Herbst therapy on joint morphology and to assess its effectiveness for Class II correction in patients with disc abnormalities. Axially corrected tomography provides a more suitable assessment of osseous remodeling than MRI of the TMJ. Standardization of imaging for identifying disc position in all regions of the joint can be carried out with MRI.

Three-dimensional reformatting is also available to assess patterns of disc displacement.

CONCLUSIONS

The following conclusions about the effect of Herbst appliance therapy on TMJ morphology can be made:

1. Changes in condyle position relative to the glenoid fossa are minor and not clinically significant.
2. The nature of condylar and glenoid fossa remodeling has not been established.
3. Disc position change has not been established.

The relevance of disc status in Herbst treatment has been highlighted by existing research. There is a need for randomized controlled studies with serial MRI and tomography to establish short- and long-term effects of Herbst treatment on TMJ osseous and soft tissue morphology.

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