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Does Bite-Jumping Damage the TMJ? A Prospective Longitudinal Clinical and MRI Study of Herbst Patients

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ABSTRACT

The aim of this prospective longitudinal study of 62 consecutively treated Class II malocclusions was to determine whether bite-jumping causes temporomandibular disorders (TMD). The function of the temporomandibular joint (TMJ) was assessed anamnestically, clinically, and by means of magnetic resonance images (MRIs) taken before (T1), after (T2), and 1 year after (T3) Herbst treatment. Average treatment time with the Herbst appliance was 7.2 months. In all subjects, Herbst treatment resulted in a Class I or overcorrected Class I dental arch relationship. Thereafter, treatment was continued with a multibracket appliance. The condyle was positioned significantly forward during treatment but returned to its original position after removal of the Herbst appliance. A temporary capsulitis of the inferior stratum of the posterior attachment was induced during treatment. Over the entire observation period from before treatment to 1 year after treatment, bite-jumping with the Herbst appliance: (1) did not result in any muscular TMD; (2) reduced the prevalence of capsulitis and structural condylar bony changes; (3) did not induce disc displacement in subjects with a physiologic pretreatment disc position; (4) resulted in a stable repositioning of the disc in subjects with a pretreatment partial disc displacement with reduction; and (5) could not recapture the disc in subjects with a pretreatment total disc displacement with or without reduction. A pretreatment total disc displacement with or without reduction did not, however, seem to be a contraindication for Herbst treatment. In conclusion, bite-jumping using the Herbst appliance does not have a deleterious effect on TMJ function and does not induce TMD on a short-term basis.

KEY WORDS: MRI, TMJ, TMD, Class II, Herbst appliance, Orthodontic treatment, Dentofacial orthopedics, Bite-jumping.

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INTRODUCTION Return to TOC

The role of orthodontic treatment as a contributing factor for the development of temporomandibular disorders (TMD) has been debated with increasing emphasis since the late 1980s. Although some studies suggest that orthodontic treatment increases the risk for developing TMD,[1–8] 2 recent review articles[9–10] concluded that, based on today's knowledge, orthodontic treatment does not increase or decrease the odds for developing TMD later in life. On the other hand, some studies have shown a lower prevalence of signs and symptoms of TMD after orthodontic treatment.[11–18] Olsson and Lindqvist[19] even concluded, "orthodontic treatment can, to some extent, prevent further development of and cure TMD." Only a limited number of studies are prospective[12,14,16–25] which might account for some of the controversy in the literature.

Since 1979, modern dentofacial orthopedics has used the Herbst bite-jumping appliance[26] with great success in the treatment of Class II malocclusions.[27–34] Due to the interference of the Herbst appliance with normal stomatognathic function,[25,35] bite-jumping (defined as a change in sagittal intermaxillary jaw relationship by anterior displacement of the mandible) has been blamed of causing TMD. These statements are mainly personal opinions. The only scientific publication supporting this viewpoint is a report by Foucart et al[36] in which 3 of 10 Herbst patients developed a disc displacement in 1 or both joints during treatment.

On a long-term basis, no structural bony changes of the TMJ are detectable after Herbst treatment[37] nor is the prevalence of the signs and symptoms of TMD higher in Herbst patients than in the general population several years after treatment.[38] As there seems to be substantial controversy on this issue, we analyzed the effects of bite jumping on the function of the TMJ in consecutive patients treated with the Herbst appliance.

MATERIALS AND METHODS Return to TOC

Subjects

Beginning in 1995, the first 70 patients with a Class II malocclusion in the permanent dentition applying for treatment at the Department of Orthodontics, University of Giessen were selected for Herbst treatment. Eight of the patients dropped out of the study reducing the study population to 62 patients (35 females and 27 males). The mean pretreatment age of the patients was 14.4 years (SD = 2.1 yrs) and the treatment time with the Herbst appliance was a mean of 7.2 months. All patients had a fixed cast splint Herbst appliance.[39] At start of treatment, the mandible was advanced to an incisal edge-to-edge position. Herbst treatment resulted in Class I or overcorrected Class I dental arch relationships in all subjects. Immediately after removal of the Herbst appliance, treatment was continued with a multibracket appliance in both jaws in all but 2 patients. Due to bad oral hygiene, the treatment was continued with an activator in these 2 patients.

Anamnestic findings

The anamnesis focused on sounds and pain from the TMJ, pain from the jaw musculature, the incidence of headaches, parafunction, biting and chewing difficulties, and restrictions of jaw movements. Questions were asked orally and the answers were recorded as yes or no.

Manual functional analysis

A clinical examination was performed according to the principles of the Manual Functional Analysis (MFA)[40–43] that includes the following registrations:

- Active jaw movements for the assessment of the mandibular movement capacity.
- Passive jaw movements and joint play evaluation for the diagnosis of clinical and subclinical soft tissue lesions.
- Isometric contractions of the jaw muscles for the diagnosis of muscular lesions.
- Dynamic tests for the differentiation of clicking.

The anamnesis and the MFA were performed at the following treatment stages:

Before (T1): Before the start of Herbst treatment (mean = 68 days before)

Start: At the start of treatment, 1 week after the Herbst appliance was placed (mean = 8 days after appliance placement)

6 Weeks: Six weeks after the Herbst appliance was placed (mean = 49 days)

3 Months: Three months after the Herbst appliance was placed (mean = 95 days)

After (T2): After Herbst treatment, when the appliance was removed (mean = 1 day)

6 Months: Six months after removal of the Herbst appliance (mean = 198 days)

1 Year (T3): One year after removal of the Herbst appliance (mean = 405 days)

The MFA, which was performed at start, 6 weeks, and 3 months, was done after temporarily removing the telescopic mechanism of the Herbst appliance.

Magnetic resonance imaging

Magnetic resonance images of the TMJ were obtained by means of a Magnetom Expert® 1.0 Tesla (Siemens AG, Erlangen, Germany) equipped with TMJ coils for simultaneous imaging of the left and right joints. The MRI protocol included closed mouth proton density weighted spin echo sequences (TR 2000/Matrix 252 × 256/FOV 150 × 150) in parasagittal (TE 40) and coronal (TE 15) orientation, as well as open mouth parasagittal T2-weighted sequences (TR 4500/TE 128/Matrix 230 × 256/FOV 201 × 203). All closed mouth images were taken with the teeth in habitual occlusion. Five slices of each joint were made. Slice thickness was 3 mm with no interslice gap. The parasagittal MRIs were taken perpendicular and the coronal MRIs were taken parallel to the long axis of the condyle.

The MRIs where taken at the following treatment stages:

Before (T1): Before the start of Herbst treatment (mean = 68 days)

After (T2): After Herbst treatment, when the appliance was removed (mean = 15 days after appliance removal)

1 Year (T3): One year after removal of the Herbst appliance (mean = 414 days)

The closed mouth parasagittal MRIs were analyzed visually and metrically, whereas the coronal and open mouth images were analyzed only visually. In the analysis of the parasagittal MRIs, the lateral, central, and medial slices of each joint were evaluated separately. For the metric analysis, all MRIs were traced. In order to facilitate comparison of the MRIs within a series and between individuals, all images were taken at the same magnification.

Articular disc position

Closed mouth MRIs (parasagittal). The sagittal position of the articular disc in the closed mouth position was assessed by 3 different approaches, 2 of them describing the posterior band location, and the third evaluating the intermediate zone location of the disc in relation to the condyle.

12 o'clock criterion. The MRIs were evaluated visually using the “12 o'clock criterion”.[44] The disc position was considered normal if the thickest part of the posterior band was situated between the 11 and 1 o'clock positions. Discs with the thickest part of the posterior band located anterior or posterior to this position were considered displaced.

Posterior band criterion. The position of the posterior band (PB) was measured (Figure 1) using the method described by Drace and Enzmann.[45] The normal range for the “Drace and Enzmann angle” as described by Silverstein et al,[46] is 18.7° to −25.7° (Ideal value = −3.5°). A positive value indicates an anterior disc position, whereas a negative value indicates a posterior disc position.

Intermediate zone criterion. The location of the intermediate zone (IZ) was measured (Figure 2) using the method described by Bumann et al.[47] The normal range for the IZ location as described by Vargas-Pereira[48] is 1.7 to −1.1 mm (Ideal value = 0.3 mm). A positive value indicates an anterior disc position, whereas a negative value indicates a posterior disc position.

Deviations from a normal disc position were defined as: (1) partial disc displacement—the disc was displaced in 1 slice (either the lateral or medial) but exhibited a physiologic position in the 2 other slices; and (2) total disc displacement—the disc was displaced in at least 2 of the slices.

Closed mouth MRIs (coronal). On the coronal MRIs, the disc position was considered normal if the articular disc was interposed between the condyle and the temporal bony surface covering the condyle over its entire medio-lateral extension. Deviations from a physiologic disc position were classified only as an existing or nonexisting transverse displacement.

Open mouth MRIs (parasagittal). The disc position in the open mouth position was considered normal if the IZ of the disc was interposed between the condyle and the tuberculum articulare throughout all slices. In cases of disc displacement in the closed mouth position, the analysis of the open mouth MRIs helped assess the degree of disc reduction. Patients were classified as: (1) disc displacement with reduction—a normal disc position was attained upon mouth opening throughout all slices; or (2) disc displacement without reduction—no normal disc position could be attained upon mouth opening.

According to the above-mentioned criteria, 3 classes of disc displacement were defined: (1) partial disc displacement with reduction (PDDwR); (2) total disc displacement with reduction (TDDwR); and (3) total disc displacement without reduction (TDDnoR).

Disc position groups. According to the disc position in the closed mouth parasagittal MRIs the subjects were divided into 5 groups: (1) Normal—joints with a normal disc position in all slices during the whole observation period as indicated by all 3 criteria (12 o'clock, PB, IZ);

(2) posterior disc displacement tendency (PDDT)—joints for which only 1 of the criteria indicated a posterior position of the disc; (3) anterior disc displacement tendency (ADDT)—joints for which only 1 of the criteria indicated an anterior position of the disc; (4) posterior disc displacement (PDD)—joints for which at least 2 of the criteria indicated a posterior position of the disc; and (5) anterior disc displacement (ADD)—joints for which at least 2 of the criteria indicated an anterior position of the disc. If at any time during the observation period the disc position in any of the slices of a joint deviated from normal, the joint was assigned to the appropriate group 2 through 5.

Condylar position

The condylar position was assessed metrically (Figure 3) on the parasagittal MRIs in the closed mouth position by means of a method described by Mavreas and Athanasiou.[49] The anterior (ant) and posterior (post) joint spaces were evaluated and a Joint Space Index (JSI) was calculated:

The physiologic range for the condylar position as described by Vargas-Pereira[48] is an index value of 21.1 to− 32.5. A positive value indicates an anterior condylar displacement and a negative value a posterior condylar displacement.

Structural bony changes

All MRIs from the different treatment stages were analyzed visually with respect to possible structural bony changes of the condylar or temporal surfaces, deviations in form (DIF), or both.

STASTICAL METHODS Return to TOC

For the MRI measurements, the arithmetic mean (Mean) and the standard deviation (SD) were calculated to indicate general tendencies. To analyze possible differences between right and left joints as well as treatment changes, Student's *t*-tests for paired samples were applied. Student's *t*-tests for unpaired samples were performed to assess group differences for disc and condyle positions. The possible interrelations between disc and condyle position were assessed by means of the Pearson correlation coefficient. A correlation below 0.3 was considered low, between 0.3 and 0.7 moderate, and above 0.7 high. The statistical significance was determined at the 0.1% (***), 1% (**) and 5% (*) levels of confidence. A confidence level greater than 5% was considered statistically not significant (ns).

For the assessment of the method error of the measurements, 10 MRIs of randomly selected subjects were traced and analyzed twice. The following formula was used for the method error (ME) calculation:[50]

where d is the difference between 2 measurements of a pair and n is the number of subjects.

The method error varied between 3.7° and 6.6° for the PB criterion, 0.2 mm and 0.6 mm for the IZ criterion, and 7.2 and 11.5 for the JSI, depending on the side and slice evaluated.

RESULTS Return to TOC

Anamnestic findings

Before treatment (T1), 5 patients (Cases 2, 3, 9, 39, and 61) reported intermittent pain from the TMJ, 1 patient reported frequent weekly headaches (Case 5), 6 patients indicated clicking of the TMJ (Cases 3, 9, 14, 50, 53, and 61), and 1 patient (Case 39) demonstrated limited mouth opening. The remaining 53 patients reported no signs or symptoms of TMD.

Clicking of the TMJ was reported by Case 3 during treatment and by Case 44 one year after treatment. None of the patients reported pain from the TMJ or the masticatory musculature during (start, 6 weeks, 3 months), after (T2), or 6 months or 1 year after (T3) Herbst treatment.

Manual functional analysis

Manual functional analysis (MFA) data were available at all examination times for at least 57 of the 62 patients. Inflammatory conditions of the temporomandibular joint are subdivided into synovitis and capsulitis.[51] For the purpose of this study; “capsulitis” refers to intracapsular inflammation primarily affecting the posterior attachment. The term “posterior attachment” is used as described by

Scapino[52,53] and refers to the vascular and innervated tissue lying behind the articular disc.

Capsulitis. No capsulitis of the superior stratum of the posterior attachment or the structures of the joint capsule could be found at any time during the observation period. The only affected structure was the inferior stratum of the posterior attachment. The lateral part of the inferior stratum showed a higher prevalence of capsulitis than the central part. In the following paragraph, only the prevalence rate of capsulitis of the lateral part of the inferior stratum will be given.

Before treatment (T1), a capsulitis of the inferior stratum was found in 21 patients with 15 right and 15 left joints (24%) affected. Five of these patients reported pain from the TMJ, thus exhibiting a clinical capsulitis, while all the other patients had only subclinical symptoms. After 1 week of Herbst treatment, 98% of the joints showed a capsulitis of the inferior stratum of the posterior attachment. The prevalence of the capsulitis increased to 100% of the joints after 6 weeks. Thereafter, a slow decrease to 96% after 3 months and to 88% after removal of the Herbst appliance (T2) was seen. Both the prevalence and the intensity of the capsulitis changed during the course of treatment. The joints were most sensitive 1 week and 6 weeks after the start of Herbst treatment. Thereafter, the sensitivity decreased continuously. During the first 6 months after removal of the Herbst appliance, the prevalence of capsulitis decreased to an average of 32% of the joints. One year after treatment (T3), only 5 patients exhibited a capsulitis with 4 right and 4 left joints (7%) being affected. Over the whole observation period (T1–T3), the capsulitis prevalence decreased from 24% to 7% of the joints. During the period from start of Herbst treatment to 1 year after Herbst treatment, none of the patients reported pain from the TMJ or the masticatory musculature; however, a pain sensation could be provoked upon passive joint loading. Thus, the capsulitis diagnosed during this period was only subclinical.

Disc displacement. Clinical signs of disc displacement were found in 9 patients (11 joints) before (T1) treatment (Cases 1, 2, 9, 14, 26, 39, 44, 47, and 50). Two joints exhibited a partial disc displacement with reduction (PDDwR), 5 joints a total disc displacement with reduction (TDDwR), and 4 joints a total disc displacement without reduction (TDDnoR). During treatment, the TDDnoR in Case 3 temporarily reduced. After treatment (T2), signs of disc displacement could only be detected clinically for 1 joint (Case 44) in which the pretreatment TDDwR prevailed. One year after treatment (T3), 2 affected joints (Case 44) with a TDDwR were identified.

Crepitus. Crepitus was found in 4 joints (Cases 2 and 39) before treatment (T1), in 1 joint (Case 2) after treatment (T2,) and 3 joints (Cases 3 and 39) 1 year after treatment (T3).

Other findings. Clicking of the lateral ligament was diagnosed in 5 patients (Cases 4, 17, 18, 53, and 60) at varying times during treatment. This clicking was not considered pathologic. Due to a structural change of the joint surface (cartilage hypertrophy), 1 patient (Case 21) exhibited clicking in 1 joint before treatment (T1). This clicking could not be detected after (T2) and 1 year after treatment (T3).

Magnetic resonance imaging

Magnetic resonance imaging data were available for 62 patients before treatment, 61 patients immediately after treatment, and 56 patients 1 year after treatment. The distribution of the study population and the number of MRI slices that could be evaluated in the 5 disc position groups is shown in Table 1.

Articular disc position. As described in the Method section, 3 different criteria were used to evaluate the position of the articular disc in the MRI. The results revealed that the different criteria did not always agree. Thus, in our analysis, a disc was only classified as displaced if at least 2 of the evaluation criteria indicated a displacement.

Individual findings. Before treatment (T1), 22 joints of 13 patients (Cases 1–3, 9, 10, 14, 25, 26, 39, 44, 45, 47, and 50) exhibited varying degrees of anterior disc displacement. Seven joints showed a PDDwR, 6 joints a TDDwR, and 9 joints a TDDnoR. A transverse displacement component was seen in 1 of the joints with PDDwR and 4 joints with TDDwR.

Immediately after treatment (T2), when the appliance was removed, all joints with a pretreatment PDDwR and 3 of the joints with a pretreatment TDDwR exhibited a normal disc position. In the remaining 3 joints with pretreatment TDDwR, the degree of displacement had progressed to a TDDnoR. In joints with a pretreatment TDDnoR, no repositioning could be achieved.

One year after removal of the Herbst appliance (T3), a stable repositioning of the disc could be seen in 4 joints with pretreatment PDDwR, while the disc displacement in the 1 joint progressed to a TDDwR. For 1 patient with pretreatment PDDwR (2 joints), no MRI was available 1 year after treatment. In the joints with pretreatment TDDwR, no stable repositioning of the disc could be achieved, as the 3 joints with a repositioning after treatment (T2) relapsed either to a TDDwR (2 joints) or a PDDwR (1 joint). In joints with a pre- and post-treatment TDDnoR, no repositioning could be achieved.

Sample findings. The analysis of the disc position for the whole study population (Table 2) revealed no statistically significant difference between left and right joints for any of the examination times. Thus, right and left joints were pooled for further analysis. Disc positions were found to vary greatly for all 3 slices and at all 3 times of examination. When comparing the disc position with the "ideal" value for the PB (−3.5 degrees) and IZ (0.3 mm) criterion, the average disc position in the sample was slightly anterior for all 3 slices before treatment.

From before to after treatment (T1–T2; Table 3) the disc attained a more retrusive position ($P < .001$) and tended to return to its original position thereafter (T2–T3; $P < .001$, only PB criterion). When looking at the total observation period (T1–T3), the disc position was unchanged according to the PB criterion and attained a more retrusive position in the lateral and central slice ($P < .05$) according to the IZ criterion.

The comparison of the 5 disc position groups (Tables 4 and 5) revealed that the disc in the PDDT and PDD groups was located more posterior, compared to the Normal group. This was true for all 3 MRI slices at all examination times in the PDDT group ($P < .01$, PB and IZ criterion). Due to the small sample size (n = 4) in the PDD group, no statistical group comparison was performed for this group.

Compared to the Normal group, the disc in the ADDT group was located more anteriorly according to the PB and IZ criteria. This was true for all 3 MRI slices at each of the examination times. However, the difference between the groups was statistically significant ($P < .05$) only for the PB criterion before treatment (all slices) and 1 year after treatment (lateral slice) and for the IZ criterion ($P < .05$) before treatment (central and medial slices)

The largest differences in disc position were found between the Normal and ADD group. The disc was located more anteriorly in the latter. This was true ($P < .001$) for all 3 MRI slices and all 3 examination times.

The largest changes in disc position were found from before treatment to after treatment (T1–T2; Table 6). During this period, the disc attained a more posterior position in all 5 disc position groups. Except for the ADD group the position changes were statistically significant for all 3 slices ($P < .05$) as indicated by either the PB or IZ criterion or both. In the ADD group, only the PB criterion of the medial slice reached statistical significance ($P < .05$).

During the period from immediately after treatment to 1 year after Herbst treatment (T2–T3), the disc became more anteriorly positioned. This was true for all slices of the Normal and the ADD groups, and for the lateral and medial slices of the PDDT group. However, except for the IZ criterion of the medial MRI slice of the ADD group, only the PB values changed significantly ($P < .05$).

During the total observation period (T1–T3), there was a tendency towards a relatively more posterior disc position compared to its original location in the Normal, PDDT, PDD and ADDT groups. However, this change reached statistical significance only for the central slice of the PDDT group ($P < .001$, IZ criterion), and the central ($P < .05$, PB-criterion) and medial slices ($P < .05$, IZ-criterion) of the ADDT group.

Condylar position. Condylar position was found to vary greatly between the 3 MRI slices and at all 3 times of examination (Table 7). As no statistically significant difference existed between the right and left joints, the 2 sides were pooled for further statistical analysis. On average, the condyle was positioned slightly anterior in the fossa both before (T1) and 1 year after treatment (T3). From before to immediately after treatment (T1–T2), the condyle became significantly more anteriorly positioned ($P < .001$) for the lateral and medial MRI slices (Table 8). After treatment (T2–T3), however, the condyle returned to its original position. Therefore, when looking at the total observation period from before to 1 year after treatment (T1–T3) condylar position was on average unchanged.

Condylar position in the disc position groups. The condylar position was assessed separately for each of the 5 disc position groups (Table 9). Compared to the Normal group, condylar position in the PDDT and PDD groups tended to be more anteriorly placed. Statistically significant differences were only found for the medial slice before treatment (T1; $P < .01$) and the lateral slice after treatment (T2; $P < .05$) in the PDDT group. On the other hand, in the ADDT and ADD groups condylar position tended to be more posterior than in the Normal group. However, the differences were significant only for the lateral, central, and medial MRI slices of the ADD group at T1 ($P < .05$).

When comparing the different examination periods (Table 10), the same trend was seen for condylar position changes for the different disc position groups as for the whole sample. The largest changes were found for the period from before to immediately after treatment (T1–T2) for all 3 slices ($P < .01$) of the ADD group. During the entire observation period (T1–T3), statistically significant changes where only found in the Normal and the ADD groups. In the Normal group, the condyle attained a slightly more posterior position in the central slice ($P < .05$) and a slightly more anterior position in the medial slice ($P < .05$). For the ADD group, a more anterior condylar position ($P < .05$) was seen 1 year after treatment (T3) for the central and medial MRI slices.

Interrelation between disc position and condylar position. For the whole sample, a moderate ($r = -0.30$ to -0.49; $P < .001$) reverse interrelation between the position of the disc and the condyle was found for both the PB and IZ criteria at T1. This implies that a more posterior condylar position was associated with a more anterior disc position and vice versa. No interrelation between disc and condylar position could be found either immediately after (T2) or 1 year after treatment (T3).

The differentiation between the disc position groups underlined the findings for the whole sample in showing a moderate to high ($r = -0.30$ to -0.75) inverse relationship between disc and condyle position for 28 of 72 calculated correlations. This interrelation was statistically significant for the PB criterion for all 3 MRI slices of the Normal group after treatment (T1; $P < .05$), the lateral and medial slices of the PDDT group before treatment (T1; $P < .05$), and the lateral slice of the PDDT group after treatment (T2; $P < .01$). For the IZ criterion, a significant interrelation could be detected for all 3 MRI slices of the ADDT group after treatment (T2; $P < .05$).

Structural bony changes. Before treatment, osteoarthrotic changes or deviations in form (DIF) were seen in 17 joints of 13 patients (Cases 1, 3, 5, 9, 14, 15, 28, 30, 33, 39, 47, 50, and 51). Seven of these patients (10 joints) exhibited a disc displacement, while the other 6 patients (7 joints) showed a normal disc-condyle relationship. The prevalence of osteoarthrotic changes, DIF, or both was highest before treatment (17 joints) and decreased to 7 affected joints after treatment. One year after treatment, osteoarthrotic changes, DIF, or both were only seen in 4 joints (Cases 3, 39, 47) with disc displacement but in no joint with a normal disc position.

DISCUSSION Return to TOC

Temporomandibular disorders according to the American Academy of Orofacial Pain [51] is a collective term embracing a number of clinical problems that involve the masticatory musculature, the TMJ, and associated structures or both. Recently, there has been increased recognition that signs and symptoms of temporomandibular joint disorders also occur in the juvenile population with a prevalence ranging from 2.4% to 67.6% depending on age, diagnostic criteria, methods, and subject selection.[20,54–70]

When summarizing the pretreatment anamnestic, clinical, and MRI findings, 30 patients (48%) of the present sample exhibited at least 1 sign or symptom of articular TMD, but none of them exhibited muscular TMD. Three of the articular TMD patients had only MRI signs. In terms of disc displacement, the anamnesis and clinical examination revealed 11 affected joints, while on MRI, 22 joints showed varying degrees of disc displacement. Analogously, a crepitus could only be diagnosed before treatment in 4 joints, whereas on MRI, structural bony changes were seen in 17 joints. The superiority of MRI in the detection of pathologic changes of the disc, condyle, and fossa, as compared to a combined anamnestic and clinical examination, has also been demonstrated earlier.[61,71–73]

Compared to findings in the literature the present pretreatment TMD prevalence rate of 48% appears relatively high. This might be explained by the fact that subclinical symptoms were included. It may seem contradictory to the definition of articular TMD given by the American Association of Orofacial Pain[51] in which the diagnostic criteria for capsulitis include pain at rest exacerbated by function and superior/posterior joint loading. When adhering strictly to those criteria, subclinical symptoms of a capsulitis are not symptoms of TMD. On the other hand, it is well known and has been proven with MRI studies[74–76] that a disc displacement without reduction, which is defined as TMD, can exist without any clinical sign or symptom, thus being subclinical. In our opinion, subclinical symptoms are vital to our understanding of the cause-effect relationship of TMD and orthodontic treatment.

Another explanation for the relatively high pretreatment TMD prevalence rate might be that all patients exhibited either a Class II, division 1 or a Class II, division 2 malocclusion. Although no clear interrelation between occlusion and TMD has been established, some occlusal features such as large overjet[67,77,78] and a distal molar occlusion[67] are associated with signs and symptoms of TMD. Additionally, internal derangements and anterior disc displacements have been found to be more frequent in Class II compared to Class I and Class III malocclusions.[79] This may imply that Class II subjects have a higher risk for developing TMD.

Capsulitis

During treatment, the prevalence of a capsulitis of the inferior stratum of the posterior attachment changed from 24% before treatment (T1) to 100% after 6-weeks, and 88% after removal of the Herbst appliance (T2). During normal jaw opening, when the condyle leaves the glenoid fossa, a negative pressure appears within the posterior attachment[80] resulting in its expansion by dilatation of the retrodiscal venous plexus, thickening of the trabeculae separating the veins, and expansion of the synovium in the posterior joint spaces.[52,53,81–84] At full jaw opening, the posterior attachment is expanded about 4 to 5 times its jaw closed volume.[84]

When inserting the Herbst appliance, the mandible is jumped anteriorly to an incisal edge-to-edge position. The condyle is located on top of the articular eminence and all mandibular movements are performed from this condylar position. During the first months of Herbst treatment the expansion of the posterior attachment remains 24-hours a day, instead of lasting only for a few seconds during uninfluenced mandibular function. Although, the expansion does not seem to have a long-lasting effect on the synovial pressure,[85] it will result in a mechanical irritation of the tissue leading to an inflammatory reaction.[51,86–88] This might account for the higher incidence of capsulitis during active Herbst treatment.

Bumann and Kaddah[89] also described a comparable increase in the frequency of capsulitis during Herbst treatment. An increased tenderness of the TMJ upon palpation during this first phase of Herbst treatment was reported by Pancherz and Anehus-Pancherz,[25] but the prevalence was lower compared to our present findings. In contrast to this study, Foucart et al,[36] did not report any pain from the posterior attachment during Herbst treatment as assessed by lateral palpation of the condyle. This might be due to Foucart et al,[36] using a removable Herbst appliance with step-by-step activation in contrast to the fixed appliance used in our study. Furthermore, the passive compression (in direction of the posterior attachment) used in the present study was more powerful in detecting a capsulitis of the posterior attachment than joint palpation, since the condyle is forced backward against the inflamed posterior attachment.[90–92]

At the end of Herbst treatment (T2), the prevalence of capsulitis was still 88.1%. The intensity had markedly decreased (as assessed by the amount of force needed to provoke pain during passive loading of the joint). Bumann and Kaddah[89] reported a decrease of capsulitis prevalence compared to pretreatment values at the time the Herbst appliance was removed. This difference in findings might be explained by the fact that, in contrast to Bumann and Kaddah,[89] most patients in our study were treated to an overcorrected Class I dental arch relationship with an anterior crossbite. As a consequence, the condyle remained in a slightly anterior position and expanding the posterior attachment as demonstrated by the average anterior condylar position after treatment (T2). Additionally, immediately after Herbst appliance removal all patients exhibited a lateral open bite of varying degrees, which closed (settling of the occlusion) during the following months after treatment.[93] Thereby, the prevalence of capsulitis decreased to 32.4% 6 months after treatment and to 7% 1 year after treatment.

When looking at the total observation period (T1–T3), the prevalence of capsulitis of the inferior stratum of the posterior attachment decreased from 24.2% to 7%. This may be a result of the normalization of the occlusion. All patients with a capsulitis after treatment exhibited only subclinical symptoms. The reduction in the prevalence of capsulitis agrees with the results of Keeling et al,[94] who reported that Class II patients with TMJ capsule pain were found to benefit from functional treatment with a bionator.

With respect to muscular TMD, no signs or symptoms were found at any treatment stage. The findings contrast with those of Pancherz and Anehus-Pancherz,[25] who reported muscle tenderness before, during, after, and 1 year after Herbst treatment. The highest prevalence occurred after 3 months of treatment.[25] The differences in findings may be due to the different investigation techniques applied. Foucart et al,[36] used isometric contractions to assess masticatory muscle function and, in concordance with our results, couldn't find any muscular symptoms before, during, or after Herbst treatment, except for 1 patient who developed a disc displacement without reduction.

Articular disc position

The disc position was found to vary significantly between the patients at all examination times (T1, T2, and T3). The largest changes in disc position, both for the whole sample and within the disc position groups, were seen during the period from before to immediately after treatment (T1–T2). The disc position changes seemed to be the result of the anterior condylar position immediately after treatment, which is known to be associated with a more posterior position of the disc relative to the condyle.[95–98] However, the disc position changes tended to revert during the post-treatment period from immediately after treatment to 1 year after treatment (T2–T3). Over the whole observation period (T1–T3), the disc position was, on the average, unchanged for the whole sample. In the Normal, the PDDT, the PDD, and ADDT groups, a slightly posterior disc position compared to pretreatment values prevailed even 1 year after treatment. A retruded disc during active Herbst treatment has also been described by Pancherz et al.[99]

The retrusive effect of the Herbst appliance on the disc was especially pronounced in the PDDwR subjects. In analyzing the whole ADD group, this was masked by the anterior disc position changes in the TDDwR and TDDnoR subjects. The anterior disc position change may be attributed to the progression of the existing disc displacement in 4 joints with pretreatment TDDwR or to an elongation of the condylar attachment of the anterior band of the disc[100–102] in subjects with TDDnoR, thus permitting a more anterior disc position.

It seems remarkable that a tendency for a mean retruded disc position prevailed 1 year after treatment (T3) despite an unchanged condylar position compared to pretreatment values. The reason for this retrusion is unknown. However, animal experiments and macroscopic anatomic studies have demonstrated that the articular disc undergoes continuous remodeling during the development of the dentition.[103,104] Thus, it might be speculated that the occlusal changes induced by Herbst appliance therapy caused a remodeling of the articular disc resulting in a more retrusive position.

The effect of Herbst appliance treatment on the position of the articular disc was also found to depend on the pretreatment disc position. None of the subjects in the Normal, PDDT, and ADDT groups was found to develop a disc displacement during Herbst treatment. This finding contrasts with the findings of Foucart et al,[36] in which 3 of 10 Herbst patients developed disc displacement in 1 or both joints. This might be due to the previously mentioned fact that the authors used a removable instead of a fixed Herbst appliance and sagittal instead of parasagittal MRIs. Sagittal MRIs have been shown to be inferior in the visualization of the posterior band of the articular disc.[105] This may result in misinterpretation of a protrusive disc position. The assumption seems even more likely, when considering that 2 of the patients of Foucart et al,[36] did not show any clinical signs or symptoms of disc displacement.

None of the present Herbst patients with a posterior disc displacement seen in the MRI showed any clinical signs or symptoms of TMD at any time during the observation period. This contrasts with the findings of Westesson et al[106] who found posterior disc displacements in clinically symptomatic subjects only. Furthermore, the subjects in the PDD group were those who had the most anterior condylar position of all analyzed subjects. The disc position changes in the PDD group seems more likely to be due to the physiologic position change of the disc relative to the condyle associated with a more anterior condylar position[95–98] than to a true pathologic condition.

In subjects with a pretreatment anterior disc displacement, the effect of Herbst treatment depended on the amount of disc displacement. A good prognosis for disc repositioning was only found for PDDwR subjects. In these patients, a normal disc condyle relationship could be reestablished in all affected joints except 1. In this joint, the disc was found to be recaptured during treatment (T1–T2), but relapsed to a TDDwR position during the period from immediately after treatment to 1 year after treatment (T2–T3). This might be due to the fact that, in this patient, the occlusal correction achieved by Herbst treatment almost completely relapsed.

In contrast to normal disc repositioning therapy, disc recapturing in subjects with PDDwR was not associated with a permanent anterior change in condylar position, which has been claimed to be a prerequisite for stable disc repositioning.[107–110] However, there is the possibility that the position of the posterior band of the disc might have been misinterpreted as a result of a decreased MR signal from the anterior part of the posterior attachment due to fibrotic changes.[111] This, however, seems unlikely, as a repositioning of the disc in the MRI was directly associated with the relief of clinical symptoms.

In 3 of the 6 joints with a pretreatment TDDwR, a repositioning of the disc was seen after Herbst treatment (T2). This relapsed 1 year after treatment (T3). For joints with a pretreatment total disc displacement, the retrusive effect of treatment on the position of the disc did not seem to be effective enough to stabilize the disc position. When the disc relapsed, the condyle attained a more posterior position from immediately after treatment to 1 year after treatment (T2–T3). This finding has been reported for disc repositioning therapy.[107–110]

In the other 3 joints with a pretreatment TDDwR, the disc displacement progressed to a TDDnoR. Progression of a disc displacement has been reported (unknown causes) in some but not all patients with disc displacement.[112–113] Before treatment, 2 of the present joints with progression in disc displacement exhibited a late reduction of the disc upon jaw opening. All 3 discs had a transverse displacement component. Both late opening click and transverse displacement have been shown to decrease the prognosis for disc recapturing.[110,114] In all cases, the progression in disc displacement took place without any limitation in mouth opening or pain. This was unnoticed by both the patient and the examiner and was only revealed by MRI.

In all joints with a TDDnoR, the displacement of the disc prevailed during and after Herbst treatment. The development of a pseudodisc due to extensive fibrotic adaptation of the posterior attachment[101,115,116] was seen in 3 of the joints.

Condylar position

A considerable variation in condylar position was found in the present sample both before and 1 year after Herbst treatment. The variation was similar to that described for asymptomatic populations[60,117–119] and for different malocclusions[120] and could thus be the result of normal variation. Additionally, a more anterior disc position was found associated with a more posterior condylar position and vice versa. This association between the position of the disc and condyle was most marked before treatment. As anterior condylar positions have been shown to be more frequent in asymptomatic Class II, division 1 compared to Class I subjects,[121] this might explain the high prevalence of subjects with a PDDT and PDD in the present sample.

During the active treatment period (T1–T2), condylar position was changed anteriorly possibly due to the sagittal occlusal overcompensation during Herbst treatment. This is contradictory to earlier investigations[122,123] reporting an unchanged condylar position after removal of the Herbst appliance. The previous results were, however, based on smaller samples.

During the post-treatment period (T2–T3), condylar position reverted as a result of the settling of the occlusion.[93] When looking at the total observation period (T1–T3), condylar position was on average unchanged for the whole sample as well as for the PDDT and ADDT groups. For the Normal group, significant changes towards a more centered condylar position were found in the central slice and towards a more anterior position in the medial slice. The cause for the differences in changes between the slices is unknown, but might be due to the remodeling of the condyle during Herbst treatment.[122–125] In accordance with earlier findings[79,126] a posterior condylar position was found before treatment in the ADD group. This condylar position could be improved by Herbst treatment; however, no perfect concentricity was achieved.

Structural bony changes

Dibbets and van der Weele[127] reported that structural condylar bony changes can occur in healthy adolescents and that their prevalence generally increases with age. However, a disappearance of osseous changes in the condyle during adolescents has also been reported.[8,127] In the Herbst patients, osteoarthrotic changes, DIF, or both were relatively common before treatment (17 joints in 13 patients being affected). Unilateral changes were found to be more frequent than bilateral.[128,129] During Herbst treatment, the prevalence of structural bony changes decreased. One year after treatment, only 4 condyles exhibited osseous changes. It might be speculated that the remodeling of the condyle that takes place during Herbst treatment[122–125] might lead to the normalization of the condylar structures.

The joints with prevailing structural bony changes 1 year after Herbst treatment were exclusively confined to condyles with TDDnoR. The fact that a TDDnoR is associated with the development of osseous changes has been shown in both animal and human studies.[115,116,130]

CONCLUSIONS Return to TOC

The findings of the present study revealed, that during the period from before treatment to 1 year after treatment, bite jumping with the Herbst appliance: (1) did not result in any muscular TMD, (2) reduced the prevalence of capsulitis and structural condylar bony changes, (3) did not induce disc displacement in subjects with a normal pretreatment disc position, (4) resulted in a stable repositioning of the disc in the majority of the subjects with PDDwR, and (5) could not recapture the disc in subjects with a TDDwR or TDDnoR. However, TDDwR and TDDnoR do not seem to be a contraindication for Herbst treatment, as signs and symptoms of TMD in these patients partially subsided during treatment. In conclusion, bite-jumping using the Herbst appliance does not have a deleterious effect on TMJ function and does not induce TMD on a short-term basis.

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FIGURE 1. Posterior band (PB) citerion. Measurement of the angle (degrees) between the 12 o'clock position and the posterior band of the articular disc

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FIGURE 2. Intermediate zone (IZ) citerion. Measurement of the distance (mm) between the midpoint of the articular disc and a line connecting the midpoint of the condyle and the tuberculum articulare. The distance “a” was measured after perpendicular projection of the midpoint of the disc to a tangent on the articular eminence

Click on thumbnail for full-sized image.

FIGURE 3. Joint Space Index. Assessment of the anterior and posterior joint spaces (mm) as the shortest distances between the condylar head and the articular eminence (ant) and the condylar head and the postglenoid spine (post)

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