Short- and Long-Term Effects of the Herbst Appliance on Temporomandibular Joint Function

Sabine Ruf

This article summarizes six papers on the short- and long-term effects of the Herbst appliance on temporomandibular joint (TMJ) and masticatory muscle function. The treatment effects as well as the clinical consequences are discussed. The available knowledge in the literature shows that bite jumping using the Herbst appliance does not have a deleterious effect on the masticatory system and does not induce temporomandibular disorder (TMD) on a short- or long-term basis. On the contrary, the Herbst appliance improves TMJ function in some Class II TMD subjects. (Semin Orthod 2003; 9:74-86.) ***Copyright 2003, Elsevier Science (USA). All rights reserved.***

One of the goals of orthodontic treatment is to improve the function of the masticatory system including both temporomandibular joint (TMJ) and masticatory muscle function. When looking at the literature, there is controversy with respect to the effect of orthodontics on TMJ function.[1,2] The effects of the Herbst appliance on the masticatory system both during and after Class II correction have been investigated in a total of 6 published studies.[3-8] This article will summarize the scientific findings of these articles and discuss their clinical implications. The material and methods of the 6 Herbst papers are given in Table 1.

Summarized Results

Article 1 (Pancherz and Pancherz, 1982[5])

During Herbst treatment of 20 patients, the lateral movement capacity of the mandible was reduced by an average of 1.9 mm but increased to pretreatment values 1 year after treatment. The frequency of joint tenderness increased from 20% to 45 % during the first 3 months of treatment. However, after treatment (15%) and 1 year after treatment (10%), reduced prevalence of joint tenderness compared with pretreatment values were seen. Muscle tenderness showed a comparable development. Masticatory performance and temporal as well as masseter muscle electromyographic (EMG) activity were markedly reduced during the first 3 months of Herbst treatment but increased to pretreatment values during the follow-up period.

Article 2 (Hansen et al, 1990[4])

Anamnestic, clinical, and radiographic findings in 19 male subjects treated with the Herbst appliance an average of 7.5 years earlier were in accordance with those of an orthodontically untreated population of young male adults. TMJ sounds could be detected in 26% and muscle tenderness in 32% of the subjects. None of the individuals exhibited joint tenderness. Structural bony changes in the TMJ were found on both sides in 1 subject. Eight percent of the condyles were posteriorly displaced. However, on average, the condyles were slightly anteriorly positioned in the fossa.

From the Department of Orthodontics, University of Giessen, Giessen, Germany.

Address correspondence to Sabine Ruf, DDS, PhD, Department of Orthodontics, School of Dentistry, University of Berne, Freiburgstrasse 7, CH-3010 Berne, Switzerland.

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Table 1. Material and Methods Used in the 6 Articles on the Short- and Long-Term Effects of the Herbst Appliance on TMJ Function

		Subjects					*Herbst*				*Observation Times*								
	Article	*No.*	*Class*	*Male*	*Female*	*Age (yr)*	*Treatment Time*	*Fixed*	*Removable*	*TMJ Methods*	*Before*	*Start*	*6 Wks*	*3 Mo*	*After*	*6 Mo*	*1 Yr*	*4 Yr*	*7.5 Yr*
1.	Pancherz and Anehus-Pancherz, 1982[5]	20	II:1	x		11–14	6 mo	x		Anamnestic clinical 1 MET, EMG	x	x		x	x		x		
2.	Hansen et al, 1990[4]	19	II:1	x		Mean 20.4	7 mo	x		Anamnestic clinical 1 tomography									x
3.	Foucart et al, 1998[3]	10	II:1	x	x	Mean 11.5	8.7 mo +6.5 nighttime		x	Clinical 2 MRI	x		during		x				
4.	Ruf and Pancherz, 1998[7]	20	II	10	10	Mean 17.4	7.4 mo	x		Anamnestic clinical 3 MRI								x	
5.	Pancherz et al, 1999[6]	15	II	10	5	12–17	7 mo	x		MRI	x	x	x	x	x				
6.	Ruf and Pancherz, 2000[8]	62	II	27	35	Mean 14.4	7.2 mo	x		Anamnestic clinical 3 MRI	x	x	x	x	x	x	x		

Note. The number of subjects, the Angle Class (Class), the gender, the age of the subjects in years, the type of Herbst appliance used, the methods used to analyze TMJ, and masticatory muscle function and the observation times are given. Clinical 1 = range of motion, TMJ sounds, TMJ, and muscle tenderness on palpation; clinical 2 = clinical 1 + isometric contraction, clinical 3 = clinical 2 + passive jaw movements, joint play, and dynamic tests for the differentiation of clicking.
Abbreviations: MET, masticatory efficiency test; EMG, electromyography.

Article 3 (Foucart et al, 1998[3])

Before treatment with a removable Herbst appliance, none of the 10 subjects examined exhibited any disc displacement or muscle or joint tenderness. During treatment muscle and joint tenderness was seen in 1 subject. Clinically, the only detectable sign of temporomandibular disorders (TMDs) after treatment was a reduced condylar translation in 1 subject. On the magnetic resonance images (MRI) of the TMJs, 3 subject exhibited varying degrees of disc displacement after treatment, the disc being displaced anteriorly an average of 8.3° ($P = .023$) compared with pretreatment values.

Article 4 (Ruf and Pancherz, 1998[7])

An average of 4 years after Herbst treatment of 20 subjects, the prevalence of anamnestic and clinical signs or symptoms of TMD was within the range of "normal" reported in the literature. The frequency of disc displacement was not higher than in asymptomatic populations. Moderate to severe signs of TMD ranging from partial to total disc displacement or deviation in form of the condyle were seen in 5 subjects (25%). Another 3 subjects (15%) showed mild symptoms of TMD with either small condylar displacement or subclinical soft-tissue lesion.

Article 5 (Pancherz et al, 1999[6])

Before Herbst treatment of 15 subjects, the articular disc was on average in a slight protrusive position relative to the condyle. At the start of treatment, the mandible was advanced to an incisal edge to edge position. Because of the physiologic relative movement of disc and condyle on mandibular protrusion, the disc attained a pronounced retrusive position. At the end of treatment, the disc had on average almost returned to its original pretreatment position. However, a slight retrusive disc position prevailed, whereas condylar position was on average unchanged during Herbst treatment.

Article 6 (Ruf and Pancherz, 2000[8])

During Herbst treatment of 62 subjects, the condyle was positioned significantly forward but returned to its original position after removal of the 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, (3) reduced the prevalence structural condylar bony changes, (4) did not induce any disc displacement in subjects with a physiologic pretreatment disc position, (5) resulted in a stable repositioning of the disc in subjects with a pretreatment partial disc displacement with reduction, and (6) could not recapture the disc in subjects with a pretreatment total disc displacement with or without reduction. The overall prevalence of TMD was reduced from 48% before treatment to 24% 1 year after treatment.

Discussion

In clinical terms, the important questions with respect to the short- and long-term effects of the Herbst appliance on TMJ function are as follows.

1. Does the Herbst appliance damage the TMJ?
2. Does the Herbst appliance improve TMJ function?
3. What kind of Class II patients benefit from Herbst treatment in terms of improved TMJ function?

In the following, these questions will be addressed in the light of the knowledge available in literature.

Does the Herbst Appliance Damage the TMJ?

The findings to be expected if the Herbst appliance generally had an adverse effect on the TMJ or the masticatory musculature would be an increase in the signs or symptoms of TMD either on a short- or long-term basis compared with both pretreatment values and untreated controls.

When summarizing the anamnestic, clinical, and MRI signs and symptoms of TMD seen in Class II patients before Herbst treatment (articles 1, 3, and 6), 0% to 48 % of the patients exhibited either clinical or subclinical TMD. However, signs and symptoms of TMD are no rarity in children and adolescents. Their fre-

quency varies between 2.4% and 67.6% depending on the age of the subjects, the subject selection, the definition of the diagnostic criteria, and the examination methods (Fig 1).[9-24]

After Herbst treatment, Pancherz and Anehus-Pancherz[5] (article 1) described a decrease in joint sounds of 100%, in joint tenderness of 25%, and in muscle tenderness of 40%. Foucart et al[3] (article 3) reported an increase in disc displacements of 30%. Ruf and Pancherz[7] (article 6), on the other hand, found a decrease in disc displacement of 45%, a decrease in structural bony changes of 41%, and an increase in subclinical capsulitis of 64%. A possible explanation for the contradictory results in terms of disc displacement might be that Foucart et al[3] (article 3) used a removable instead of a fixed Herbst appliance and took sagittal instead of angulated sagittal MRIs. On straight sagittal MRIs of the TMJ the posterior band of the articular disc is not imaged reliably, especially in the lateral and medial joint sections,[25] resulting in an overestimation of disc displacements. The latter explanation seems quite likely as Foucart et al[3] (article 3) reported that 2 out of 3 disc displacement patients were clinically symptom free over the entire observation period.

One year after treatment, the prevalence of TMD in Herbst subjects was 24% compared with 48% pretreatment (article 6).[8] Correspondingly a 20% reduction in muscle tenderness, 50% reduction in joint tenderness, and 100% reduction in TMJ sounds was described by Pancherz and Anehus-Pancherz (article 1).[5] Such a reduction in TMD prevalence has not been reported to date for any orthodontic appliance.

An average of 4 years after Herbst treatment (article 4), the anamnestic, clinical, and MRI data using the same criteria as in article 6 revealed that 35% of the former Herbst patients showed clinical or subclinical TMD. Because both patient materials of articles 4 and 6 had the same pretreatment malocclusion characteristics and were treated with the same approach (Herbst appliance followed by multibracket appliance), it seems valid to compare them. Thus, on one hand, the TMD prevalence 4 years after Herbst treatment was less than in a group of Class II patients before Herbst treatment (article 6), despite the fact that an increase of signs and symptoms of TMD with age should have been expected.[18,26-29] On the other hand, the TMD prevalence 4 years after treatment increased compared with 1 year after Herbst treatment (article 6). This increase might be explained by the increase in age of the subjects[18,26-29] and by the multifactorial etiology of TMD.[29-31] In general, the prevalence of TMD in subjects 4 years after treatment was comparable to that seen in normal untreated populations.[32-38]

Furthermore, it was found (article 2) that patients an average of 7 years after Herbst treatment exhibit normal structural conditions of the condyle and fossa and their anamnestic and clinical TMD findings are in accordance with those of an orthodontically untreated population of young adults. Thus, it can be concluded that the Herbst appliance does not seem to have an adverse effect on TMJ function on a short- or long-term basis.

Does the Herbst Appliance Improve TMJ Function?

A possible improvement of TMJ function is much more difficult to detect then a deterioration because of the fact that the etiology of TMD is multifactorial.[29-31] If the Herbst appliance would improve TMJ function, the presence of a TMD promoting factor such as parafunction might disguise the positive effect of orthodontic treatment. Thus, because of the multifactorial etiology of TMD, it would be unrealistic to expect a complete disappearance of all signs and symptoms of TMD in orthodontic patients. Furthermore, certain kinds of TMD such as disc displacements without reduction, which might be present pretreatment, cannot be treated orthodontically. Thus, a certain prevalence of TMD will inevitably prevail after orthodontic treatment, despite a possible positive effect of the orthodontic appliance on TMJ function.

As described earlier, the prevalence of TMD in Class II subjects decreased by 50% from before to after Herbst treatment and by 27% from before to 4 years after Herbst treatment (articles 4 and 6). Thus, the frequency change was opposite to that in the normal population in which the TMD prevalence increases with age.[18,26-29] Therefore, it can be said that TMJ function was in fact improved by Herbst appliance treatment, possibly because of the normalization of the occlusion. However, the signs and symptoms of

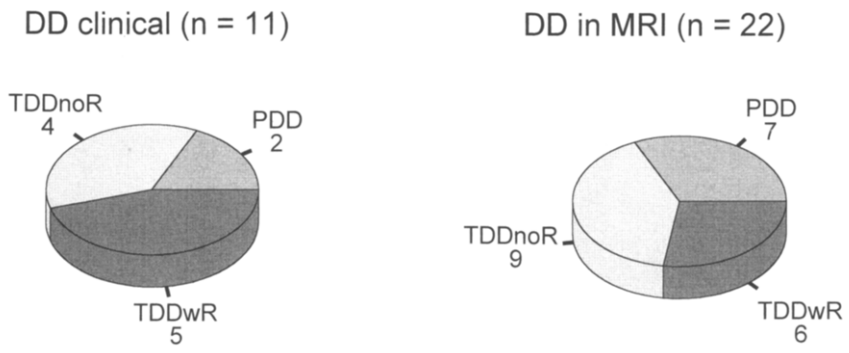

Figure 1. Prevalence of disc displacements (DD) in 62 consecutive Herbst patients before treatment analyzed clinically and by means of MRI. The total number of joints with disc displacements (n), the number of partial (PDD), and total disc displacments with reduction (TDDwR) as well as the number of total disc displacements without reduction (TDDnoR) is given.

TMD could not be completely resolved by Herbst treatment, which, as mentioned earlier, might be because of the fact that the etiology of TMD is multifactorial.

What Kind of Class II Patients Benefit From Herbst Treatment in Terms of Improved TMJ Function?

To be able to inform a patient specifically on the benefits of Herbst treatment in terms of improved TMJ function, it must be differentiated between the appliance effects on (1) disc position, (2) condylar position, (3) TMJ soft tissues, (4) TMJ bony structures, and (5) the masticatory musculature.

Disc Position

A slight retrusion of the disc compared with pretreatment values is seen at the end of Herbst treatment (article 5). This seems at least partly to be the result of a slight anterior position of the condyle after treatment (Fig 2). During the posttreatment period (after to 1 year after Herbst treatment), the amount of disc retrusion decreased (article 6). However, a slight retrusive disc position prevailed even 1 year after Herbst treatment. This seems even more remarkable because this retrusion was not associated with an anterior position of the condyle (Fig 2). The reason for this disc retrusion is unknown. It could, however, be the result of a change in

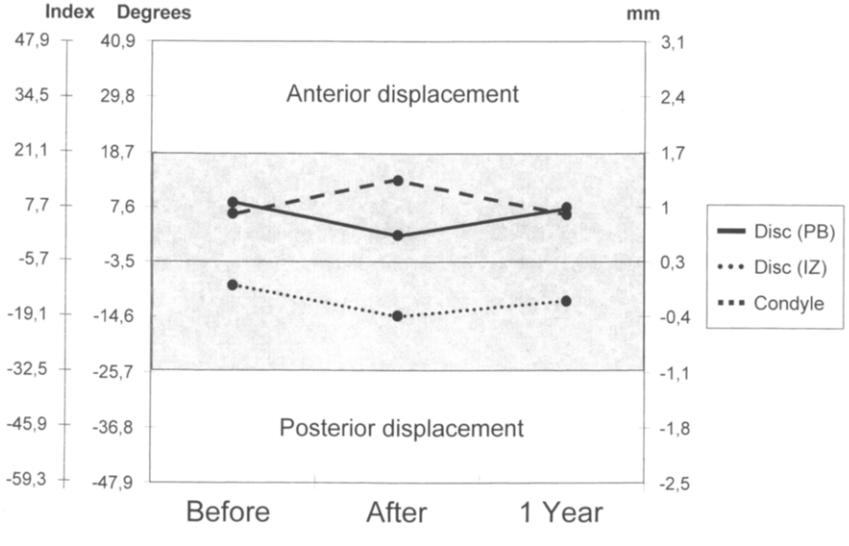

Figure 2. Average changes in articular disc and condylar position from before to one year after treatment in 62 consecutive Herbst patients. Disc position was measured using the posterior band (PB) or intermediate zone (IZ) criterion (article 6). The gray shaded area represents the physiologic range.

form because of the remodeling processes of the condyle and fossa. Furthermore, a remodeling of the disc[39,40] in the course of bite jumping might also have contributed to the disc retrusion, although because of its avascularity the remodeling capacity of the disc is limited.

The effect of the Herbst appliance on the position of the articular disc was found to depend on the pretreatment disc position. In patients with a physiologic pretreatment disc position or a displacement tendency, the position of the disc remained unchanged or improved, respectively, during Herbst treatment (articles 5 and 6). This is in contrast to the findings of Foucart et al[3] (article 3), who reported that 3 out of 10 healthy Herbst patients developed a disc displacement during treatment. This, as already described earlier, is probably because of the fact that Foucart et al[3] (article 3) used a removable instead of a fixed Herbst appliance and took sagittal instead of angulated sagittal MRIs.

In concordance with previous investigations,[41] it was found that the prognosis for disc repositioning depended on the degree of disc displacement existent pretreatment. Partial disc displacements (Fig 3) could be repositioned successfully and remained stable until the end of the observation period (article 6). In contrast to normal disc repositioning therapy,[41-44] recapturing of the disc during Herbst treatment was achieved by a retrusion of the disc and not by a protrusion of the condyle. A possible misinterpretation of disc repositioning in the MRI because of a fibrosis of the posterior attachment[45] seems unlikely as disc repositioning was associated with a disappearance of the clinical symptoms.

In the case of total disc displacements with reduction, only a temporary repositioning of the disc could be achieved during Herbst treatment (article 6). Thus, with an increasing degree of displacement, the retrusive effect of the Herbst appliance on disc position seems to be insufficient to stabilize the disc. Consequently and in concordance with previous findings,[41-44] the disc relapsed to a displaced position when the condyle moved backwards in the fossa during the posttreatment period.

In joints with a total disc displacement without reduction, the displacement of the disc prevailed during the entire observation period (article 6). The development of a pseudodisc because of extensive fibrotic adaptation of the posterior attachment[46-48] was, however, seen in some joints (Fig 4). TMJ function in general improved, however, in all subjects with a total disc displacement without reduction. Clinically, these subjects were indistinguishable from healthy individuals after treatment. Thus, without any MRI, the disc displacement would never have been diagnosed.

To date, the disc-recapturing capacity of other functional appliance than the Herbst appliance has not been investigated, except for the activator.[49] This appliance was found to be unable to recapture any displaced disc independent of the degree of displacement. Thus, until further knowledge is available, the Herbst appliance must be considered the only functional appliance able to improve the position of the articular disc in the course of treatment.

Clinical consequences. It must be pointed out that a disc displacement that presents no other symptoms than clicking does not warrant treatment.[30] However, if there is an indication for orthodontic treatment because of an existing Class II malocclusion, the disc position must be considered in treatment planning to achieve maximum benefits for the patient.

Treatment considerations for Class II patients with different degrees of disc displacement. With partial disc displacement, there is a good prognosis for disc repositioning. The Herbst appliance should be the appliance of choice to achieve maximum functional improvement during orthodontics even if the degree of malocclusion severity itself might not justify the use of the Herbst appliance.

With total disc displacement with reduction, there is a bad prognosis for disc repositioning. Appliance selection for Class II treatment should be based on malocclusion severity only.

With total disc displacement without reduction, there is no chance for disc repositioning. There is a good prognosis for tissue adaptation and functional improvement when using the Herbst appliance.

Condylar Position. A marked interindividual variation in condylar position was found before, after, 1 year after, 4 years after, and even 7 years after Herbst treatment (articles 2, 4, and 6). Comparable variations in condylar position have

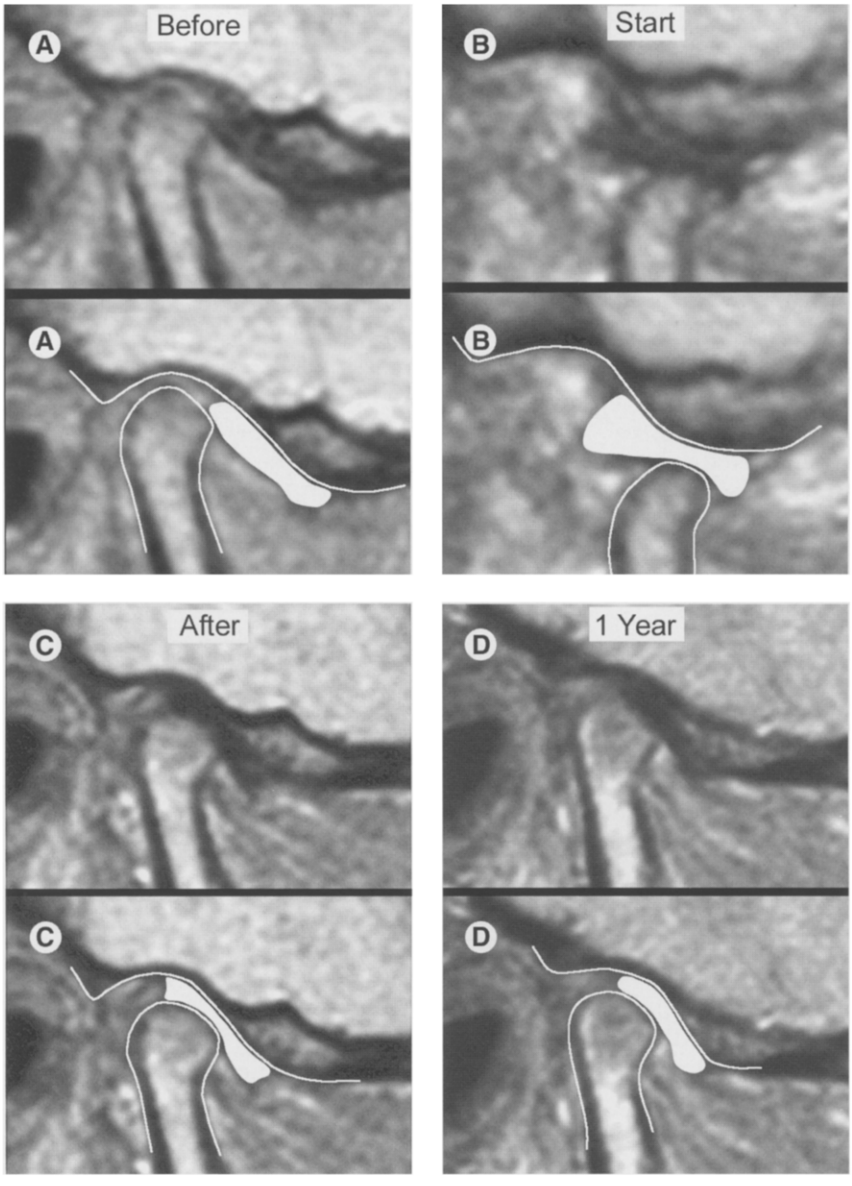

Figure 3. Parasagittal MRIs of the TMJ of a 12-year-old male Class II:1 subject treated with the Herbst appliance. Before treatment note the partial disc displacement with reduction (A). The disc was recaptured at start of Herbst treatment (B). Both after (C) as well as 1 year after Herbst treatment (D) the recaptured disc is in a physiologic disc-condyle relationship.

also been reported for asymptomatic populations[23,50-52] and for different malocclusions.[53] However, it seems remarkable that a tendency toward an average anterior condylar position was present at all examination times (articles 2, 4, and 6). This might be an expression of the Class II morphology.[54]

During Herbst treatment, the amount of anterior position of the condyle was temporarily increased (Fig 2). This was the result of an overcorrection of the Class II dental arch relationship in the patient material analyzed (article 5). Nevertheless, when the occlusion settled after treatment,[55] the condyle returnd to its original fossa position. Thus, on a general basis condylar position will not be altered permanently by Herbst treatment.

There was an inverse relationship between the position of the disc and the condyle, which was especially pronounced before treatment (article 6). In concordance with the literature,[56,57] this interrelation was more obvious in subjects with a disc displacement; a more posterior condylar position was associated with a more an-

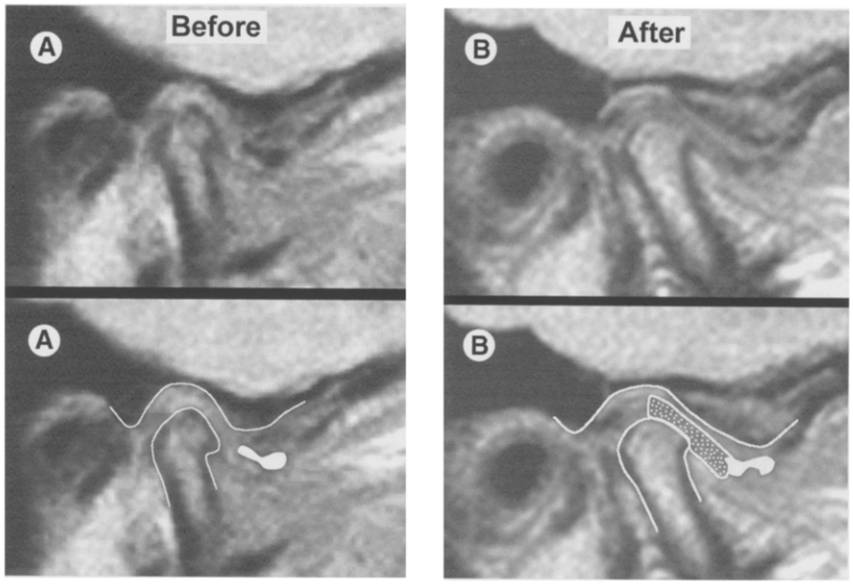

Figure 4. Parasagittal MRIs of the TMJ of a 15-year-old male Class II:1 subject treated with the Herbst appliance. Before treatment, a total disc displacement without reduction was present (A). After treatment, a pseudodisc (dotted area) has developed. Note also the improvement in condylar bony shape (B).

terior disc position. During Herbst treatment, condylar position in these patients could be improved although an optimal-centered condylar position could not be achieved.

Clinical consequences. In subjects with disc displacements, an improvement of the condylar position from a posterior toward a more centered position within the fossa can be expected. This implies an unloading of the TMJ soft tissues in the retrodiscal area, thus promoting tissue adaptation and improved TMJ function. Because comparable positive effects of other functional appliances on the condylar position have not been reported in literature, the Herbst appliance should be considered as the appliance of choice in Class II patients with posterior condylar displacements.

TMJ Soft Tissues

In general, inflammatory conditions of the temporomandibular joint are subdivided into synovitis and capsulitis.[30] In the following, capsulitis refers to an intracapsular inflammation primarily affecting the posterior attachment. The term posterior attachment is used as described by Scapino[58,59] and refers to the vascular and innervated tissue lying behind the articular disc.

No effects of Herbst treatment on the superior stratum of the posterior attachment or the structures of the joint capsule could be observed (article 6). The only affected structure was the inferior stratum of the posterior attachment. The lateral part of the inferior stratum reacting more than the central part. In the following, only the prevalences for the lateral part of the inferior stratum will be given.

During Herbst treatment, the prevalence of a capsulitis of the inferior stratum of the posterior attachment changed from 24% pretreatment to 100% after 6 weeks Herbst treatment and 88% immediately after removal of the Herbst appliance (Fig 5). It must, however, be stressed that the existing capsulitis pretreatment was both clinical and subclinical, whereas, during and after Herbst treatment, all findings where solely subclinical, meaning that none of the patients was complaining of TMJ pain (article 6). During the posttreatment settling of the occlusion,[55] the capsulitis prevalence decreased to 32% 6 months after removal of the Herbst appliance and to 7% 1 year after. Thus, over the entire observation period, the prevalence of a capsulitis of the inferior stratum of the posterior attachment was reduced from 24% to 7% (Fig 5). This is most likely the result of a normalization of the occlusion (article 6).

The development of a capsulitis in the course of Herbst treatment was not an effect restricted to a mechanical bite jumping with the Herbst appliance. Comparable reactions of the inferior stratum of the posterior attachment have been

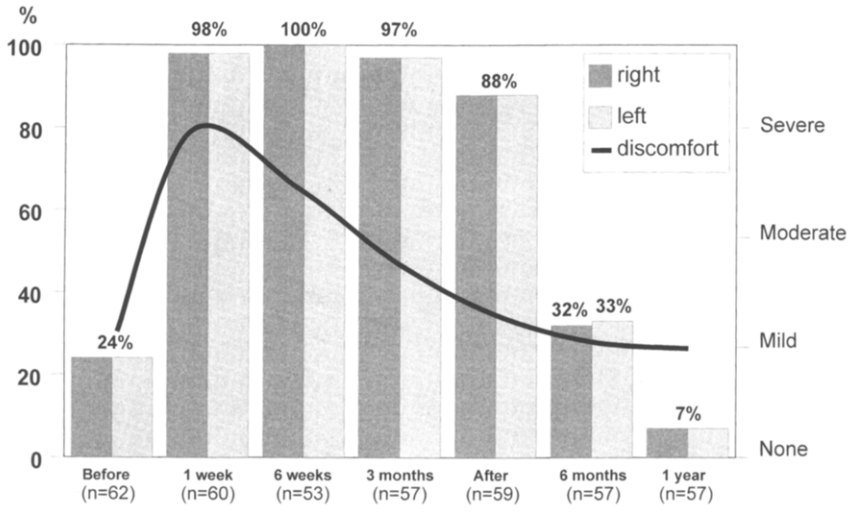

Figure 5. Prevalence of a capsulitis of the lateral part of the inferior stratum of the posterior attachment in 62 consecutive Herbst patients. The percentage (%) of affected joints is given separately for the left and right TMJ. The level of discomfort and the number (n) of analyzed patients is shown.

found in activator patients[49] and thus also for functional bite-jumping procedures.

The induction of a temporary subclinical capsulitis of the inferior stratum of the posterior attachment is probably caused by the advancement of the condyle provoked by the Herbst appliance, which results in an expansion of the posterior attachment.[58-64] In contrast to normal mouth opening or protrusive jaw movement, during which this expansion (Fig 6) prevails only for seconds, in Herbst treatment it remains 24 hours a day. Although the soft-tissue expansion does not seem to have a long-lasting effect on the synovial pressure,[65] no doubt it will result in a mechanical irritation of the tissue leading to an inflammatory reaction[30,66,67]: the observed capsulitis of the inferior stratum of the posterior attachment.

Clinical consequences. Becauase patients exhibiting a capsulitis of the posterior attachment pretreatment have a 70% chance to adapt during a period from before to 1 year after treatment, the Herbst appliance should be considered for treatment in Class II cases with clinically manifest capsulitis of the inferior stratum of the posterior attachment.

TMJ Bony Structures

Normally the prevalence of structural bony changes increases with age.[68] However, a spontaneous healing of osseous condylar changes during adolescence has also been reported.[68,69] During Herbst treatment, the prevalence of structural bony changes of the condyle (flattening, subchondral sclerosis, erosions, osteo-

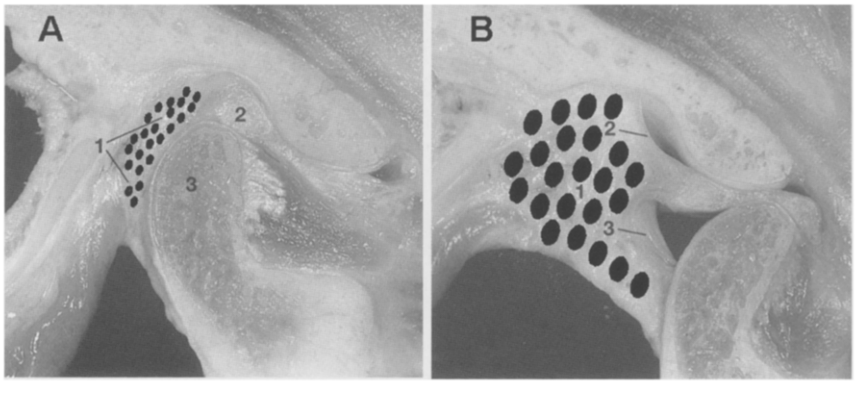

Figure 6. Anatomic section of the temporomandibular joint region[83] in closed (A) and open-mouth position (B). Note the expansion of the posterior attachment upon mouth opening, which is maintained 24 hours daily during Herbst treatment.

phytes) decreased (article 6). Although before treatment nearly 14% of the joints exhibited condylar bony changes, this was the case for only 3% 1 year after Herbst treatment. Probably the remodeling processes of the condyle induced by the Herbst appliance[70-73] promoted the normalization of the condylar bony structures. For example, the disappearance of osteophytes might be explained by the anterior resorptive process[74-76] taking place in the course of condylar remodeling during Herbst treatment.

In all joints with a physiologic disc-condyle relationship, the signs of structural bony changes disappeared during the observation period from before to 1 year after Herbst treatment. In joints with a pretreatment disc displacement without reduction, a condition which in both clinical and animal studies has been shown to be more susceptible to the development of bony changes,[46,48,77] the condylar bony changes improved during Herbst treatment (Fig 4).

Clinical consequences. In Class II patients with pretreatment structural bony changes, there is no contraindication for the Herbst appliance.

Masticatory Musculature

The reaction of the masticatory musculature to Herbst treatment was analyzed using 2 different methods: (1) muscle palpation (articles 1, 2, and 3) and (2) isometric muscle contraction exercises (articles 3, 4, and 5). The results of these 2 different approaches are difficult to compare.

In the assessment of myofascial pain, isometric muscle contractions have been shown to exhibit less intra- and interexaminer variability[78-81] than muscle palpation. Furthermore, in contrast to muscle palpation, myofascial pain provoked by means of isometric contractions is associated with morphologic changes of the muscle, in form of a muscle edema detectable by means of MRI.[82]

In using palpation to assess myofascial pain, it could be shown that during Herbst treatment (article 1) the percentage of patients exhibiting muscle tenderness increased from 25% before to 55% after 3 months Herbst treatment. Foucart et al[3] (article 3) described an increase from 0% to 10% during treatment. After treatment, muscle tenderness was either absent (article 3) or present in 15% of the subjects (article 1). One year after Herbst treatment, a total of 20% (article 1), and 7 years after 32% (article 2) of the subjects showed tender muscle sites. This increase might be explained by the age increase of the subjects[18,26-29] and by the multifactorial etiology of TMD.[29-31]

By using isometric contractions to assess myofascial pain, no pathologic findings were detectable either before, during, after, 1 year after, or 4 years after Herbst treatment (articles 3, 4, and 6).

Clinical consequences. Treatment with the Herbst appliance does not seem to have a significant effect on the functional status of the masticatory musculature.

Conclusion

Bite jumping using the Herbst appliance does not seem to have a deleterious effect on TMJ and masticatory function and does not seem to induce TMD on a short- or long-term basis. On the contrary, the Herbst appliance improves TMJ function in some Class II TMD subjects.

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