

Signs and symptoms of TMJ disorders in adults after adolescent Herbst therapy: A 6-year and 32-year radiographic and clinical follow-up study

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ABSTRACT

Objective: To analyze radiographic signs of temporomandibular joint (TMJ) osteoarthritis and clinical TMJ symptoms in patients 6 years and 32 years after treatment with a Herbst appliance.

Materials and Methods: Fourteen patients were derived from a sample of 22 with Class II division 1 malocclusions consecutively treated with a banded Herbst appliance at the age of 12–14 years old (T1-T2). The subjects were reexamined after therapy at the ages of 20 years (T3) and 46 years (T4). The TMJs of the 14 patients were analyzed radiographically (conventional lateral tomography at T3 and cone-beam computed tomography at T4) and clinically/anamnesticly at T3 and T4.

Results: Six years after Herbst therapy, signs of osteoarthritis were seen in one patient. At the 32-year follow-up, two additional patients had developed signs of osteoarthritis. At the 6-year follow-up, TMJ clicking was present in two patients, though none of the patients reported TMJ pain. At the 32-year follow-up, six patients had TMJ clicking and one patient had TMJ pain.

Conclusions: This longitudinal very-long-term follow-up study after Herbst therapy revealed only minor problems from the TMJ. The TMJ findings 6 years and 32 years after Herbst treatment corresponded to those in the general population. Thus, in the very long term, the Herbst appliance does not appear to be harmful to the TMJ. (*Angle Orthod.* 2015;85:735–742.)

KEY WORDS: TMJ disorders; Herbst therapy

INTRODUCTION

During Herbst treatment¹ the mandible is held in a permanent protruded position that will interfere with the physiologic function of the stomatognathic system. Because of this, Herbst treatment has been blamed of causing temporomandibular disorders (TMD). Except for the study of Foucard et al.² using a removable Herbst appliance, critical statements are mainly personal opinions.

Earlier studies of Herbst appliances^{3–6} have shown that, on a short-term basis, Herbst therapy for

adolescent patients with Class II malocclusion does not cause disorders of the muscular or temporomandibular joint (TMJ) part of TMD. Although two of the Herbst investigations^{3,6} have follow-up periods of 7.5 years and 4 years, respectively, the studies are not longitudinal in nature, and no information exists with respect to TMD after the age of 20 years.

The present longitudinal radiographic and clinical very-long-term follow-up study after Herbst therapy is concerned with the TMJ part of TMD. The aim was to reexamine patients consecutively treated with a Herbst appliance 32 years after therapy and to compare signs and symptoms of TMJ disorders in these subjects at 20 years and 46 years of age. Emphasis was placed on signs and symptoms of osteoarthritis and disc displacement.

MATERIALS AND METHODS

Subjects

The patients in this study were derived from a sample of 22 consecutive patients with Class II division 1 malocclusion (19 males and 3 females) treated with a

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Table 1. Characteristics of 14 Class II, Division 1 Malocclusions (Cases 1–14) Treated with the Herbst Appliance and Followed 32 Years after Therapy^a

Case ^b	Gender	Treatment	Age (years)				Follow-up Periods (years)		Retention (Years)	Class II Correction
	Male/Female	Herbst/Extraction	T1	T2	T3	T4	T2 -T3	T2-T4	Fixed/Removable	Stable/Relapse
1X	Male	Herbst / extraction	13	17 ^c	21	48	4	31	F/R (2 years)	Stable
2	Male	Herbst	13	14.5	20.5	48	6	33.5	No retention	Stable
3	Male	Herbst	11	12.5	19	45	6.5	32.5	No retention	Stable
4	Male	Herbst	13	14.5	20.5	47.5	6	33	R (4 years)	Stable
5	Male	Herbst	13.5	15	19	46.5	4	31.5	R (3 years)	Relapse
6	Male	Herbst	13	14.5	20.5	47.5	6	33	No retention	Relapse
7	Female	Herbst	13	14.5	20.5	48	6	33.5	R (2 years)	Stable
8X	Male	Herbst / extraction	13	15	22	48	7	33	F/R (4 years)	Stable
9	Male	Herbst	12.5	14	20	45	6	31	R (2 years)	Stable
10	Male	Herbst	12	14	20	44	6	30	No retention	Stable
11	Female	Herbst	11	12.5	18.5	42.5	6	30	R (2 years)	Stable
12	Male	Herbst	12.5	14	21	46	7	32	F/R (3 years)	Relapse (one side)
13	Male	Herbst	12.5	14	21	45	7	31	R (2 years)	Relapse
14	Male	Herbst	12.5	14	22	45	8	31	R (2 years)	Relapse (one side)
Summary	12 males,	12 Herbst;	12.5	14.3	20.4	46.1	6.1	31.8	4 No retention,	9 stable,
Mean	2 females	2 Herbst/extraction							10 retention	5 relapse

^a T1 indicates before treatment; T2, after treatment, that is, 12 months after the Herbst appliance was removed and the occlusion had settled; T3, 6 years after treatment (lateral tomography of TMJs); T4, 32 years after treatment (CBCT of TMJs); F, fixed retention with a mandibular lingual canine to canine retainer; R, removable retention with an activator or a maxillary Hawley plate; F/R, fixed mandibular canine retainer in combination with a removable maxillary Hawley plate.

^b Cases 1X and 8X were treated by extractions after active Herbst therapy.

^c Includes a 2-year break in treatment during the period T1-T2.

Herbst appliance at the University of Malmö/Sweden in 1977–1978.⁷

In the years 2011 and 2012, 30 to 33 years after Herbst therapy, the 22 subjects were recalled to the Orthodontic Department in Malmö for a late follow-up investigation. Two patients were deceased and six declined to come. Thus, the final follow-up sample comprised 14 subjects (12 males and 2 females) and is presented in detail in Table 1.

Treatment in all subjects was performed by one of the authors (Dr Pancherz) using a banded type of Herbst appliance with a simple anchorage system.⁷ In all subjects, at the start of treatment, there was a one-time full mandibular advancement. Before treatment, all subjects had an increased overjet (mean = 8.2 mm) that, by treatment, was reduced by an average of 5.1 mm.⁷ After active Herbst therapy, the condyles were positioned concentrically in their fossae.⁷ Due to major tooth irregularities after Herbst therapy, extractions of four premolars were performed in two subjects (Case 1X and 8X), and upper and lower fixed multi-bracket appliances were placed for about 1 year.

Methods

The patients were analyzed according to the following protocol:

- Six years after treatment (T3): The TMJs were examined radiographically by means of conventional

lateral tomography, clinical examination, and a questionnaire.⁶

- Thirty-two years after treatment (T4): The TMJs were examined radiographically by means of cone-beam computed tomography (CBCT), clinical examination, and a questionnaire.

TMJ Radiography

All radiographic examinations of the TMJ, both conventional lateral tomography at T3 and CBCT at T4, were carried out at the Department of Oral and Maxillofacial Radiology, Faculty of Odontology, University of Malmö/Sweden.

At T3, conventional lateral tomography of the TMJs was performed with a Polytome U (Massiot-Philips, Paris, France) using a hypocycloidal motion pattern.⁶ Two exposures were made on each TMJ to cover the total medial-lateral width of the TMJs. A multisection cassette was used containing four pairs of rare-earth screens and four films.

At T4, CBCT examinations of the TMJs were performed using the TMJ imaging protocol on a Veraviewepocs 3De (J. Morita Mfg. Corp, Kyoto, Japan). The protocol implied a field of view of 4 × 4 cm, a tube voltage of 80 kV, a tube current of 5 mA, and a scanning time of 9.4 seconds. Two volumes, one for each TMJ, were acquired for each patient. Reconstructions of images were performed in the

Table 2. Osseous Diagnoses for the Temporomandibular Joint from Conventional Lateral Tomography and Cone-Beam Computed Tomography Using Scoring Options A, B, or C^a

A. No osteoarthritis	
1.	Normal relative size of the condylar head; and
2.	No subcortical sclerosis or articular surface flattening; and
3.	No deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis.
B. Indeterminate for osteoarthritis	
1.	Normal relative size of the condylar head; and
2.	Subcortical sclerosis with/without articular surface flattening; or
3.	Articular surface flattening with/without subcortical sclerosis; and
4.	No deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis.
C. Osteoarthritis	
1.	Deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis.

^a From Ahmad et al.⁸

software iDixel, version 2 (J Morita Mfg Corp, Kyoto, Japan). The slice thickness was 1.5 mm and the slice interval was 1 mm.

All radiographic examinations were done in a closed-mouth position. Sagittal images were perpendicular to the long axis of the condyle (T3, T4), and the coronal images were parallel to the axis (T4). The TMJs (condylar head, mandibular fossa, and articular eminence) were interpreted for structural bone changes. The diagnosis of osteoarthritis was made according to Ahmad et al.⁸ (Table 2).

The interpretations of the radiographs were made by one observer (AP) at T3⁶ and by two observers (Dr Petersson and Dr Salé) at T4. Observer Dr Petersson had many years of experience interpreting TMJ images and Dr Salé had several years of experience. At T4 the two observers were calibrated by evaluating 10 TMJ-CBCTs from patients who were not participating in this study. After calibration the observers interpreted the present TMJ CBCT images individually. The observers were blinded to case history and clinical status. When the observer assessments differed, consensus was reached through discussion.

Clinical Examination and Questionnaire

Clinical examinations were carried out at T3 and T4 to gain information on TMJ clicking, crepitus, locking, and TMJ pain. The clinical examination at T3 was done by one examiner (Dr Hansen)⁶ using the method of Carlsson and Helkimo.⁹ At T4, Dr Salé performed the clinical examination according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD).¹⁰ The questionnaires at T3 and T4 included questions regarding symptoms from the TMJs such as pain, clicking, crepitus, limited mouth opening, and locking.

Data Analysis

At T3 and T4, the individual data from the radiographic and clinical examinations as well as from the questionnaire were analyzed. Because of the small sample, statistical tests were not performed. The study was approved by the Ethical Committee University of Malmö/Sweden, No 2012/44.

RESULTS

The individual TMJ findings at T3 and T4 derived from conventional lateral tomography and CBCT, clinical analyses, and questionnaires are presented in Table 3. The individual TMJ radiographs (lateral tomography and CBCT) from all patients are shown in Figures 1A through C.

TMJ Osteoarthritis

TMJ osteoarthritis was present in 1 of the 14 patients at T3 and in 3 of the 14 patients at T4. In the patient with osteoarthritis at T3 (Case 5; Figure 1A; Table 3), bone changes were present bilaterally. The right condyle had erosions and an osteophyte anteriorly, and the left condyle was flattened and also had an anterior osteophyte. At T4 in Case 5, erosion had developed on the posterior part of the articular eminence in the right TMJ, and the previous osteophyte remained. However, the erosion on the anterior part of the right condyle had disappeared. At T4 the structural bone changes in the left TMJ were unchanged. In another two patients at T4 (Cases 8X and 14; Figures 1B and 1C, respectively; Table 3) structural bone changes had developed in the TMJs. Cases 8X had developed an erosion and an osteophyte on the right condyle as well as subcortical sclerosis and an osteophyte on the left condyle. Case 14 had developed an erosion on the posterior part of the articular eminence in the left TMJ. At T4, for one patient (Case 13; Figure 1C) osteoarthritis in the left TMJ was indeterminate.

TMJ Symptoms

Seven patients did not report any TMJ symptoms at T3 or T4. At T3, TMJ clicking was present in three TMJs (in two patients). At T4, TMJ clicking was present in eight TMJs (in six patients) (Table 3). According to the RDC/TMD, all clicking was due to disc displacement with reduction. At T3 none of the patients had TMJ crepitus, but at T4 crepitus was registered bilaterally in one patient. Both at T3 and T4, no TMJ locking was reported by any of the patients.

At T3 none of the patients reported TMJ pain. At T4, one patient experienced unilateral pain (Table 3) when

Table 3. TMJ Findings from Radiography, Clinical Examination and Anamnestic Recordings in 14 Class II, Division 1 Subjects (Cases 1–14) Treated with a Herbst Appliance and Followed 6 Years (T3) and 32 Years (T4) after Therapy^a

Case ^b	Gender	Osteoarthritis ^c				TMJ Clicking/Creptus				TMJ Pain	
		Lateral Tomography at T3		CBCT at T4		Clinical/Questionnaire at T3		Clinical/Questionnaire at T4		Questionnaire at T3 / T4	
		Male / Female	TMJ Right	TMJ Left	TMJ Right	TMJ Left	TMJ Right	TMJ Left	TMJ Right	TMJ Left	TMJ Right
1X	Male					Clicking			Clicking		
2	Male										
3	Male										
4	Male										
5	Male	OA	OA	OA	OA	Clicking	Clicking	Clicking	Clicking		
6	Male										
7	Female										
8X	Male			OA	OA						
9	Male							Clicking			
10	Male					Creptus		Clicking	Clicking		
11	Female							Creptus	Creptus	Pain at T4	
12	Male							Clicking			
13	Male				Indeterminate			Clicking			
14	Male				OA						
Summary	12 males 2 females	1/28 TMJs with OA at T3		5/28 TMJs with OA at T4 1 TMJ indeterminate OA at T4		3/28 TMJs with clicking at T3 1/28 TMJ with creptus at T3		8/28 TMJs with clicking at T4 2/28 TMJs with creptus at T4		1/28 TMJ with pain at T4	

^a Clinical indicates clinical examination, questionnaire, anamnestic recording; CBCT, cone-beam computed tomography; TMJ indicates temporomandibular joint; OA, osteoarthritis; RDC/TMD, Research Diagnostic Criteria for Temporomandibular Disorders.

^b Cases 1X and 8X were treated by extractions after active Herbst therapy.

^c Osteoarthritis diagnosis according to Ahmad et al.⁸ (Table 2).

chewing tough food. No other patients reported difficulties in chewing food.

DISCUSSION

The loss of subjects at follow-up represents a potential source of bias.¹¹ At the recall of the present 22 patients, 30–33 years after therapy, the attendance rate was 70% (when excluding the two persons who were deceased), which must be considered acceptable, especially in relation to the long follow-up period. Furthermore, with respect to dentoskeletal characteristics, length of treatment, immediate treatment, and 6-year posttreatment results,^{12,13} the six not attending subjects did not differ from the 14 attending ones. Thus, the participating subjects must be considered an unbiased group for a reliable long-term follow-up study. A possible study limitation was the lack of a control group, but the results reported were compared with those from epidemiologic studies on TMD.

In 1990, at the time of the T3 evaluations,⁶ lateral tomography was the method of choice. The CBCT technique was not available until several years later. However, the two different radiographic modalities are not likely to affect the results significantly as the diagnostic accuracy of TMJ bone changes for CBCT and conventional tomography has been found to be comparable.¹⁴

In the clinical and anamnestic evaluations of the TMJs, at T3 the procedure of Carlsson and Helkimo⁹ was used. As RDC/TMD¹⁰ is widely used today, the T4 clinical evaluations were based on RDC/TMD. High reliability has been found for the clinical criteria.^{15,16} Both examination protocols at T3 and T4 included TMJ palpation and anamnestic information to achieve information regarding TMJ pain, sounds, and locking.

TMDs are common among children and adults. In previous epidemiologic, mainly cross-sectional, studies, the prevalence has been reported to vary between 6% and 71%.^{17–19} Furthermore, longitudinal studies have disclosed a significant and unpredictable fluctuation of TMD over time.^{20,21} In the aforementioned studies of TMD both the TMJ and the associate musculature were considered. This study, on the other hand, was confined to TMJ disorders exclusively. Thus, a direct comparison, between the present findings and those from epidemiologic studies is difficult.

The criteria for TMJ osteoarthritis used in this study included surface erosion, osteophyte, subcortical cyst, or sclerosis.⁸ The results showed that 1 of the 14 patients (7% of TMJs) had osteoarthritis at the 6-year follow-up and 3 of the 14 patients (18% of TMJs) at the 32-year follow-up. These results are in line with the frequencies of osteoarthritis found in a recent CBCT study on subjects without ongoing pain.²²

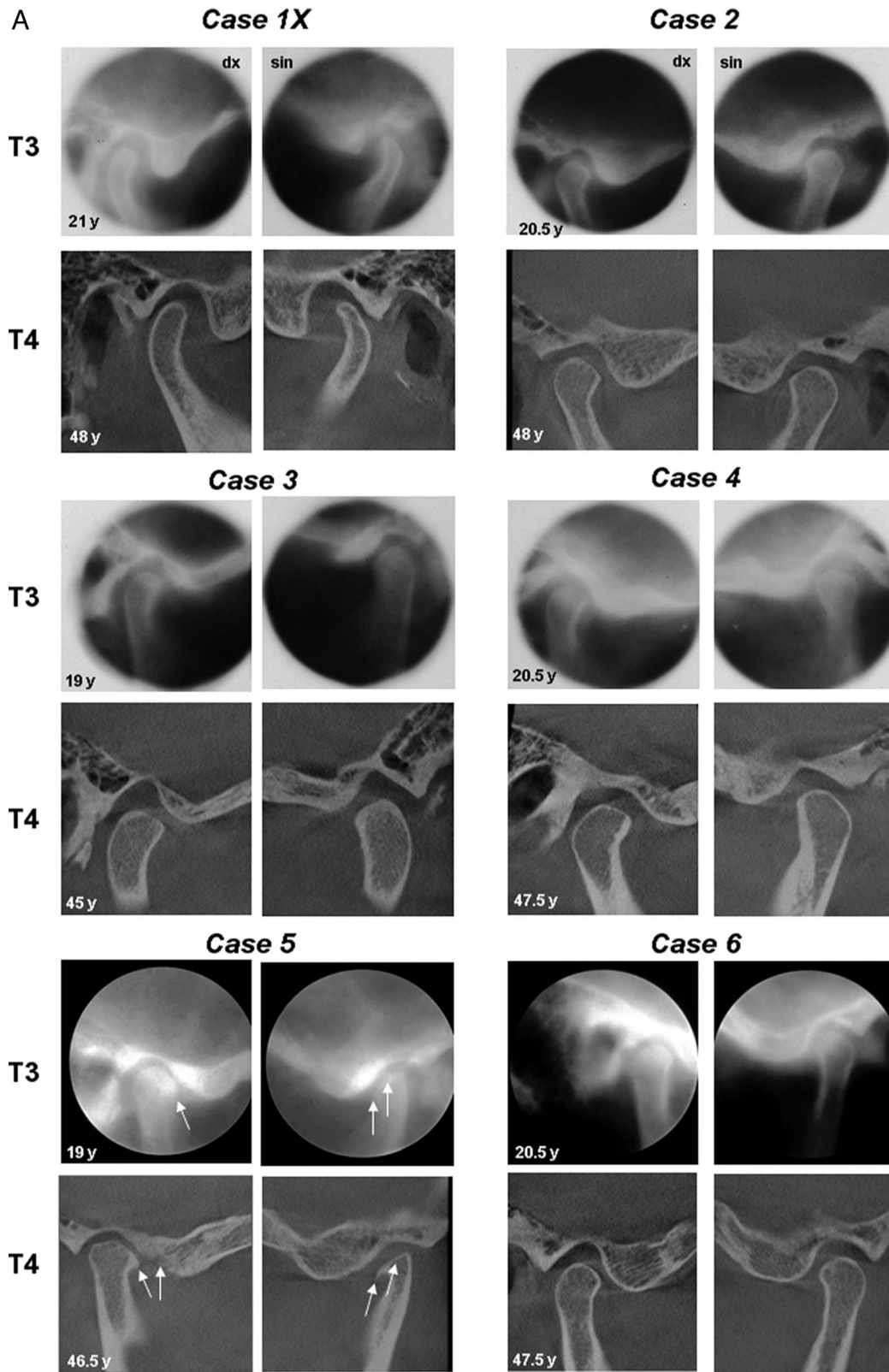


Figure 1. (A) TMJ radiographs (right and left side) from 14 Class II division 1 malocclusions (Cases 1–6) treated with the Herbst appliance. Conventional lateral tomograms from T3 (6 years after treatment) and CBCT examinations from T4 (32 years after treatment). Note the osteoarthritic changes in Case 5 at T3 and T4 (arrows). **(B)** TMJ radiographs (right and left side) from 14 Class II division 1 malocclusions (Cases 7–12) treated with the Herbst appliance. Conventional lateral tomograms from T3 (6 years after treatment) and CBCT examinations from T4 (32 years after treatment). In the Cases 9 and 11 (females) no lateral tomograms existed from T3. Note osteoarthritic changes in Case 8X at T4.

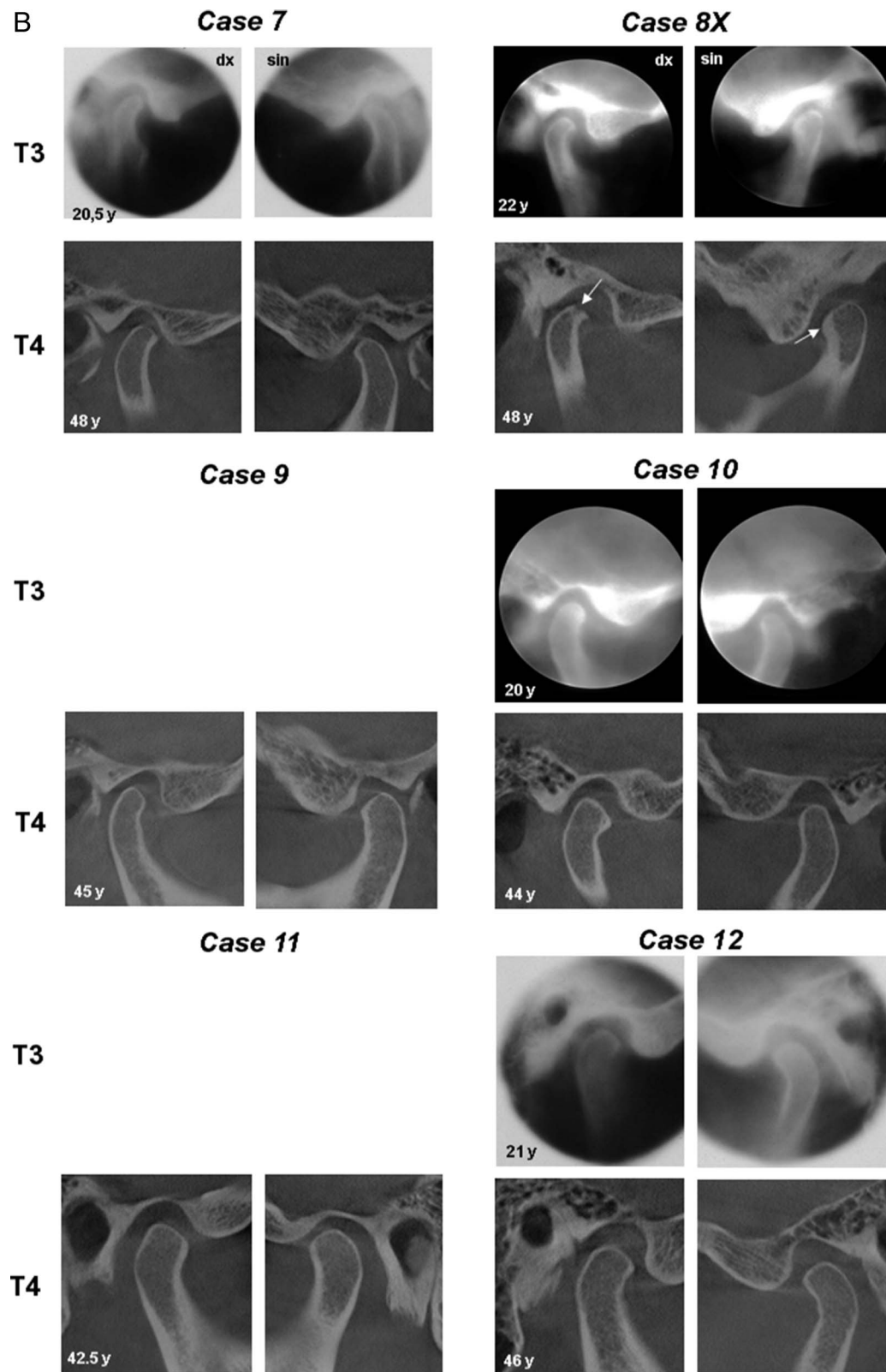


Figure 1. Continued. (arrows). (C) TMJ radiographs (right and left side) from 14 Class II division 1 malocclusions (Cases 13 and 14) treated with the Herbst appliance. Conventional lateral tomograms from T3 (6 years after treatment) and CBCT examinations from T4 (32 years after treatment). Note osteoarthritic changes in Case 14 at T4 (arrow). The T3 lateral tomograms are from the publication of Hansen et al.⁶ with kind permission of the *European Journal of Orthodontics*.

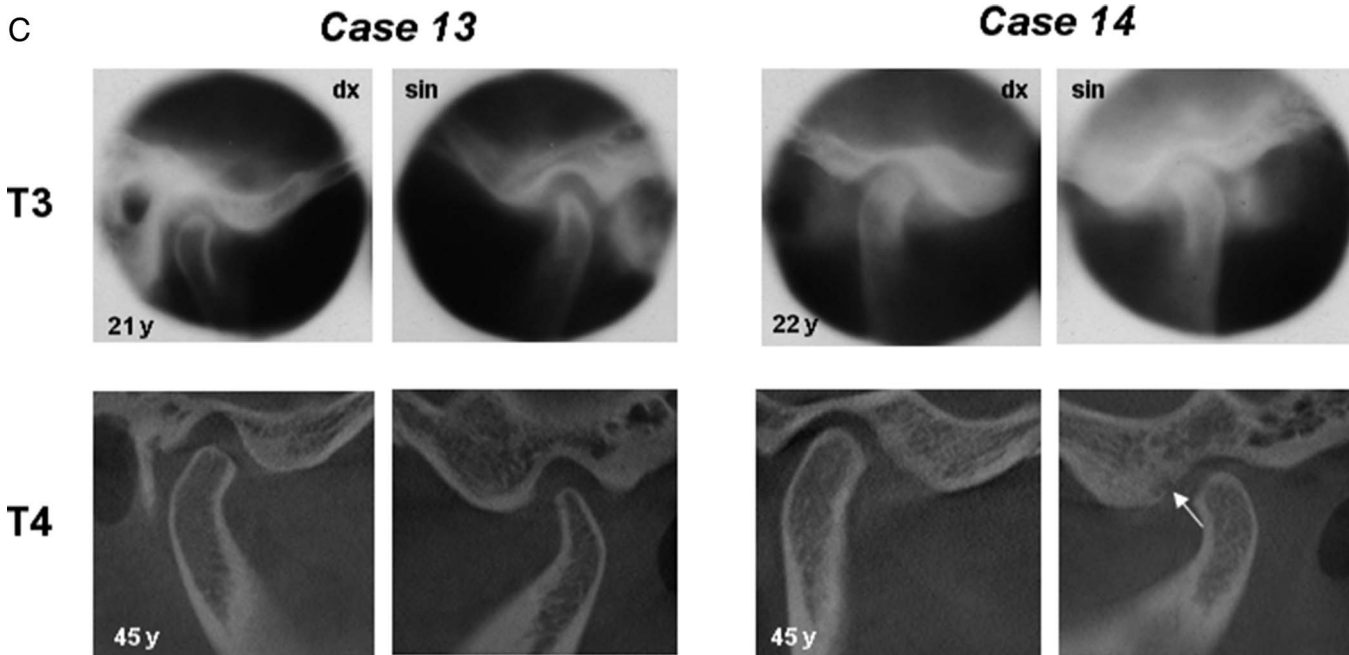


Figure 1. Continued.

In asymptomatic patients, TMJ osteoarthritis has been reported to be more common in Class II (43%) and Class III (20%) than in Class I (3%) malocclusions.²³ Furthermore, it has been shown that TMJ osteoarthritis is more frequent in older than in younger persons, thus being an age-related change.²⁴ A similar age dependency was also noted in our material: osteoarthritis was diagnosed at T3 in two (7%) joints and at T4 in five (18%) joints.

Previous studies have found a poor correlation between TMJ osteoarthritis and TMJ pain.^{22,25} The result of this study supports these findings, as none of the patients with TMJ osteoarthritis had TMJ pain. The poor correlation between CBCT findings of osteoarthritis and TMJ symptoms emphasizes the importance of evaluating the TMJs both radiographically and clinically. In our patients, TMJ pain was registered in only one TMJ with crepitus at T4. None of the patients had any TMJ locking or difficulties in chewing tough food. The results indicate that when TMJ symptoms were present, they were mild.

The clinical diagnosis of disc displacement was based on the RDC/TMD.¹⁰ As it has been proven by magnetic resonance imaging (MRI)²⁶ that a disc displacement without reduction can exist without any clinical signs or symptoms, clinical diagnostic procedures will underestimate the actual prevalence of disc displacements.²⁷ So in the absence of any MRI data, the present RDC/TMD clinical findings will not reveal all disc displacements.

A previous clinical Herbst study has shown that TMJ clicking, which was present before treatment, had

disappeared after therapy and remained absent during the first 12 months after treatment.⁵ Furthermore, two MRI investigations revealed that the position of the disc became relatively more retrusive by Herbst treatment.^{28,29} Thus, from the results of the aforementioned three studies it was concluded that Herbst therapy did not result in any adverse changes in TMJ disc position. On the contrary, it was suggested that Herbst treatment may possibly promote repositioning of a displaced disc in patients with anterior disc displacement.²⁸ In the present patients the prevalence of TMJ clicking was 11% (3/28 TMJs) at T3 and 25% (7/28 TMJs) at T4 (Table 3), and was thus of the same magnitude as that found in subjects representing normal populations.^{22,30,31}

Summarizing our results, there was no indication that any of the long-term follow-up findings on TMJ disorders were related to Herbst therapy.

CONCLUSIONS

- The TMJ findings 6 years and 32 years after Herbst treatment corresponded to those in the general population.
- In the very-long-term perspective, the Herbst appliance was not thought to be harmful to the TMJ.

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REFERENCES

1. Pancherz H, Ruf S. *The Herbst Appliance. Research-based Clinical Management*. London, UK: Quintessence Publishing Co Ltd; 2008.
2. Foucard JM, Pajoni D, Carpentier P, Pharaboz C. MRI study of the temporomandibular joint disk behavior in children with hyperpropulsion appliances. *Orthod Fr*. 1998;69:79–91.
3. Ruf S, Pancherz H. Long-term TMJ effects of Herbst treatment: a clinical and MRI study. *Am J Orthod Dentofacial Orthop*. 1998;114:475–483.
4. Ruf S, Pancherz H. Does bite-jumping damage the TMJ? A prospective longitudinal clinical and MRI study of Herbst patients. *Angle Orthod*. 2000;70:183–199.
5. Pancherz H, Anehus-Pancherz M. The effect of continuous bite jumping with the Herbst appliance on the masticatory system: a functional analysis of treated Class II malocclusions. *Eur J Orthod*. 1982;4:37–44.
6. Hansen K, Pancherz H, Petersson A. Long-term effects of the Herbst appliance on the craniomandibular system with special reference to the TMJ. *Eur J Orthod*. 1990;12:244–253.
7. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. *Am J Orthod*. 1982;82:104–113.
8. Ahmad M, Hollender L, Andersson Q, et al. Research diagnostic criteria for mandibular disorders (RDC/TMD): development of images analysis criteria and examiner reliability for image analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;107:844–860.
9. Carlsson GE, Helkimo M. Funktionell undersökning av tuggapparaten. In: Host JJ, Nygaard Östby B, Osvald O, eds. *Nordisk Klinisk Odontologi*. Copenhagen, Denmark: A/S Forlaget for faglitteratur; 1972:8-1-1–8-1-21.
10. Dworkin SF, LeResche I. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord*. 1992;6:301–355.
11. Zelle BA, Bhandari M, Sanches AI, Probst C, Pape HC. Loss of follow-up in orthodontic trauma: is 80% follow-up still acceptable? *J Orthop Trauma*. 2013;27:177–181.
12. Pancherz H, Bjerklín K, Lindskog-Stockland B, Hansen K. A 32-year follow-up study of Herbst therapy. A biometric dental cast analysis. *Am J Orthod Dentofacial Orthop*. 2014;145:15–27.
13. Pancherz H, Bjerklín K, Hashem K. Late adult skeletofacial growth after adolescent Herbst therapy. A 32-year longitudinal follow-up study. *Am J Orthod Dentofacial Orthop*. 2015. In press.
14. Hintze H, Wiese M, Wentzel A. Cone beam CT and conventional tomography for the detection of morphological temporomandibular joint changes. *Dentomaxillofac Radiol*. 2007;36:192–197.
15. John MT, Dworking SF, Mancl LA. Reliability of clinical temporomandibular disorder diagnoses. *Pain*. 2005;118:61–69.
16. Schmitter M, Ohlmann B, John MT, Hirsch C, Rammelsberg P. Research diagnostic criteria for temporomandibular disorders: a calibration and reliability study. *Cranio*. 2005;23:212–218.
17. Vanderas AP. Prevalence of craniomandibular dysfunction in children and adolescents: a review. *Pediatr Dent*. 1987;9:312–316.
18. Dibbets JM, van der Weele LT. Prevalence of structural bony changes in the mandibular condyle. *J Craniomandib Disord*. 1992;6:254–259.
19. dos Anjos Pontual ML, Freire JSL, Barbosa JMN, Frazao MAG, dos Anjos Pontual A, Fonseca da Silveria MM. Evaluation of bone changes in the temporomandibular joint using cone beam CT. *Dentomaxillofac Radiol*. 2012;41:24–29.
20. Magnusson T, Egermark I, Carlsson GE. A longitudinal epidemiologic study of signs and symptoms of temporomandibular disorders from 15 to 35 years of age. *J Orofac Pain*. 2000;14:310–319.
21. Vänman A, Agerberg G. Recurrent headaches and craniomandibular disorders in adolescents: a longitudinal study. *J Craniomandib Disord*. 1987;1:229–236.
22. Bakke M, Petersson A, Wiese M, Svanholt P, Sonnesson L. Bony deviations revealed by cone beam computed tomography of the temporomandibular joint in subjects without ongoing pain. *J Oral Facial Pain Headache*. 2014;28:331–337.
23. Krisjane Z, Urtane I, Krumina G, Ragovska I. The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study. *Int J Oral Maxillofac Surg*. 2012;41:690–695.
24. Widmalm SE, Westesson PL, Kim IK, Pereira FJ Jr, Lundh H, Tasaki MM. Temporomandibular joint pathosis related to sex, age, and dentition in autopsy material. *Oral Surg Oral Med Oral Pathol*. 1994;78:416–425.
25. Falconet G, Ludlow JB, Tyndall DA, Lim PF. Correlating cone beam CT results with temporomandibular joint pain of osteoarthritic origin. *Dentomaxillofac Radiol*. 2012;41:126–130.
26. Ribeiro RF, Tallents RH, Katzberg RW, et al. The prevalence of disc displacement in symptomatic and asymptomatic volunteers aged 6 to 25 years. *J Orofac Pain*. 1997;11:37–47.
27. Wiese M, Wenzel A, Hintze H, et al. Osseous changes and condyle position in TMJ tomograms: impact of RDC/TMD clinical diagnoses on agreement between expected and actual findings. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106:e52–e63.
28. Pancherz H, Ruf S, Thomalske-Faubert C. Mandibular articular disc position changes during Herbst treatment: A prospective longitudinal MRI study. *Am J Orthod Dentofacial Orthop*. 1999;116:207–214.
29. de Arruda Aida LA, Dominguez GC, Abrahao M, Yamashita HK, Vigorito JV. Effects of Herbst appliance treatment on temporomandibular joint disc position and morphology: a prospective magnetic resonance imaging study. *Am J Orthod Dentofacial Orthop*. 2009;136:412–424.
30. Dworkin SF, Huggins KH, LeResche L, et al. Epidemiology of signs and symptoms in temporomandibular disorders: clinical signs in cases and controls. *J Am Dent Assoc*. 1990;120:273–281.
31. Salé H, Bryndahl F, Isberg A. Temporomandibular joints in asymptomatic and symptomatic volunteers: a prospective 15-year follow-up clinical and MR imaging study. *Radiology*. 2013;267:183–194.