A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion

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This study investigated the treatment effects produced by two types of functional appliance, one primarily tooth-borne (the Herbst appliance) and one primarily tissue-borne (the FR-2 of Fränkel). Serial cephalometric radiographs from 45 patients who had been treated with the acrylic splint Herbst appliance and from 41 patients who had been treated with the FR-2 appliance were compared with serial radiographs of 21 untreated persons with Class II malocclusions. Treatment effects were identified through the use of a conventional cephalometric analysis. The results of this study indicated that both appliances had influenced the growth of the craniofacial complex in treated persons. Significant skeletal changes were noted in both treatment groups, with both groups showing an increase in mandibular length and in lower facial height, as compared with controls. Greater dentoalveolar treatment effects were noted in the group wearing the tooth-borne functional appliance than in those wearing the tissue-borne appliance. (AM J ORTHOD DENTOFAC ORTHOP 1990;98: 134-44.)

Various types of functional jaw orthopedic appliance are used to treat patients with Class II malocclusion. Although there is a wide variety of such appliances (e.g., activator, bionator, Herbst, Fränkel, orthopedic corrector, Bimler), there are many similarities among them. In general, any functional appliance designed to correct a Class II malocclusion has some component that produces a change in the position of the mandible. This alteration in mandibular posture can be produced in a variety of ways, depending on whether or not the appliance is primarily tooth-borne or tissue-borne. An appliance that is tooth-borne might be expected to have a greater dentoalveolar treatment effect than would an appliance that was tissue-borne, with only minimal contact of the teeth.

The FR-2 appliance of Fränkel and the Herbst appliance, two of the functional appliances that are often used in the correction of Class II malocclusion, are excellent examples of (1) an appliance that is primarily tissue-borne and (2) one that is primarily tooth-borne, respectively. Although several studies of treatment effects produced by both appliances have appeared separately in the literature, no direct comparison of these two therapies has been reported. A brief overview of these appliances is provided below.

The functional regulator of Fränkel

The functional regulator (FR-2) was developed by Fränkel[1-3] for use during the mixed- and early permanent-dentition stages of development to produce changes in anteroposterior, transverse, and vertical jaw relationships in persons with Class II malocclusion. Unlike other functional appliances, the Fränkel appliance uses the buccal vestibule as a base of operation. The vestibular shields and the lower labial pads of the appliance are designed to restrain the musculature and remove forces that would otherwise restrict skeletal and dental development. The appliance provides a framework against which the craniofacial muscles function, in order to promote more normal patterns of muscle activity.

The stimulus for mandibular repositioning with a Fränkel appliance is provided by the inferior border of the vestibular shield, the lower labial pads that touch the labial mucosa, and the lingual shield that touches the lingual mucosa. The pressure produced on the mucosa elicits a forward posturing of the mandible. The appliance usually is worn on a full-time basis for 18 to 24 months, after which time the appliance is worn on a part-time basis until fixed appliances are placed to align and detail the permanent teeth.

Although the Fränkel appliance is considered to be primarily a tissue-borne appliance, some dentoalveolar

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changes might also be expected to occur. In the maxillary arch, notches are placed in the deciduous teeth (when present) in the posterior area.[4] This notching allows for a positive seating of the appliance between the deciduous canine and the first deciduous molar and also between the deciduous second molar and the first permanent molar. An additional wire lies in the buccal groove of the upper first molar, serving as an occlusal rest. Thus some inhibition of the downward and forward movement of the upper posterior teeth might be anticipated when the FR-2 appliance is used. Little forward movement of the lower teeth should be observed, since no part of the FR-2 appliance contacts the mandibular dentition except for the lower lingual wires that lie passively on the cingula of the lower incisors.

One additional treatment effect of the FR-2 is the lateral expansion that occurs spontaneously.[5-6] Although no direct force is placed on the teeth to move them laterally, 4 to 6 mm of increase in maxillary arch width and 2 to 4 mm of increase in mandibular arch width are typically observed. This expansion may be due to the fact that the vestibular shields inhibit the cheek muscles from acting against the occlusion and thus allow for a greater role of the tongue in determining the lateral positioning of the teeth. Fränkel argues that the vestibular shields stimulate additional growth laterally by causing tension on the alveolar periosteum.[5]

The FR-2 appliance does produce a change in mandibular posture that may result in a change in mandibular growth. In addition, dentoalveolar changes that include dental arch expansion have been shown to occur. Presumably, some downward and forward inhibition of maxillary dental movement may also occur.

Acrylic splint Herbst appliance

The original type of banded Herbst appliance was introduced by Herbst[7] in the early 1900s. After achieving some initial popularity, the Herbst bite-jumping mechanism fell into disuse until it was reintroduced in the late 1970s by Pancherz.[8-10]

The Herbst appliance, like the FR-2, produces a forward repositioning of the mandible during function. This repositioning is achieved through the use of the Herbst bite-jumping mechanism, a telescoping rod that extends from the region of the upper first molar to the region of the lower first premolar. It is usually attached to the teeth directly through the use of bands or stainless steel crowns. Closure of the mandible can occur only in a protruded position.

We have modified the Herbst appliance by replacing the original banded design of Herbst with upper and lower acrylic splints that anchor the bite-jumping mechanism.[11-13] The maxillary acrylic splint can be removable or can be bonded in place, particularly if a rapid palatal expansion appliance or anterior brackets are connected to the splint. The mandibular splint is always removable.

Because the appliance is connected to the teeth, dentoalveolar treatment effects can be expected to occur both anteroposteriorly and vertically (e.g., distal movement of the upper posterior teeth, mesial movement of the lower anterior teeth). In contrast to the FR-2 appliance, acrylic splints allow no lateral movement of the teeth except when a rapid palatal expansion appliance is used in conjunction with the splints.

PREVIOUS STUDIES OF TREATMENT EFFECTS

Over the last decade, a number of clinical studies of functional appliance therapy have appeared in the orthodontic literature. The treatments that have been studied include the banded Herbst appliance[8-10] and the cast splint Herbst appliance, combined with headgear.[14] In general, these studies indicate that both skeletal and dentoalveolar treatment effects are produced by the Herbst appliance, including higher mandibular length increments, a distalization of the upper posterior teeth, and some mesial movement of the lower teeth.

Findings from previous studies of the Fränkel appliance are much less consistent, and conflicting results have been noted. McNamara et al.[15] note that the contradictions evident in the previous clinical studies of functional regulator therapy must be interpreted in light of many factors, such as the following:

Nature of the treated sample. Many previous clinical studies have been characterized by relatively small samples (e.g., 10 to 15 cases). Previous investigations also have been vague about the clinician's criteria for selection of patients for a given practitioner and the selection of films from a given patient. In addition, there has often been a wide range of ages during which treatment was started. With the exception of our previous study,[15] no equivalence of starting form between treatment and control groups has been demonstrated.

Nature of controls. Only a few studies[15-18] have used persons with untreated Class II malocclusion as controls. Many other studies either refer to Class I controls or present no control data whatsoever.

Variation in treatment technique. As mentioned earlier, Fränkel's treatment methods require notching of the posterior deciduous teeth. The studies of Creekmore and Radney,[19] Robertson,[20] and Schulhof and Engel[21] imply that their samples had no such notching.

Another factor that may be related to the effect of the appliance on the lower anterior teeth is the position of the lower labial pads of the FR-2 appliance. Pads positioned too far superior to the depth of the vestibule

Table I. Distribution by age at start of treatment (before application of last exclusionary rule)

Age (yr)	Herbst appliance (n = 81)	Fränkel appliance (n = 100)
6	0	1
7	2	4
8	3	15
9	2	17
10	5	18
11	10	21
12	22	15
13	17	7
14	11	2
15	5	0
16	2	0
17	0	0
18	2	0

or too far anterior to the mandibular alveolus can lead to incisor proclination because the pads have a lip bumper effect on the orbicularis oris muscle rather than the desired restricting effect on the activity of the mentalis muscle.

Choice of measurement. Most studies of treatment effects of functional appliances have used many different sets of landmarks and variables. Definitions of mandibular length and lower anterior facial height vary widely, as do strategies for measuring change.

All cases analyzed in this study represent a sample of patients treated with a reasonably consistent orthodontic technique. The basis for assessment of treatment effect is a fairly well-matched group of untreated individuals on whom longitudinal cephalometric records have been taken. However, because the data presented in this study were gathered retrospectively, this study is still subject to possible unintentional practitioner bias, a lack of systematic gathering of treatment records on all potential patients, and other familiar limitations of any retrospective study design.

This study compared two popular functional appliances with different technical designs, contrasting treatment effects produced by both a tooth-borne appliance and one that is primarily tissue-borne.

MATERIALS AND METHODS

Three samples were considered in this study. Records of patients who had been treated with the functional regulator (FR-2) of Fränkel were compared with records of patients treated with the acrylic splint Herbst appliance and also with records of untreated children with Class II malocclusion. Records of the Fränkel and control patients were part of the samples previously described and evaluated by McNamara et al.[15]

Groups studied and exclusion criteria

Fränkel sample. Records of approximately 150 patients who finished Fränkel therapy during a two-year period were submitted by eight private practitioners.[15] The practitioners *withheld* cases from the study in which one or more of the following conditions was found to apply:

1. The clinician judged that the patient's cooperation was poor. This judgment was based not on the success of treatment but, rather, on reports from parents or patients or on the lack of evidence of hyperemia for many of the soft tissues of the oral region. To be included in this study, the patients must have been judged to have worn the appliance for at least 18 hours a day during the first 18 months of the study period.
2. The patient did not have a Class II malocclusion, that is, at least an end-to-end molar and canine relationship.
3. The patient had a retroclination of the upper incisors, as in a Class II, Division 2 malocclusion.
4. The initial lateral headfilm had been taken more than 2½ months before the onset of Fränkel treatment, or the second film had been taken more than 1 month after the end of Fränkel treatment. These latter cases were eliminated because the cephalometric records included a substantial amount of growth during a period when the appliance was not being worn.

When the records from the practitioners had been received, once again the exclusionary rules described above were applied, and 25 of the 150 cases were eliminated, chiefly because of the length of time before or after treatment that the film had been taken. We then applied two additional exclusionary criteria, eliminating an additional 25 cases. These criteria were as follows:

1. The anatomic landmarks necessary for the analysis were not readily identifiable on the radiographs (20 cases).
2. There was a 2 to 3 mm difference in successive films of the distance between the anterior border of the atlas and the closest point of the anterior border of the ramus, indicating a difference in mandibular position (posture) between the two films (5 cases).

The application of the above exclusionary rules reduced the Fränkel sample to 100 patients. Then an additional exclusionary rule was applied, which was that Fränkel therapy had to have been initiated after the time the patient had reached 10 years 6 months of age but before 13 years 1 month of age. The purpose of this final exclusionary rule was to ensure that groups were reasonably matched as to age at the onset of treatment. In general, Fränkel therapy is initiated at an earlier average age than is Herbst therapy (Table I). This

Table II. Comparison of starting forms

Form	Herbst (n = 45)		Fränkel (n = 41)		Control (n = 21)		Significance		
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	Herbst-Fränkel	Herbst-Control	Fränkel-Control
Maxillary skeletal									
Condylion-ANS (mm)	94.0	3.7	92.4	5.1	91.8	3.8	NS	NS	NS
Midfacial length (Co-point A) (mm)	91.5	3.7	90.4	5.0	89.8	3.7	NS	NS	NS
SNA angle	82.6°	3.3°	80.8°	3.7°	81.2°	2.6°	*	NS	NS
Nasion perp/point A (mm)	0.2	3.5	−0.2	2.3	−0.3	3.2	NS	NS	NS
Maxillary dental									
Upper molar horizontal (mm)	25.9	3.5	25.3	3.0	26.0	2.7	NS	NS	NS
Upper molar vertical (mm)	44.5	2.7	43.1	2.5	43.3	2.6	*	NS	NS
Upper incisor/point A (mm)	5.5	2.1	5.1	2.0	4.9	1.7	NS	NS	NS
Upper incisor horizontal (mm)	57.6	4.4	56.4	4.4	57.0	4.0	NS	NS	NS
Upper incisor vertical (mm)	50.7	3.4	50.6	2.9	50.4	4.4	NS	NS	NS
Mandibular dental									
Lower molar horizontal (mm)	31.5	2.2	32.0	2.2	31.9	2.5	NS	NS	NS
Lower molar vertical (mm)	31.9	2.5	31.2	2.0	31.8	1.6	NS	NS	NS
Lower incisor horizontal (mm)	8.1	2.8	8.6	2.7	7.6	3.1	NS	NS	NS
Lower incisor vertical (mm)	42.1	3.3	41.7	3.3	42.0	2.5	NS	NS	NS
Mandibular skeletal									
Mandibular length (Co-Gn) (mm)	112.6	5.5	110.3	4.4	110.7	3.4	*	NS	NS
Pogonion/N perpendicular (mm)	−8.7	6.3	−9.5	4.6	−9.5	5.7	NS	NS	NS
Facial plane angle	85.4°	3.4°	85.0°	2.3°	85.0°	3.0°	NS	NS	NS
SNB angle	76.7°	3.3°	75.0°	3.5°	75.6°	4.7°	*	NS	NS
ANB angle	5.9°	2.1°	5.9°	1.7°	5.7°	1.9°	NS	NS	NS
Vertical									
Anterior facial height (ANS-Me) (mm)	65.0	4.8	64.2	4.2	65.2	3.4	NS	NS	NS
Posterior facial height (Co-Go) (mm)	54.7	4.1	52.7	3.3	52.9	3.1	*	NS	NS
Corpus length (Go-Po) (mm)	73.5	3.6	71.9	3.8	71.9	2.6	*	NS	NS
SN plane	7.6°	2.8°	9.0°	2.7°	8.2°	2.0°	*	NS	NS
Palatal plane	1.6°	3.5°	0.9°	3.0°	1.4°	2.5°	NS	NS	NS
Occlusal plane	10.0°	3.8°	10.1°	3.1°	10.3°	3.7°	NS	NS	NS
Mandibular plane angle	24.0°	5.3°	25.4°	4.8°	25.0°	3.7°	NS	NS	NS
Facial axis angle	−1.5°	3.3°	−2.6°	4.7°	−2.3°	2.6°	NS	NS	NS

NS = not significant.
$*p < 0.05$.
$**p < 0.01$.
$***p < 0.001$.

exclusionary rule eliminated most of the younger Fränkel patients and, as will be described below, many of the older Herbst patients.

The application of the final exclusionary rule to the Fränkel sample reduced the size of the sample to 41 cases (22 girls and 19 boys). The average age of the patients in the sample was 11 years 6 months at the time of the initial film.

Herbst sample. Cephalometric records of 138 patients treated with the acrylic splint Herbst appliance were obtained from the private practices of three of the investigators involved in this study. These cases were treated according to the protocols described by McNamara and Howe.[13]

All records of patients who had finished Herbst therapy during a 2-year period in the three private practices were considered. The same exclusionary rules that applied to the Fränkel cases were applied to this sample:

1. Only two cases were excluded because of poor patient cooperation.

2. Five cases were excluded because the patients did not have a Class II malocclusion—that is, at least an end-to-end molar or canine relationship. Several patients were technically Class I patients, as defined by the exclusionary rules of this study.

3. No cases were eliminated because of severe retroclination of the upper incisors.

4. The biggest reason for exclusion from this study was the unavailability of lateral headfilms taken less than 2½ months before the onset of Herbst treatment

Table III. Actual increments in treatment intervals: Herbst, 12 months; Fränkel, 21 months; control, 22 months

Form	Herbst (n = 45)		Fränkel (n = 41)		Control (n = 21)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Maxillary skeletal						
Condylion-ANS (mm)	0.8	1.2	2.7	1.8	2.4	1.5
Midfacial length (Co-point A) (mm)	0.7	1.4	2.3	1.5	2.4	1.4
SNA angle	−0.2°	1.8°	−0.6°	1.2°	0.1°	1.4°
Nasion perpendicular/point A (mm)	−0.4	1.4	−0.5	1.2	0.3	1.1
Maxillary dental						
Upper molar horizontal (mm)	−1.3	1.6	1.3	2.0	2.4	1.7
Upper molar vertical (mm)	0.5	1.1	2.9	2.4	3.0	1.4
Upper incisor/point A (mm)	−0.7	1.4	−0.9	1.6	0.3	1.1
Upper incisor horizontal (mm)	−0.6	2.0	0.1	2.4	1.9	1.7
Upper incisor vertical (mm)	1.9	1.2	2.3	1.4	2.0	1.3
Mandibular dental						
Lower molar horizontal (mm)	1.4	1.1	0.1	1.2	0.9	1.2
Lower molar vertical (mm)	1.4	1.2	3.0	1.9	1.4	1.0
Lower incisor horizontal (mm)	1.6	1.7	−0.1	1.9	−0.6	1.0
Lower incisor vertical (mm)	−1.0	1.5	1.3	1.8	1.7	1.2
Mandibular skeletal						
Mandibular length (Co-Gn) (mm)	4.4	1.4	7.6	3.7	4.1	2.5
Pogonion/N perpendicular (mm)	2.3	2.4	2.1	2.7	0.8	2.2
Facial plane angle	1.3	1.2	1.4	1.3	0.6	1.2
SNB angle	1.7°	1.6°	1.1°	1.2°	0.2°	1.0°
ANB angle	−1.9°	1.1°	−1.7°	1.3°	−0.1°	0.9°
Vertical						
Anterior facial height (ANS-Me) (mm)	1.7	2.1	3.9	2.6	1.8	1.6
Posterior facial height (Co-Go) (mm)	3.1	1.5	5.4	2.9	2.5	1.9
Corpus length (Go-Po) (mm)	1.7	2.1	3.4	2.4	3.0	1.7
SN plane	−0.2°	0.8°	0.2°	0.7°	0.2°	1.4°
Palatal plane	−0.7°	1.3°	−0.5°	1.1°	−0.6°	1.3°
Occlusal plane	2.8°	3.2°	0.4°	3.1°	−1.7°	2.9°
Mandibular plane angle	−0.3°	1.5°	−0.6°	1.6°	−0.6°	1.4°
Facial axis angle	0.8°	1.6°	0.6°	1.4°	0.2°	0.9°

and less than 1 month after the end of Herbst treatment. In all, 28 cases were eliminated for this reason.

5. Six cases were eliminated because the anatomic landmarks necessary for the analysis were not readily identifiable on the radiographs.

6. Seven cases were eliminated because of obvious errors in mandibular position in the pretreatment or posttreatment films.

In addition, three cases were eliminated because the maxillary splint had been bonded in place before the initial film was taken.

The application of these exclusionary rules eliminated 57 of the cases, leaving 81 Herbst cases for consideration. The application of the last exclusionary rule, in which all cases beginning treatment after 10 years 6 months of age but before 13 years 1 month of age eliminated an additional 36 cases, giving a remaining sample size of 45 Herbst patients (18 girls and 27 boys). The average age of this sample at the time of the first film was 12 years 0 months.

Control sample. Changes over the course of treatment for Fränkel and Herbst patients were compared with changes recorded for a sample of untreated Class II children from The University of Michigan Elementary and Secondary School Growth Study.[22] These control subjects included all of the dental Class II subjects in the Michigan sample for whom longitudinal cephalometric records were available for the age ranges studied. The subjects in the control sample were subjected to the exclusionary rules applied to the treatment sample, except for parameters that were limited to treated patients. This plan resulted in the selection of records for 41 cases of untreated Class II malocclusion.

When the exclusionary rule was applied regarding the age of the subject at the time of the initial film, a control sample of 21 cases (13 girls and 8 boys) was

Table IV. Annualized increments

Form	Herbst (n = 45)		Fränkel (n = 41)		Control (n = 21)		Significance		
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	H-F	H-C	F-C
Maxillary skeletal									
Condylion-ANS (mm)	0.9	1.4	1.6	1.0	1.3	0.8	**	NS	NS
Midfacial length (Co-point A) (mm)	0.8	1.5	1.4	0.9	1.3	0.7	**	*	NS
SNA angle	−0.4°	1.3°	−0.4°	0.7°	0.0	0.8	NS	NS	NS
Nasion perpendicular point A (mm)	−0.5	1.2	−0.3	0.7	0.2	0.8	NS	**	NS
Maxillary dental									
Upper molar horizontal (mm)	−1.4	1.9	0.7	1.1	1.3	0.7	***	***	NS
Upper molar vertical (mm)	0.5	1.3	1.6	1.0	1.6	0.6	***	***	NS
Upper incisor/point A (mm)	−0.8	1.5	−0.7	1.1	0.2	0.5	NS	**	**
Upper incisor horizontal (mm)	−0.5	2.1	−0.1	1.5	0.9	0.7	NS	**	*
Upper incisor vertical (mm)	1.9	1.2	1.3	0.7	1.1	0.7	**	***	NS
Mandibular dental									
Lower molar horizontal (mm)	1.4	1.3	0.1	0.7	0.5	0.7	***	***	NS
Lower molar vertical (mm)	1.3	1.5	1.7	0.9	0.8	0.5	NS	NS	**
Lower incisor horizontal (mm)	1.6	3.2	0.1	1.1	−0.4	0.5	***	***	NS
Lower incisor vertical (mm)	−1.1	1.6	0.6	0.9	0.9	0.5	***	***	NS
Mandibular skeletal									
Mandibular length (Co-Gn) (mm)	4.8	2.3	4.3	1.3	2.1	1.0	NS	***	***
Pogonion/N perpendicular (mm)	2.7	3.4	1.2	1.5	0.3	0.9	**	***	NS
Facial plane angle	1.6°	1.7°	0.8°	0.7°	0.3°	0.5°	**	***	NS
SNB angle	1.7°	1.7°	0.6°	0.7°	0.1°	0.5°	**	***	NS
ANB angle	2.1°	1.6°	−1.0°	0.7°	−0.1°	0.5°	***	***	**
Vertical									
Anterior facial height (ANS-Me) (mm)	1.8	1.9	2.2	1.1	1.0	0.8	NS	*	**
Posterior facial height (Co-Go) (mm)	3.4	2.0	3.1	1.4	1.3	0.9	NS	***	***
Corpus length (Go-Po) (mm)	1.8	1.6	1.9	1.1	1.6	0.7	NS	NS	NS
SN plane	−0.1°	0.6°	−0.1°	0.5°	0.1°	0.6°	NS	NS	NS
Palatal plane	−0.7°	1.4°	−0.3°	0.7°	−0.4°	0.6°	NS	NS	NS
Occlusal plane	2.9°	3.5°	0.4°	1.9°	−0.9°	1.2°	***	***	NS
Mandibular plane angle	−0.3°	2.1°	−0.4°	1.0°	−0.3°	0.7°	NS	NS	NS
Facial axis angle	0.8°	1.6°	0.4°	0.8°	0.1°	0.5°	NS	*	NS

NS, Not significant.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

identified. The average age of this sample was 11 years 1 month at the time of the first observation.

Method of analysis

Each cephalometric headfilm was traced by two investigators to verify anatomic outlines and landmark placements. Landmark locations were then digitized with a Summagraphics digitizing tablet.

The effect of functional appliance treatment on the growth of the craniofacial region was determined by use of a conventional cephalometric analysis that is an extension of that devised by McNamara.[23] This analysis comprises a predetermined set of measurements of angles and distances that are applied to each cephalometric tracing. The angular and linear measurements are listed in Tables II to IV. The series of measurements were the same conventional measures used in the study by McNamara et al.[15]

Statistical methods. An analysis of variance initially was carried out among all three groups. If a level of significance less than 0.05 was observed, Scheffe's method of multiple comparisons was used to determine differences among groups.

Error of the method

To determine the accuracy of the method, 10 cephalograms were retraced a second time. Thirty landmarks, including those used in this study, were digitized again and the variables considered in this study were recalculated. The error was within acceptable limits.

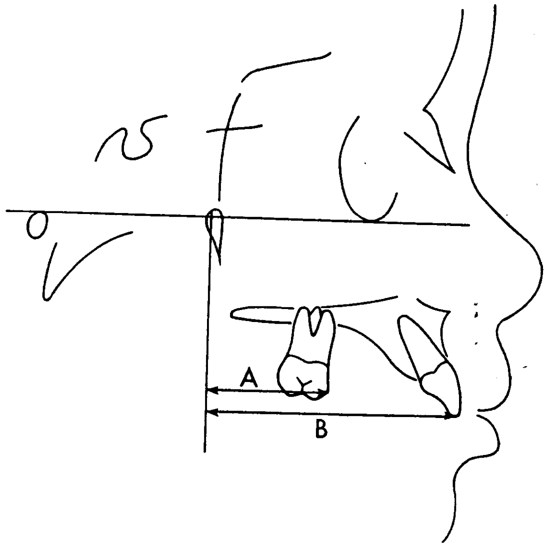

Fig. 1. Determination of changes of horizontal position of upper first molar and upper central incisor. **A**. Distance from mesial surface of upper molar to pterygoid vertical. **B**, Distance from tip of upper incisor to pterygoid vertical. (From McNamara JA Jr, Brookstein FL, Shaughnessy TG. AM J ORTHOD 1985;88:91-110.)

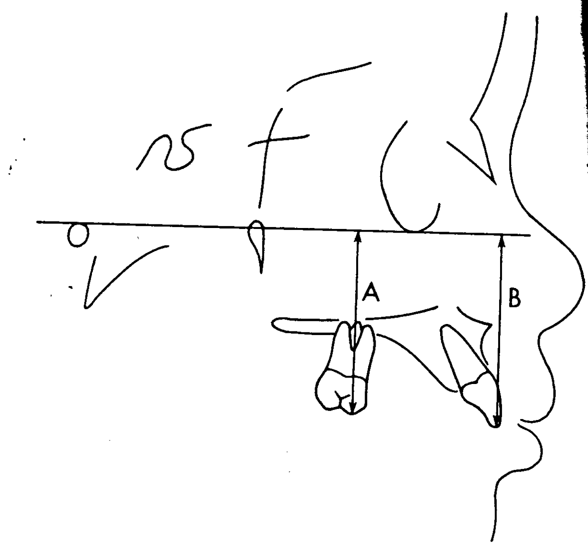

Fig. 2. Determination of changes of vertical position of the upper first molar **(A)** and the upper central incisor **(B)**. (From McNamara JA Jr, Brookstein FL, Shaughnessy TG. AM J ORTHOD 1985;88:91-110.)

For example, the average difference between the duplicate measurement of maxillary length was 0.3 mm (SD 0.6 mm), and for mandibular length it was 0.1 mm (SD 0.5 mm). The difference in lower anterior facial height was 0.3 mm (SD 0.7 mm). The difference in the measurement from point A to the nasion perpendicular was 0.1 mm (SD 0.8 mm). The SNA angle (sella-nasion-point A) varied 0.1° (SD 0.6°) and the SNB angle (sella-nasion-point B) varied 0.1° (SD 0.4°).

RESULTS

Comparisons of starting forms (Table II)

As in our previous study,[15] we examined the equivalence of starting forms by comparing pretreatment skeletal and dental cephalometric values.

Skeletal measures. There were no statistically significant differences in starting forms with respect to any of the 17 horizontal or vertical skeletal measures in the treatment groups as compared with the forms of the control group. However, there were some differences when the Herbst treatment group was compared with the Fränkel treatment group. Generally, the craniofacial measures of the Herbst patients were slightly larger, perhaps reflecting the slightly older average age in this group at the beginning of treatment. The Fränkel group had a slightly more retrusive chin position, as indicated by a slightly more acute SNB angle and a shorter mandibular length as measured from condylion to gnathion. This difference in length may have been associated with a larger corpus length in the Herbst group. The Herbst group also had a slightly longer posterior facial height, as measured from condylion to gonion (54.7 mm vs. 52.7 mm).

Dentoalveolar measures. There was no significant difference in any of the dental measures among the two treatment groups and the control group. The only statistically significant difference was in the vertical position of the upper first molar: the upper molar in the Herbst group was located in a slightly more inferior position than in the Fränkel group.

Overall comparison. We considered these groups to be as well-matched as is feasible in any study short of a fully randomized prospective clinical trial. Of the 75 comparisons considered, only 7 of the variables showed any statistically significant differences, and several of the statistically significant variables were measures of the same anatomic relationships: posterior facial height or the anteroposterior position of the chin.

Analysis of treatment effects (Tables III and IV)

The analysis of the effects of treatment used the same variables that were used to compare starting forms. Because the interval between the pretreatment and posttreatment films varied among the three groups analyzed, two types of data are presented. Table III shows the increments of growth for the three groups without any adjustment for elapsed time between films. Table IV shows increments that have been annualized

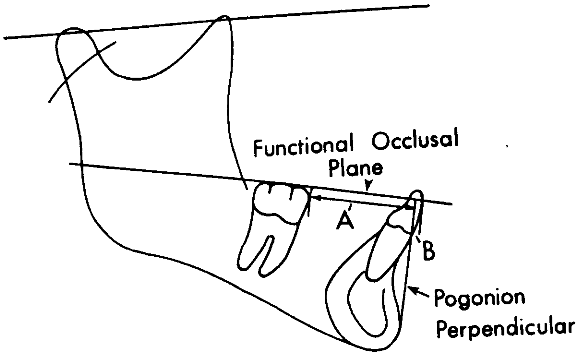

Fig. 3. Determination of horizontal position of lower molar relative to the constructed pogonion perpendicular. Mandibular plane is established and perpendicular line is drawn from the orientation line to pogonion. **A,** Distance from mesial contact point of lower first molar to pogonion perpendicular. **B,** Distance from most anterior point on lower incisor to pogonion perpendicular. (From McNamara JA Jr, Brookstein FL, Shaughnessy TG. Am J Orthod 1985;88:91-110.)

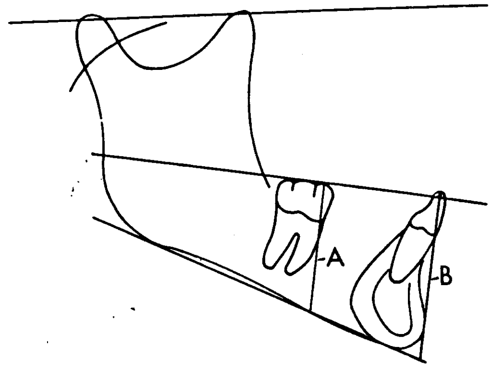

Fig. 4. Determination of vertical position of lower dentition. **A,** Functional occlusal plane is constructed and perpendicular line is drawn through most superior aspect of mesiobuccal cusp of the lower first molar to its intersection with the mandibular plane. **B,** Position of lower incisor is determined by drawing line perpendicular to functional occlusal plane through incisal contact point to intersection with the mandibular plane. (From McNamara JA Jr, Brookstein FL, Shaughnessy TG. Am J Orthod 1985;88:91-110.)

to provide a more direct comparison of biologic activity. Although the annualized values for the Fränkel and control groups were obviously less than the actual values, the mean annualized increments (Table IV) for the Herbst patients tended to be slightly greater than the corresponding actual increments (Table III). The median duration for treatment of these patients was less than the mean of 1 year.

Maxillary skeletal relationships. In the four maxillary skeletal measures considered, there were no significant differences between the Fränkel treatment group and the controls. However, there was a statistically significant difference in midfacial length increments when the Herbst appliance group was compared with controls. Even greater differences were observed when the Herbst group was compared with the Fränkel group. While these differences were statistically significant ($p < 0.05$), the actual differences in increments were less than 1 mm, on the average. Thus, neither therapy had a clinically meaningful effect on the growth and development of the maxillary complex.

Maxillary dentition. The change in the horizontal position of the upper molar was measured by dropping a line from the most posterosuperior point on the pterygomaxillary fissure perpendicular to the Frankfort horizontal (Fig. 1). A direct linear measurement was then made from the pterygoid perpendicular to the mesial contact point of the upper first molar. In the control group, the upper first molar moved forward an average of 1.3 mm on an annualized basis (Table IV). The opposite movement was observed in the Herbst group, in which the upper first molar moved backward (-1.4 mm), causing a net difference of 2.7 mm per year in the upper first molar position. This change is significant, both statistically and clinically, since the average change in molar position produced in Class II correction is approximately 6 mm. No statistically significant difference in changes of horizontal position of the upper first molar was observed between patients wearing the Fränkel appliance and the controls.

The vertical movement of the upper first molar was measured by determining the distance from the tip of the mesial cusp of the upper first molar to the Frankfort horizontal (Fig. 2). The upper first molar of both the Fränkel group and the controls moved inferiorly an average of 1.6 mm on an annualized basis (Table IV), in contrast to the average movement of the upper first molar in the Herbst group, which was reduced to 0.5 mm/yr, indicating a restrictive effect of the acrylic splints of the Herbst appliance on the eruption of the upper first molar.

Statistically significant changes in upper incisor position were observed in both treatment groups as compared with controls. The upper incisor in the control group moved forward an average of 0.9 mm/yr relative to the pterygoid vertical; the same value was -0.1 mm/yr in the Fränkel group and -0.5 mm/yr in the Herbst group. The vertical movement in the upper incisor was greater in the Herbst group than in the Fränkel group or in the controls.

Mandibular dental relationships. The average horizontal movement of the lower molar and lower incisor was measured by drawing a line perpendicular to the mandibular plane through pogonion (Fig. 3). Measurements were made from the mesial contact point of the lower molar and the facial surface of the lower incisor to the constructed pogonion perpendicular.[15] A forward movement of the lower molar or lower incisor relative to the pogonion perpendicular was reported as a positive value. There was no significant difference in the average horizontal molar movement when the Fränkel group was compared with the controls. However, there was a statistically significant ($p < 0.001$) greater movement of the lower molar (1.4 mm) in the Herbst group relative to the movement of the same tooth in the Fränkel group (0.1 mm) or in the controls (0.5 mm).

The vertical movement of the lower molar was measured by the perpendicular distance relative to the functional occlusal plane through the tip of the mesial cusp to the intersection of the mandibular plane (Fig. 4). This measure indicated that only the Fränkel group had statistically ($p = <0.01$) greater vertical movement in the first molar region.

The horizontal movement of the lower incisor was measured relative to a line drawn perpendicular to pogonion and projected along the mandibular plane (Fig. 3). According to this method of measurement, there was an average of 1.5 mm greater forward movement of the tip of the lower incisor in the Herbst group than in the Fränkel group and 2.0 mm greater forward movement in the Herbst group than in the controls (Table IV).

The vertical movement of the lower incisor was measured relative to the distance from the lower incisor tip to the mandibular plane (Fig. 4). There was no signficant difference in lower incisor movement when the Fränkel group (0.6 mm) was compared to the controls (0.9 mm). An average movement in the opposite direction (− 1.1 mm) was observed in the Herbst group, an indication of the downward and forward tipping of the lower incisor during treatment.

Mandibular skeletal relationships. As measured from condylion to gnathion, mean mandibular length in the control group increased an average of 2.1 mm/yr during the treatment period; in the Herbst patients the measurement increased by 4.8 mm/yr and in the Fränkel patients, 4.3 mm/yr, values statistically significant with respect to the same measurement from the controls. Differences in treatment effects were not noticeable between the Herbst and Fränkel groups when other measurements were compared. The chin point (pogonion) advanced an average of 2.7 mm/yr in patients treated with the Herbst appliance. This change contrasts with the average values for the Fränkel patients (1.2 mm/yr) and the controls (0.3 mm/yr). Other measures of horizontal change, such as the facial plane angle and the SNG angle, were greater in the Herbst group than in the Fränkel or control groups (Table III and IV).

Vertical dimension. Lower anterior facial height, as measured from anterior nasal spine to menton, increased an average of 1 mm a year in the untreated Class II sample (Table IV). Lower anterior facial height increased an average of 2.2 mm in the Fränkel group and 1.8 mm in the Herbst group. Posterior facial height increases were also observed in the controls (Tables III and IV). No significant differences were observed between either of the treatment groups or the control group with regard to corpus length, sella-nasion plane angle, palatal plane angle, or mandibular plane angle, the latter three angles formed with the Frankfort horizontal. A slight increase in the occlusal plane angle measurement for the Herbst group was the only statistically significant difference observed.

DISCUSSION

The results of this study suggest that both the acrylic-splint Herbst appliance and the FR-2 appliance of Fränkel produce skeletal and dentoalveolar treatment effects on the growing craniofacial complex. These effects are not uniformly distributed but, rather, have specific target areas, depending on the appliance used.

In general, neither the Herbst nor the Fränkel appliance had a profound effect on the growth of the maxillary complex. In none of the four variables considered for this region was the effect produced by the Fränkel appliance statistically different from that observed for the controls. On the other hand, the Herbst appliance had a slight (0.5 mm) effect on the position to point A. The movement of point A may be a reflection of the spontaneous lingual tipping of the upper incisor that occurs during Herbst appliance treatment. The findings of this study agree with those of Pancherz regarding treatment with the Herbst appliance.[8,9]

The effects of the two therapies on the movement of the upper first molar were quite different. While there was no discernible difference in vertical or horizontal movement between the Fränkel group and the untreated controls, profound treatment effects were observed when the Herbst cases were analyzed and compared with the other two groups. The Herbst appliance apparently prevented the vertical eruption of the upper first molar by an average of almost 1 mm/yr (0.5 mm/yr versus 1.6 mm/yr in the other two groups). In addition, the average 1.4 mm/yr posterior movement of the upper first molar observed in the Herbst appliance group was in contrast to the average 1.3 mm/yr forward movement observed in the control group and a 0.7 mm/yr forward movement observed in the Fränkel group. Similar findings on patients treated with the banded Herbst appliance were reported by Pancherz.[4-6]

A lingual tipping of the upper incisor was observed in both the Fränkel and Herbst appliance groups. This finding is quite interesting because the Fränkel appliance has a labial wire that touches the upper anterior region, while the Herbst appliance has no such wire. Thus the role of the upper labial wire of the Fränkel appliance in producing lingual tipping of the upper incisors is open to question.

A greater mean treatment effect was detected in the region of the mandibular molar in those cases that had been treated with the Herbst appliance than in those treated with the Fränkel appliance. An average difference of 1 mm more forward movement was observed in the Herbst group, compared with the Fränkel and control groups. In contrast, more vertical eruption was observed on an annual basis in the lower molar region among the Fränkel group (1.7 mm) and the Herbst group (1.3 mm) than in the control group (0.8 mm).

The Herbst appliance also had a greater treatment effect in the lower incisor region than did the Fränkel appliance. No statistical difference in mean lower incisor horizontal or vertical movement could be found between the Fränkel group and the control group, based on the methods of measurement used in this study. In contrast, the facial surface of the lower incisor moved 2 mm more anteriorly in the Herbst group than in the controls. There was also a drop in the vertical position of the lower incisor in the Herbst group, probably owing to lower incisor anterior tipping.

Accelerated increments of mandibular length were observed in the Herbst and Fränkel groups. Whereas mandibular length in the control group increased an average of 2.1 mm on an annualized basis, in the Herbst appliance group it increased an average of 4.8 mm, while in the Fränkel group it increased an average of 4.3 mm. However, this increase in mandibular length was expressed more anteriorly in the Herbst group (2.7 mm) than in the Fränkel group (1.2 mm). This difference in position change was associated with an increased vertical dimension produced by the Fränkel appliance.

Significant increases in lower anterior facial height were observed in both the Fränkel and the Herbst cases. The mean treatment effect of the Fränkel and Herbst cases was 2.2 and 1.8 mm/yr, respectively. Lower anterior facial height increased an average of 1.0 mm/yr in the control group. Similar differences were observed in both treatment groups in posterior facial height. In neither treatment group was an increase or decrease in the mandibular plane angle noted, and only in the Herbst appliance group was there a significant mean change in the facial axis angle.

Thus it appears that craniofacial growth can be altered significantly in specific dental and skeletal areas of the craniofacial complex by both the Herbst appliance and the Fränkel appliance. If the two appliance systems studied represent generic tissue-borne and tooth-borne functional appliances, one can conclude (as expected) that greater dentoalveolar changes are produced in patients wearing a functional appliance that is tooth-borne than in patients wearing primarily tissue-borne appliances. It should also be noted that both functional appliance systems produced significant mean increases in mandibular length and lower anterior facial height when the effects were examined on an annualized basis. However, it should be stressed that the interval between films of patients treated with the Fränkel appliance in this study averaged 21 months in comparison with the 12 months for the Herbst group. Thus the actual growth increments reported in Table III demonstrate a much more sustained effect through the use of the Fränkel appliance in comparison with the other treatment method.

SUMMARY AND CONCLUSIONS

A cephalometric study of treatment effects was carried out in 45 patients who had been treated with the acrylic-splint Herbst appliance, 41 treated with the Fränkel (FR-2) appliance, and 21 untreated persons—all individuals who had Class II malocclusion at the beginning of treatment. All subjects were between 10 years 6 months of age and 13 years 0 months at the time of the first cephalometric observation. Growth data were reported both in actual increments and in annualized increments, since the elapsed time between films varied with the treatment used.

This study demonstrated that both the Herbst appliance and the Fränkel appliance have measurable treatment effects in dental and skeletal elements of the face. Both produced increases in mandibular length and varying increases in lower anterior facial height. Greater dentoalveolar effects were observed with the Herbst appliance than with the Fränkel appliance.

This clinical study considered only specific skeletal and dental measures as observed cephalometrically. It does not evaluate the relative effect of the two functional appliance treatments on the soft tissue components of the craniofacial region. These factors must also be considered when one selects a specific type of functional appliance treatment for a given patient.

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REFERENCES

1. Fränkel R. The theoretical concept underlying the treatment with functional correctors. Trans Eur Orthod Soc 1966;42:233-54.
2. Fränkel R. The treatment of Class II, division 1 malocclusion with functional correctors. AM J ORTHOD 1969;55:265-75.
3. Fränkel R. Technik und Handhabund der Funktionregler. Berline: VEB Verlad Volk und Gesundheit, 1976.
4. McNamara JA Jr, Huge SA. The Fränkel appliance (FR-2): Model preparation and appliance construction. AM J ORTHOD 1981;80:478-97.
5. Fränkel R. Decrowding during eruption under the screening influence of vestibular shields. AM J ORTHOD 1974;65:372-406.
6. McDougall P, McNamara JA Jr, Dierkes JM. Arch width development in Class II patients treated with the Fränkel appliance. AM J ORTHOD 1982;82:10-22.
7. Herbst E. Atlas und Gründriss der Zahnärztlichen Orthopädie. München: JF Lehmenn Verlag, 1910.
8. Pancherz H. Treatment of Class II malocclusion by jumping the bite with the Herbst appliance: a cephalometric investigation. AM J ORTHOD 1979;76:423-42.
9. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment: a cephalometric investigation. AM J ORTHOD 1983;83:104-13.
10. Pancherz H. The Herbst appliance: its biological basis and clinical management. AM J ORTHOD 1985;87:1-20.
11. Howe RP. The Herbst appliance: an alternative design using a bonded splint. J Clin Orthod 1982;16:663-7.
12. McNamara JA Jr. Fabrication of the acrylic splint Herbst appliance. AM J ORTHOD DENTOFAC ORTHOP 1988;94:10-8.
13. McNamara JA Jr, Howe RP. Clinical management of the acrylic splint Herbst appliance. AM J ORTHOD DENTOFAC ORTHOP 1988;94:142-9.
14. Wieslander L. Intensive treatment of severe Class II malocclusions with a headgear-Herbst appliance in the early mixed dentition. AM J ORTHOD 1984;86:11-3.
15. McNamara JA Jr, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy. AM J ORTHOD 1985;88:91-110.
16. Righellis EG. Treatment effects of Fränkel activator and extraoral traction appliances. Angle Orthod 1983;53:107-21.
17. Bookstein FL. Measuring treatment effects on craniofacial growth. In: Clinical alterations of the growing face. McNamara JA Jr, Ribbens KA, Howe RP, eds. Ann Arbor: The University of Michigan, 1983. (Monograph 14, Craniofacial Growth Series, Center for Human Growth and Development.)
18. Baumrind S, Korn EL, Molthen R, West EE. Changes in mandibular dimensions associated with the use of force to retract the maxilla. AM J ORTHOD 1981;79:17-59.
19. Creekmore TD, Radney LJ. Fränkel appliance therapy: orthopedic or orthodontic? AM J ORTHOD 1983;83:89-109.
20. Robertson HRE. An examination of treatment changes in children treated with the function regulator of Fränkel. AM J ORTHOD 1983;83:299-310.
21. Schulhof RJ, and Engel GA. Results of Class II functional appliance treatment. J Clin Orthod 1982;16:587-99.
22. Riolo ML, Moyers RE, McNamara JA Jr, Hunter WS. An atlas of craniofacial growth: cephalometric standards from The University of Michigan School Growth Study. Ann Arbor: The University of Michigan, 1974. (Monograph 2, Craniofacial Growth Series, Ann Arbor, Center for Human Growth and Development.)
23. McNamara JA Jr. A method of cephalometric evaluation. Am J Orthod 1984;86:469.

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