Mandibular Growth, Condyle Position and Fränkel Appliance Therapy

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A statistical evaluation of condyle position and mandibular length changes in 10 patients after one year of Fränkel appliance therapy, finding the condyle forward on the eminence in 4 of them. Large variations were found in mandibular growth, with no significant difference from the means of patients treated with the Edgewise appliance.

Functional appliance therapy, as with the Fränkel appliance, is an accepted method of treatment for Class II, Division I malocclusions during the growing years.[1,2] One suggested mechanism is the stimulation of mandibular growth.[1]

These appliances are designed to act as bite guides to cause some of the muscles of mastication to move the mandible into a protrusive position in order to establish a new centric relation at least 3-5mm anterior to the original centric position. The condyles are repositioned out of the fossa and onto the eminence, ultimately leading to alteration of condylar growth and an increased anteroposterior length of the mandible.[3-5]

One explanation is that the growth stimulation may be related to the increased activity of the lateral ptygeroid muscles, which are attached to the heads of the condyles and most ac-

tively involved in holding the mandible forward.[3] Additional condyle growth is expected to cause them to grow back into the fossae.[6]

From this brief description of the rationale of this aspect of functional appliance therapy, two clinical concerns become apparent. The first involves the ability to significantly stimulate mandibular growth. The second relates to the movement of the mandible from centric relation to an eccentric position.

The evidence that mandibular growth can be stimulated has been obtained principally from animal studies, where altered condylar growth has been found after repositioning the condyles forward.[3,7-11] Most notably, Petrovic,[3] with tritiated thymidine, has demonstrated increased mitotic activity in the prechondroblastic zones of rat condyles when modified functional appliances were placed. Similarly, Stöckli and Willert[11] Elgoyhen *et al*[4] and McNamara[5,10] noted greater condylar growth in monkeys subjected to functional type appliance actions. McNamara[5] reported a 25% to 50% increase in mandibular growth.

There is some doubt, however, that functional appliances can stimulate condylar growth in humans under clinical conditions. In fact, of 20 reports examined, the opinions are approximately evenly divided, with 11 supporting the hypothesis that mandibular growth can be stimulated and 9 rejecting it. In support were McNamara,[1] Fränkel,[2] Korkhaus,[6] Hotz,[12] Marshner and Harris,[13] Pancherz,[14] and others.[15-19]

On the other hand, Björk,[20] Harvold and Vargervic,[21] Woodside *et al*,[22] Wieslander and Lagerström,[23] and others[24-28] have reported no effect on mandibular growth with functional appliance therapy. Harvold[21] indicated that therapeutic changes were due to maxillary growth inhibition rather than mandibular growth stimulation.

The movement of the mandible from centric relation to an eccentric position causes concern because one commonly stated treatment objective is to adjust the occlusion so that centric relation and centric occlusion are reasonably coincident at the end of treatment. Some call this position at the end of treatment centric relation occlusion.[29] As yet, no studies have focused on condyle position during and after treatment, although Korkhaus[6] suggested that it "will grow back" into the fossa within 9-18 months.

Materials and Methods

Since there is uncertainty concerning both mandibular growth stimulation and condyle position during functional appliance therapy, we undertook a study to assess these factors in patients treated with the Fränkel appliance. The mandibular growth analysis involved a comparison of mandibular growth rates in patients treated for one year with a Fränkel appliance and others treated with Edgewise appliance and cervical traction. Laminographs of the temporomandibular joint were used to evaluate condyle position.

The Fränkel appliance group consisted of 10 patients between the ages of 9 and 13, with Class II, Division I malocclusions. Crowded maxillary incisors in 4 of these patients had been treated with either fixed or removable appliances to align the incisors prior to the placement of the Fränkel appliance.

The Fränkel appliances were constructed from wax bites taken in pro-

trusive position with skeletal midlines coincident. Overjet was totally reduced in those patients with no more than to 5-6mm of overjet. In those with larger overjet, the wax bites were taken in a Class I molar position, without total reduction of the overjet. The bite opening at the molars was about 3mm.

Appliances were fabricated by a commercial laboratory, with vestibular shields expanded 6mm transversely in the maxillary alveolar region and 1mm in the mandibular regions.

The cervical traction group consisted of 15 patients between the ages of 10 and 13, with Class II, Division I malocclusions currently under treatment with combined Edgewise and cervical traction appliances. No intermaxillary forces were used at any time.

Conventional orthodontic records, including standardized cephalometric radiography, were taken prior to treatment.

The patients treated with the Fränkel appliances were instructed to wear them full time after a 2 week "break-in" period during which the appliance was worn no more than half-time.

Posttreatment radiographs were made after approximately one year, using a leaf gauge according to the methods described by Williamson[30] to insure that the condyle was located in the fossa. This was done because the action of the Fränkel appliance is to protract the mandible, moving the condyle out of the fossa and onto the eminence. Accordingly, confusion could arise when analyzing a cephalometric radiograph in which the mandible is in a forward position. We believed that comparison of serial cephalometric radiographs would be more valid if the leaf gauge was used for posttreatment radiographs, even though it was not used for pretreatment films.

Mandibular length was measured from articulare to gnathion on acetate tracings. More conventionally, mandibular length is measured from condylion to gnathion, but condylion could not always be reliably identified in this sample. Articulare-gnathion increases at essentially the same incremental rate as condylion-gnathion.[31] Changes in mandibular length were annualized.

The S-N-B angles were also measured and the change recorded for the Fränkel group.

Mandibular growth increments and the change in S-N-B angles were statistically evaluated with Student's 't' test.

Evaluation of Condyle Position in Patients Treated with the Fränkel Appliance

Standardized laminographs were taken according to the method described by Beckwith,[32] exposed both before and after the treatment period, with and without the Fränkel in place. After treatment, the patients were also placed on a leaf gauge and a third laminograph taken on those who demonstrated more than 1mm change in occlusal relationships. To determine changes in condyle position, the supracondylar space extending from the top of the condyle to the roof of the fossa was measured on the left side pre- and posttreatment laminographs (Fig. 1).

Results

Variation in mandibular growth was large in both groups (0.8-3.5mm and 0.8-4.1mm). There was no significant difference in the average mandibular growth increment, which was 2.4mm in both groups (Table 1).

TABLE 1
Mandibular Growth Increments

	n	Mean Change in AR-GN (mm)	Range	"t"
Fränkel Group	10	2.36 ± 0.95	0.77-3.51	NS
Extraoral Traction Group	15	2.40 ± 1.52	0.80-4.08	

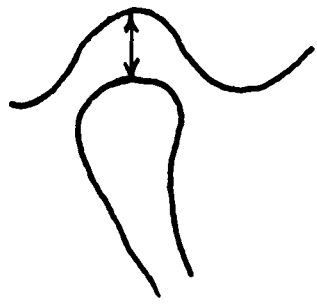

Fig. 1 Supracondylar space measured from the top of the condyle to the roof of the fossa.

TABLE 2
Supracondylar Space

	n	Mean (mm)	"t"
Before Fränkel Appliance Placement	10	2.97 ± .76	p<.01
After Fränkel Appliance Placement	10	3.97 ± 1.28	

S-N-B Angle Change:

The S-N-B angle change in the Fränkel group was 0.3° ± 1.0°, which is not significant.

Condyle Position

Fig. 2a is a laminograph of the condyle region of a representative patient with the Fränkel appliance in place. The condyle is seen on the eminence. This occurred in all patients. Fig. 2b shows the same patient after about one year of appliance use. The condyle is still positioned on the eminence, but not as far anteriorly. Fig. 2c was taken at the same session without the appliance; note that the condyle is positioned inferiorly relative to the fossa.

The mean 3.0mm supracondylar space before treatment increased to 4.0mm after treatment (Table 2). This average 1mm increase in supracondylar space could be interpreted to indicate that the condyles tended to be positioned slightly more inferiorly after one year of treatment, but those were only the averages.

No increase in the space was found in the majority of the patients. The average increase is attributable to somewhat larger changes in 4 of the 10 patients; in 3 of those the supracondylar space increased more than 2.0mm. Two of those also demonstrated the largest molar correction as determined on the laminographs.

As an example, Fig. 3a is a laminograph of a patient who had also received 2 months of treatment with a fixed appliance to align the maxillary incisors before the Fränkel appliance was placed. The bands were then removed and a Fränkel appliance inserted. Changes during that period were not recorded. Fig. 3b is a laminograph of the same patient after Fränkel treatment. Note the molar and bicuspid correction, the increased supracondylar space and the more inferiorly positioned condyle.

Fig. 3c is a posttreatment laminograph of the condylar fossa region of the same patient after placing a leaf gauge for 6 minutes. The condyle had moved upward and backward into the fossa, and the molar relationships were similar to those recorded before

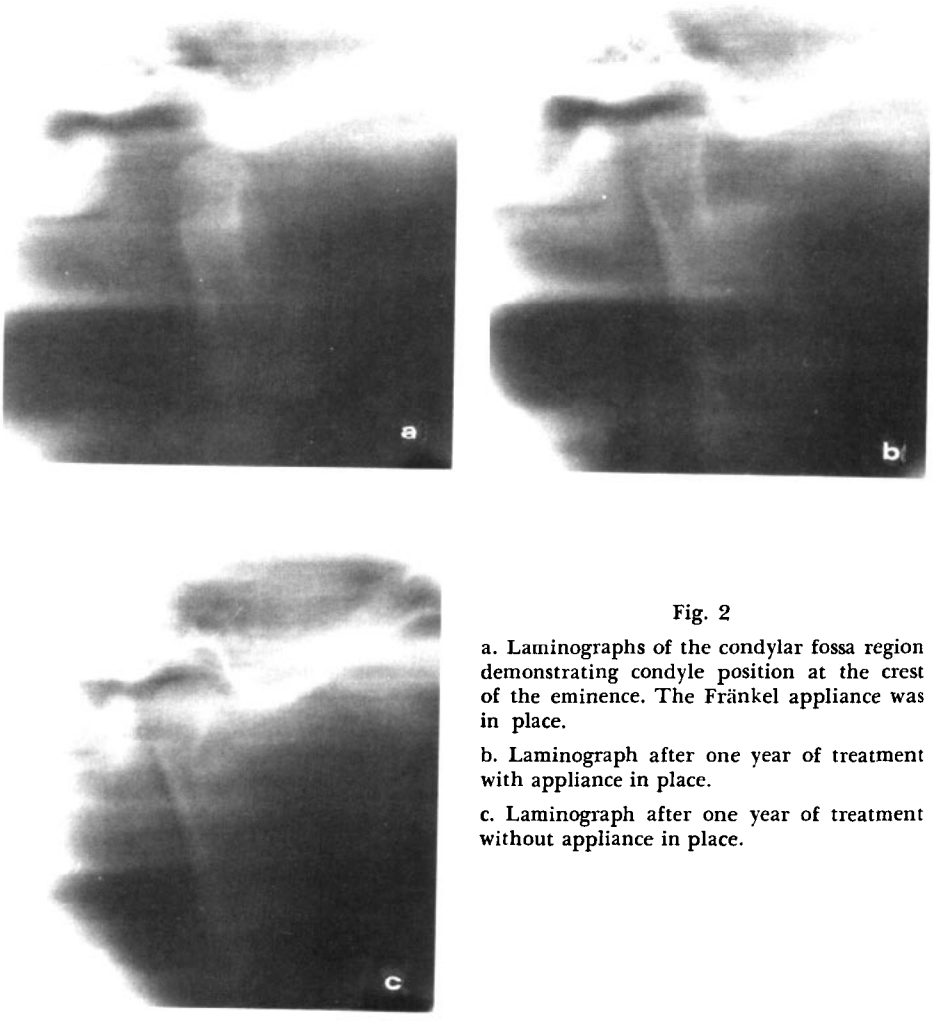

Fig. 2

a. Laminographs of the condylar fossa region demonstrating condyle position at the crest of the eminence. The Fränkel appliance was in place.

b. Laminograph after one year of treatment with appliance in place.

c. Laminograph after one year of treatment without appliance in place.

the placement of the Fränkel appliance (Fig. 3a).

When placed on a leaf gauge, the patients who demonstrated the largest supracondylar space also repositioned their mandibles more posteriorly than the other patients.

Discussion

This study was undertaken with the objectives of evaluating mandibular growth and condyle position under treatment with a Fränkel appliance.

Mandibular growth

One objective was to provide some information concerning the ability of the Fränkel appliance to stimulate mandibular growth in the first year of treatment. The reason that we focused on this time period is that we wanted

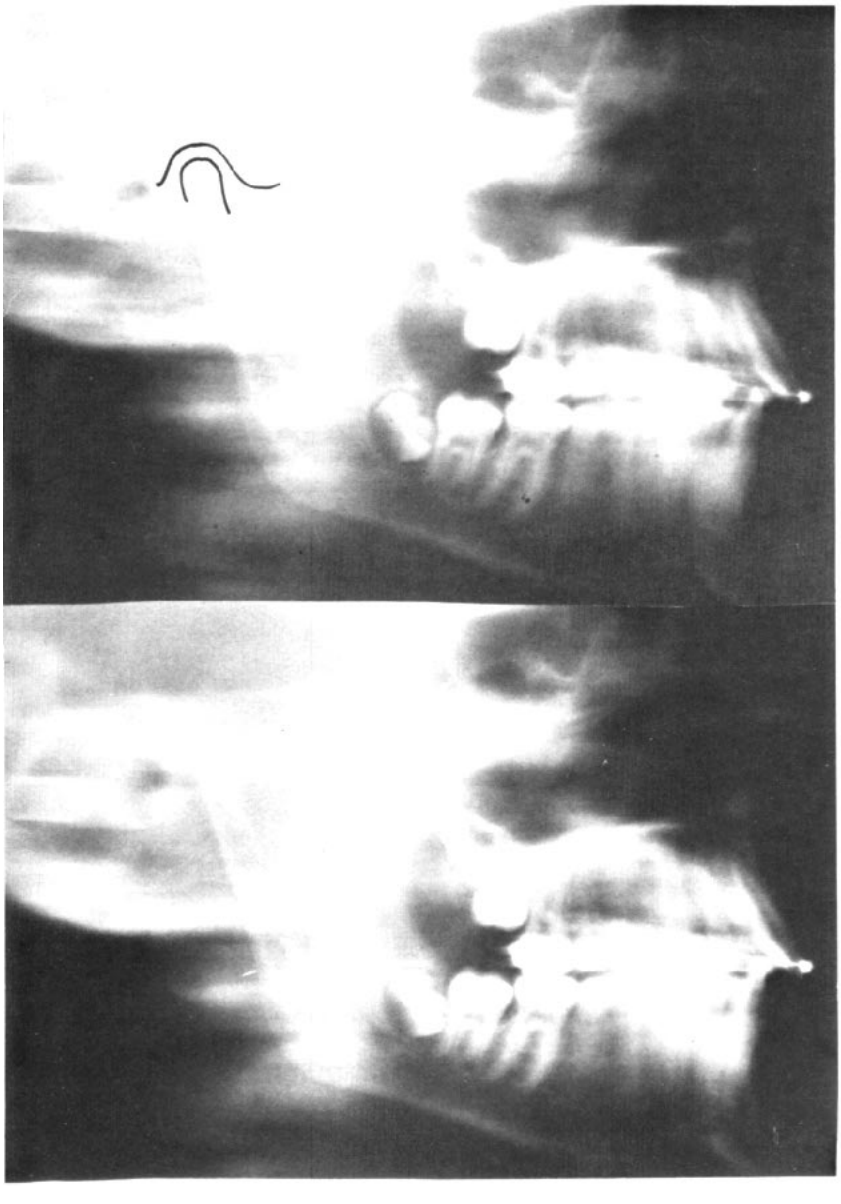

Fig. 3a Laminographs illustrating condylar fossa and dental relationships in one patient before treatment.

The heads of the condyles and the fossae are outlined for clarity in the upper illustration.

The fixed appliance noted on the radiograph was used to align the incisors prior to the insertion of the Fränkel appliance.

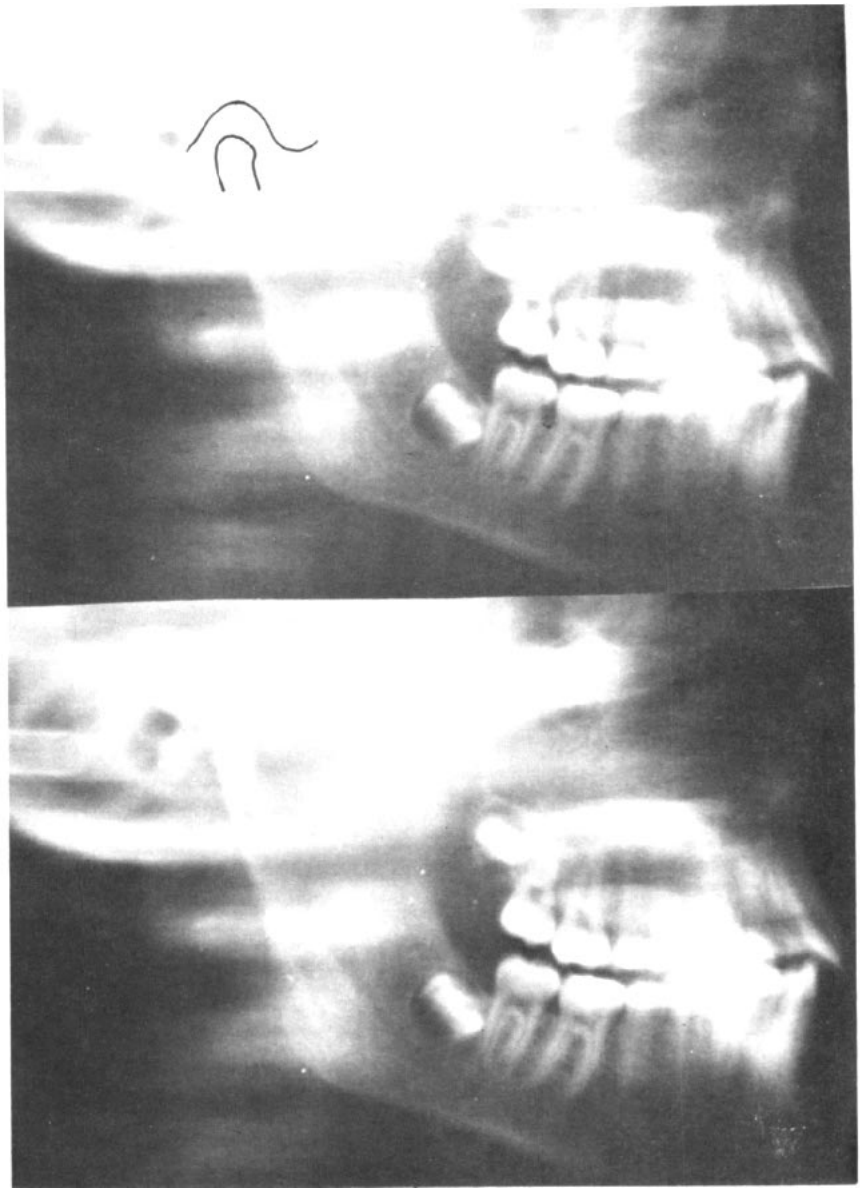

Fig. 3b Laminograph of the same patient after one year. The molar and bicuspid relationships are essentially Class I. The condyle is positioned inferiorly relative to the pretreatment position.

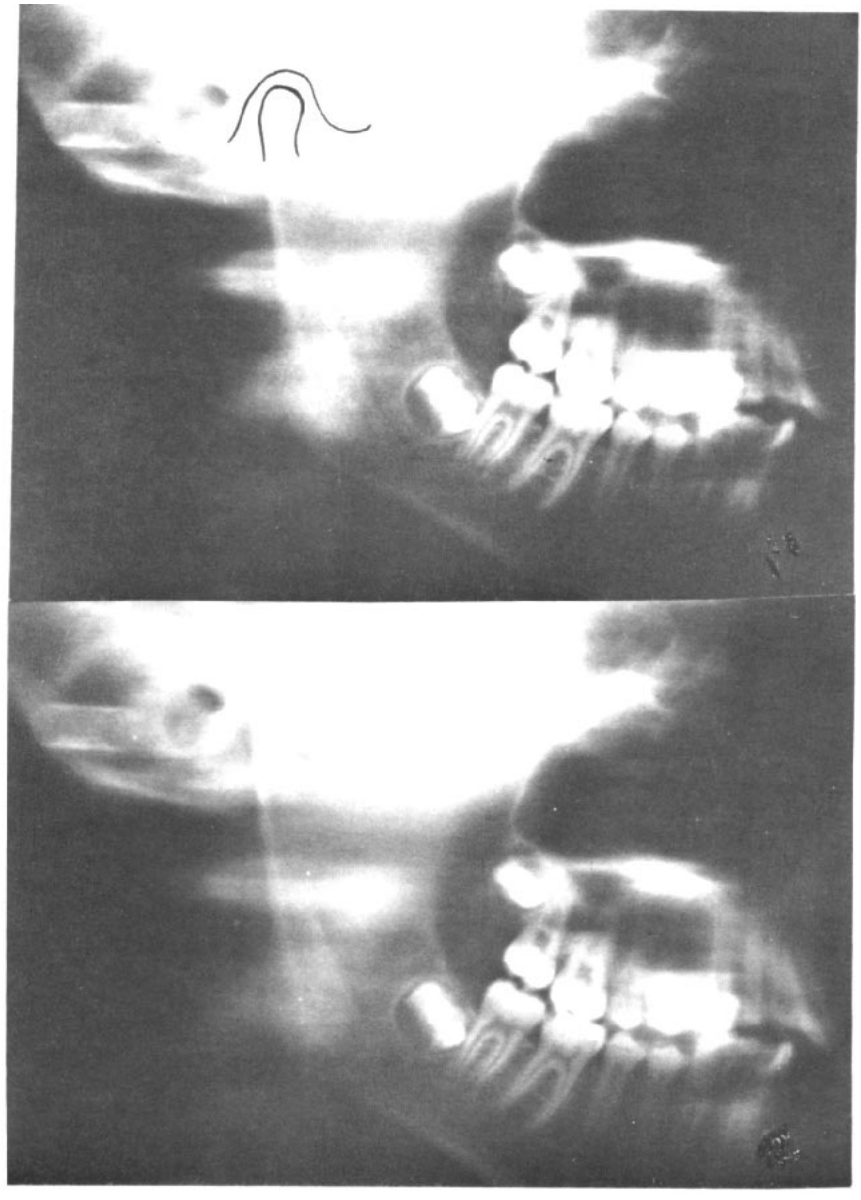

Fig. 3c Laminograph of the same patient after one year, with the condyle repositioned with a leaf gauge. The Condyle, fossa and dental relationships approximate the pretreatment condition.

to compare data from humans with the findings from primate studies which represent the biologic verification of mandibular growth stimulation with functional type appliances.[4,5,10,11,33] A number of these have indicated that the major part of the experimentally induced increase in mandibular growth following appliance insertion in monkeys occurred within the first 3 months.[4,10,11,33] Primates age 3 to 4 times faster than humans,[4] so it was reasoned that a 1-year investigation involving humans could be considered comparable to the primate studies.

In primates, Elgoyhen *et al*[4] noted larger monthly increments of growth of the condyles within the first 3 months after placement of functional type appliances. The greatest increments occurred during the second month and the growth rates returned to a normal level by the fourth month. Similarly, Stöckli and Willert[11] recorded an increase in condyle growth only in the first 3 months after appliance insertion.

The changes in lateral pterygoid activity of monkeys were studied electromyographically by McNamara,[10] and the principal increase in activity also occurred within the first 3 months, with the maximum change between the 4th and 8th week.[11]

The close correlation between condyle growth changes and electromyographic data led to the following hypotheses. The appliances changed the oral environment, inducing the muscles of mastication to protract the mandible. One particularly active group of muscles was the lateral pterygoids which insert into the heads of the condyles. The muscle activation is converted to a stimulus for increased cellular proliferation in the condyles to produce structural changes. When the increased activity ceases after approximately 3 months, the condylar cartilage proliferation rate returns to a normal level.[33]

However, our results did not demonstrate that patients treated by means of the Fränkel appliance experienced more average mandibular growth than patients treated by extraoral traction with the Edgewise mechanism. We could not duplicate the experimental findings in a clinical situation.

The mandibular change noted in both groups corresponds closely to the average yearly mandibular growth increments in untreated patients recorded by Ricketts (2.5mm)[34] and by Riolo *et al* (2.7mm)[32] for this 9-13 year age period.

On a clinical level we believe that these findings support those who believe that the Fränkel appliance in particular,[24] and functional appliances in general, do not stimulate mandibular growth.[20-23,25-28]

Yet, there are others who would take issue with our conclusion since they have demonstrated increased mandibular growth when treating with functional appliances.[1,2,12-19]

Why these differences? One possible reason is the procedures followed in the present study. Since the mandible is intentionally moved forward while wearing the Fränkel appliance, we used a leaf gauge on those post-treatment cases to insure that the condyles were located in the fossae when recording our data.

The expectation is that the mandibular growth that follows will make the transitory positional change of the mandible permanent by increasing mandibular length. As this occurs, the condyles would "grow back into the fossa" with 9-18 months, as Korkhaus[6] suggested.

However, there is no documenta-

tion at the present time that this orderly reestablishment of the condyle-fossa relationship occurs. An assessment of facial pattern with the mandible in a forward position would not be the same as when the mandible is in centric relation. Measurements of mandibular prognathism would differ. This may explain why Fränkel recorded a 3° increase in S-N-B in less than 1 year of treatment[2] while our results, recorded with the mandible in the position established by the leaf gauge, showed essentially no change in a comparable period of time.

A second factor that may explain the differences of opinion concerning mandibular growth is the amount of mandibular growth stimulation. McNamara recorded increased growth of up to 50% in monkeys subjected to functional appliances.[5] There was wide variation as there was in this study, and one monkey initially described as experiencing a 40% increase had only a 25% growth increase when experimental and control data were corrected to represent similar time periods.

If we assume an average growth stimulation of 35% and relate that to humans, the growth increase per year would be less than 1mm. (35% of the Ricketts norm of 2.5mm./yr.) This would be difficult to detect with mandibular growth increments of individual patients varying so widely.

A third factor is that any lack of cooperation may skew the average results toward the view that the Fränkel appliance does not stimulate growth.

The failure to detect growth stimulation is not a particular surprise if we consider two clinical conditions. One is the pseudo-Class III malocclusion. This problem is, in part, a naturally occurring functional appliance. The mandible is positioned anteriorly by the musculature because of an occlusal interference. The authors have seen patients who have had an uncorrected pseudo-Class III malocclusion for years that were still partially resolved by correcting the anterior crossbite to allow the mandible to assume a more posterior position.

The question should immediately arise—if mandibular protraction can lead to growth stimulation, why do people with pseudo-Class III malocclusion not develop a skeletal Class III malocclusion? This leads to a more functional question. Is the clinical syndrome 'Pseudo-Class III malocclusion somewhat incompatible with significant mandibular growth stimulation mediated by mandibular protraction, or does the normal condyle position in rest position neutralize that effect?

A similar clinical entity is a crossbite (most often bilateral) with a shift of the mandible to one side, producing an apparent facial asymmetry. The mandibular shift is a muscle-directed position in which one condyle is momentarily distracted from the fossa on closure. Correction of the crossbite generally eliminates the prematurity which provokes the functional shift and facial balance is restored. Again, the question arises—why does the mandible not become longer on one side if the mechanism to stimulate mandibular growth is to protract the condyle out of the fossa?

Admittedly, this situation may not be as compelling as a Pseudo-Class III malocclusion since the mandibular shift may not be as large. However, each condition represents to some extent a naturally occurring circumstance which leads to muscle-directed movements distracting the condyles

from the fossae. In both conditions, there often appears to be no significant mandibular growth effect.

Condyle position

The second objective of this study was to observe condyle position during treatment with the Fränkel appliance. When the appliance was in place, the condyle was distracted from the fossa and positioned on the eminence immediately after insertion. With time and mandibular growth, the condyle moved back toward the fossa. However, it did not reach the fossa in all patients during the treatment period, although one could speculate that it would ultimately "grow back into the fossa" as Korkhaus[6] has suggested as treatment progressed into the second year.

When the appliance was not in place and the patients closed in centric occlusion, the condyles of 4 of the 10 patients were positioned inferiorly and somewhat forward relative to the original condyle-fossa recording.

This indicates that the centric occlusion developed as these patients wore the Fränkel appliance was no longer coincident with the original condyle position in the fossa. Furthermore, the mandibular repositioning may explain, in part, the apparent rapidity noted in the reduction of Class II relationships in selected patients.

At present, we are using the leaf gauge routinely to control condyle position because the possibility is always present that the mandible may be in a forward position. One of our treatment goals is to have centric relation and centric occlusion as close together as possible, and our view is that those who use appliances which relocate the condyle should monitor condyle-fossa relation in some way. Our use of the leaf gauge is based on evidence from Williamson,[30] and our own observations indicate that it serves this purpose particularly well. We intentionally did not define the leaf gauge position as "centric relation."

Summary

Our results indicate that the condyles of a significant number (40%) of patients were repositioned inferiorly in centric occlusion after one year of Fränkel appliance use. Mandibular growth stimulation was not apparent in the overall averages within the first year of treatment.

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