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The functional regulator (FR-3) of Fränkel

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This article describes the construction of the FR-3 appliance classically used in cases of Class III malocclusion characterized by maxillary skeletal retrusion. Included is a description of proper impression technique, construction bite registration, preparation of the work models, and a complete description of the fabrication of the FR-3 appliance. Specific steps in the clinical management of this appliance are also presented. The cephalometric records of three patients treated with the FR-3 appliance are then presented. (Am J Orthod **88:** 409-424, 1985.)

Key words: Functional regulator, Fränkel, Class III malocclusion, impressions, bite registration

THE FUNCTIONAL REGULATOR (FR-3) OF FRÄNKEL

A method of functional jaw orthopedics that has gained increased popularity in the United States is predicated on the system of functional regulator appliances[1,2] developed by Professor Rolf Fränkel of the German Democratic Republic. One of these appliances, the FR-3,[1-4] is used in the treatment of Class III malocclusions. This appliance has been used during the deciduous, mixed, and early permanent dentition stages to correct Class III malocclusion characterized by maxillary skeletal retrusion and not mandibular prognathism.[2,3] According to Fränkel,[2,3] the vestibular shields and upper labial pads function to counteract the forces of the surrounding muscles that restrict forward maxillary skeletal development and retrude maxillary tooth position. Fränkel[2] has also stated that the vestibular shields stand away from the alveolar process of the maxilla but fit closely in the mandible, thus stimulating maxillary alveolar development and restricting mandibular alveolar development.

Fränkel[3] reported a study of 74 severe Class III cases treated with the FR-3, comparing these cases to 58 Class II cases treated with the FR-1 appliance. He noted greater forward movement of maxillary landmarks in the Class III cases than in the Class II cases. He also stated that the changes in maxillary position in the Class II cases were minimal in comparison to what would normally occur during growth. He concluded from this study that the forward development of the maxilla is stimulated by the FR-3 appliance. However, a definitive study of the precise mechanism of action of this appliance or a controlled clinical trial of the efficacy of this type of functional regulator has not been published.

Another use of the FR-3 has been suggested by Petit[5] in the treatment of severe Class III cases. Petit advocates the use of heavy orthopedic forces generated by the facial mask to achieve the initial correction of the malocclusion. Further, he suggests that an FR-3 may be used to retrain the maxillary anteroposterior correction and to retrain the associated musculature.

Eirew[6] has stated that the FR-3 is an excellent retraining device and aid to muscular reeducation following surgical correction of mesiocclusion.

The purpose of this article is to describe the construction and clinical management of the Fränkel FR-3 appliance as it is currently used in the United States. Reports of three treated cases will also be presented.

PARTS OF THE APPLIANCE

The FR-3 (Fig. 1) is composed of wire and acrylic. As with the FR-2 appliance,[7] the base of operation is the buccal and labial vestibule. The FR-3 is less complicated than the FR-2 appliance in that there is no lingual shield, which is necessary in the FR-2 to prompt a forward repositioning of the lower jaw.

There are four acrylic parts of the FR-3: two vestibular shields and two upper labial pads (Fig. 1, *A* and *B*). The vestibular shields extend from the depth of the mandibular vestibule to the height of the maxillary vestibule. These shields act to remove the restrictive forces created by the buccinator and associated facial muscles against the lateral surfaces of the alveoli and the associated buccal dentition.

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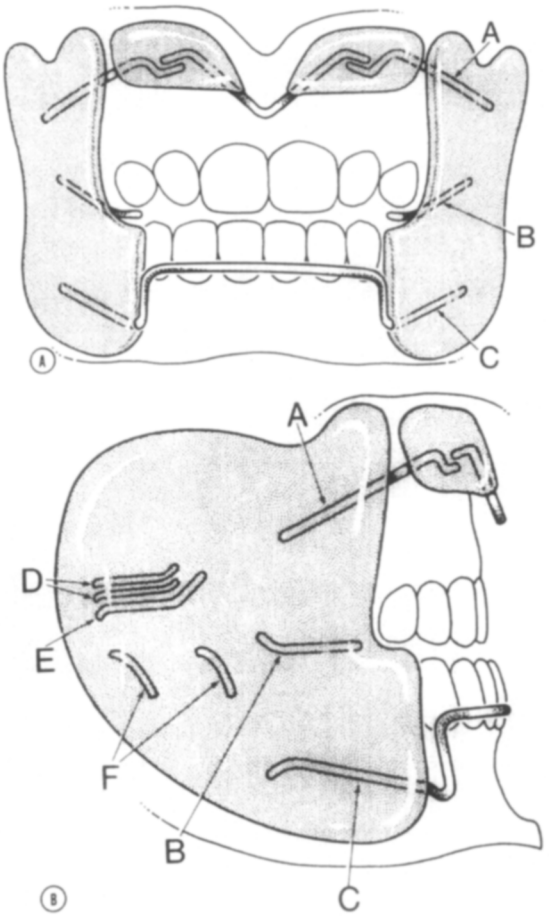

Fig. 1. Schematic illustration of the FR-3 appliance of Fränkel. **A,** Frontal view. **B,** Lateral view. The wire components of the appliance are *(A),* Upper labial wires (three-wire design), *(B),* Upper lingual wire, *(C),* Lower labial support wire, *(D),* Upper occlusal rest, *(E),* Palatal wire, and *(F),* Lower occlusal rest.

The upper labial pads that lie in the labial vestibule above the upper incisors (Fig. 1) function to eliminate the restrictive pressure of the upper lip on the underdeveloped maxilla. The upper labial pads are larger and more extended than the corresponding lower pads of the FR-2[7] and are more easily tolerated by the patient despite this greater extent. According to Fränkel,[2,3] these pads also provide a stretching of the adjacent periosteum, stimulating bone apposition on the labial alveolar surface. This has not been verified by others. The upper labial pads of the FR-3 are in an inverted tear-drop shape in sagittal view (Fig. 2). They should lie in the height of the vestibular sulcus parallel to the contour of the alveolus. The force of the upper lip is transferred by the upper labial pads to the vestibular shields. Since the vestibular shields lie in close approximation to the mandibular alveolus, the force of

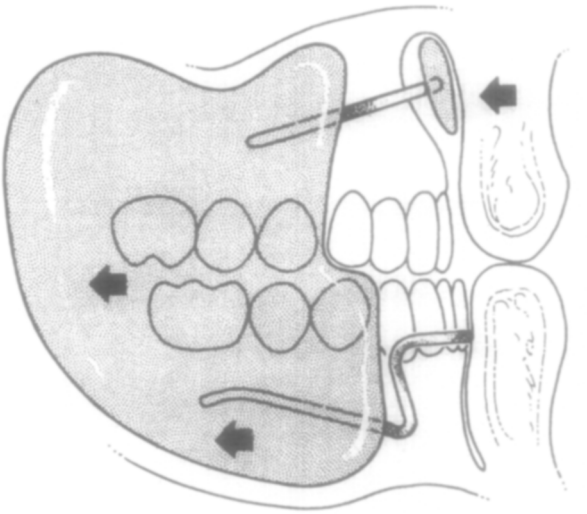

Fig. 2. The proposed method of action of the FR-3 appliance. The distracting forces of the upper lip are removed from the maxilla by the upper labial pads. The force of the upper lip is transmitted through the appliance to the mandible because of the close fit of the appliance to that arch (after Fränkel[1]).

the associated soft tissue may be transmitted through the appliance to the mandible. Presently there are no studies to indicate that the force generated by the appliance is sufficient to lead to a significant retardation of mandibular growth. However, the three case reports presented in this article indicate that the vector of mandibular growth may be redirected vertically.

There are five wire components in the Fränkel FR-3, some of which are also found in the FR-2. The upper labial pads are connected to the vestibular shields by a support wire that may be a single continuous wire or a series of three adjacent wires (Fig. 1). The lower aspects of the vestibular shield are connected by a lower labial wire that rests against the labial surface of the lower incisors. On the lingual surface, an upper lingual wire (Fig. 3, *A*) originates in the vestibular shield, traverses the interocclusal space, and rests against the cingula of the upper incisors. In contrast to the FR-2, the upper lingual wire does not lie between the canine and first deciduous molar (or first premolar), but rather lies in the interocclusal space between the upper and lower dental arches (Fig. 4).

The palatal wire (Fig. 3, *A*) originates in the vestibular shields and traverses the palate. In contrast to the FR-2 in which the palatal wire lies between the second deciduous molar and the first permanent molar, the palatal wire crosses the palate behind the last molar present (Fig. 4). Thus, the maxilla and the maxillary dentition are not restricted in their forward movement by the wires of the appliance.

There are two pairs of occlusal rests in the molar region, one of which is optional. A lower occlusal rest (Fig. 3, *B*) originates in the vestibular shield, makes a gentle right angle bend along the central groove of the lower first molar, and then extends again back into the vestibular shield posteriorly. The purpose of this wire is to prevent the eruption of the lower first molar as is advocated by Harvold[8] in the treatment of Class III malocclusions. Eirew[6] recommends that the mandibular occlusal rest be constructed to cover all erupted or even partially erupted mandibular molars.

The maxillary occlusal rest (Fig. 3, *A*) is necessary only in cases of anterior crossbite. This wire should be placed so that only enough vertical opening is achieved to allow for the correction of the anterior crossbite. As soon as the crossbite has been corrected, the upper occlusal rest should be removed from the appliance to minimize bite opening. The upper occlusal rest originates in the posterior aspect of the vestibular shield, traverses the central groove of the upper first molar, and then recurves back on itself. The upper occlusal rest is designed in this manner so as not to restrict the forward movement of the maxilla during functional therapy.

Impression technique

As in any appliance that is primarily tissue-borne, successful Fränkel treatment depends upon the fit and comfort of the appliance. Thus, it is imperative that a proper impression-taking technique be used. An accurate reproduction of the dentition and the associated soft tissue is essential for proper appliance fabrication. The extension of the buccal vestibule must be clearly defined and the upper limits of the anterior maxillary region must be clearly discernible.

During the past few years, a number of different types of impression trays have been used. The type of tray that we have found to be most successful is a thermal sensitive acrylic tray[9] that is softened in hot water, placed in the mouth, and molded to the configuration of the hard- and soft-tissue structures. In addition, we advocate the use of a molding compound in the upper anterior region to provide additional extension of the tray into the anterior vestibule. Compound can also be applied in the posterosuperior aspects of the tray to provide additional definition in the tuberosity region. A custom tray that is fabricated for the individual case can also be used.

It is extremely important in the fabrication of the FR-3 that the impressions not be overextended or underextended. The use of overextended trays including stock styrofoam trays is usually contraindicated because of the vertical and lateral distortion of the soft tissue produced by these types of trays.[5]

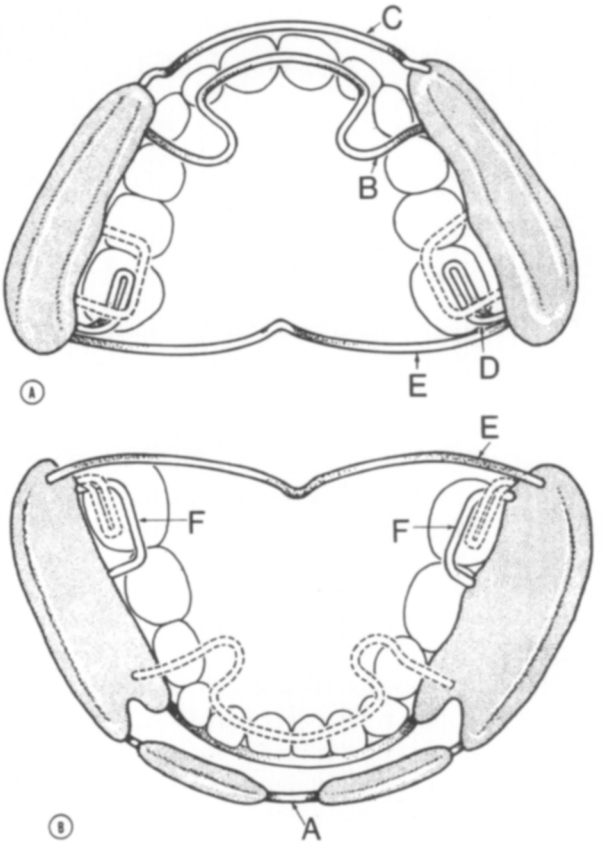

Fig. 3. Schematic view of the FR-3. **A,** Maxillary view with upper lingual wire *(B)*, lower labial support wire *(C)*, upper occlusal rest *(D)*, and palatal wire *(E)*. **B,** Mandibular view with upper labial support wire *(A)*, palatal wire *(E)*, and lower occlusal rest *(F)*.

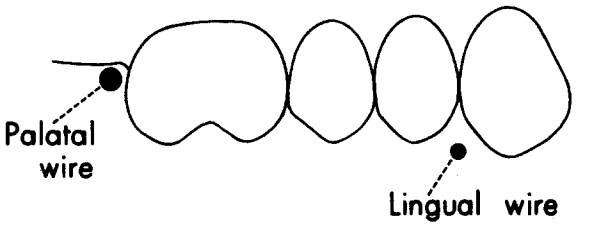

Fig. 4. Position of palatal and lingual wires of the FR-3 appliance (after Fränkel[1]).

Construction bite

As with the FR-2 appliance, a proper construction bite is essential to appliance fabrication. A horseshoe wafer of medium hard wax is used to orient the upper and lower dental arches in all three planes of space (horizontal, transverse, and vertical). Any arbitrary ad-

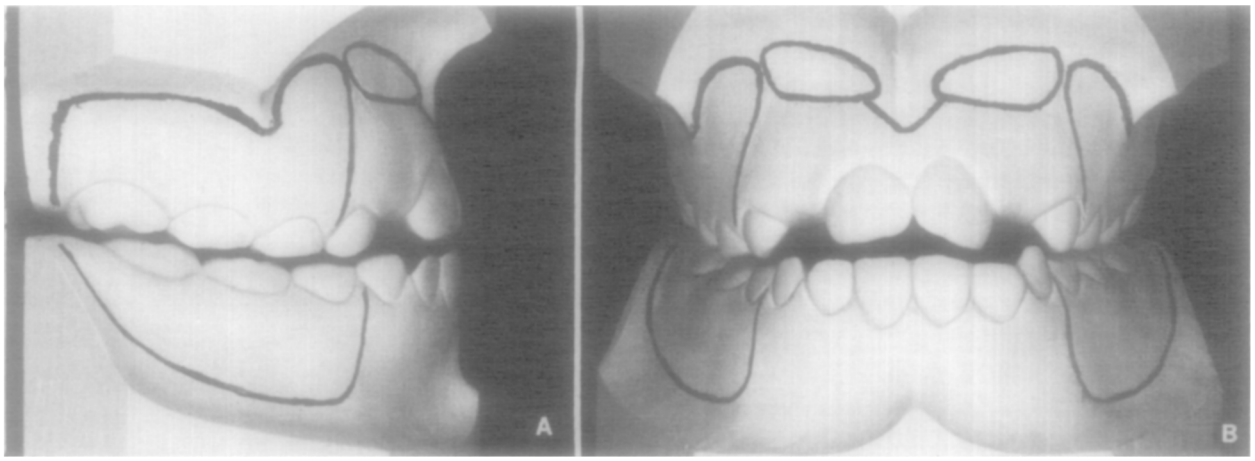

Fig. 5. Preparation of work models and pencil outline for future vestibular shields and upper labial pads. **A,** Lateral view. **B,** Frontal view.

justments in work-model orientation during appliance fabrication can lead to an appliance that does not fit properly.

The bite registration is taken with the patient's mandible in the most comfortably retruded position. It is necessary to allow 1 to 2 mm of interocclusal space in the molar region for the construction of the lower and, when necessary, upper occlusal rests. A wide open-bite registration should be avoided. In cases with an anterior open bite, only 1 mm of vertical bite-opening in the posterior region is necessary.

Preparation of work models

After the impressions have been taken, they are poured in either hard plaster or stone with a base sufficient to allow adequate trimming (Fig. 5). It is important that an adequate base be present to allow for carving, particularly in the upper anterior region. The models are trimmed with the wax bite in place; the backs of the models should be trimmed flush with each other.

The first step in carving the work models is to remove excess flash and bubbles. The models should then be carved to help define the borders of the eventual vestibular shields. In most instances it is not necessary to carve the mandibular region, particularly if the lower border of the mandibular sulcus has been defined by the impression. However, it is sometimes necessary to carve the upper vestibular region in the area of the tuberosity to allow for a better definition of the superior extent of the vestibular shield. In addition, it is sometimes necessary to define the areas of muscle attachment that usually appear adjacent to the upper first premolar (Fig. 5).

It is almost always necessary to define the position of the upper labial pads, even when a close-fitting tray and compound extension have been used to obtain the impression. This area is carved to allow proper placement of the upper labial pads (Fig. 5).

When the preparation of the work models is completed, the wax bite is inserted and the posterior surfaces of the model are checked to ascertain that the backs of the models are flush. This is an important step because it will allow the laboratory to check the wax bite when the work models are received and it will also allow the clinician to check the bite registration when the appliance is returned from the laboratory.

Prescription sheet

Usually there is little variation with regard to the prescription for the FR-3 laboratory fabrication. A standard amount of wax relief is ordinarily used. Three millimeters of wax relief is prescribed for the maxillary alveolar area and the upper labial pad region; there is no wax relief prescribed for the mandibular model. Specific alterations in the amount of wax relief in the maxillary region can be indicated on the prescription sheet. Little variation in wax relief is prescribed in the mandibular vestibule since this area cannot tolerate significant lateral extension of the appliance.

In contrast to the FR-2 appliance precription, notching of the maxillary teeth is not required for the FR-3. Every effort is made to allow forward movement of the maxilla during treatment.

APPLIANCE FABRICATION

Mounting the work models

The work models are checked by the technician after they have reached the laboratory. Any obvious distortion or problems with the wax bite should be noted. If the models and the wax bite are satisfactory, the work models are then mounted in a fixator model holder with

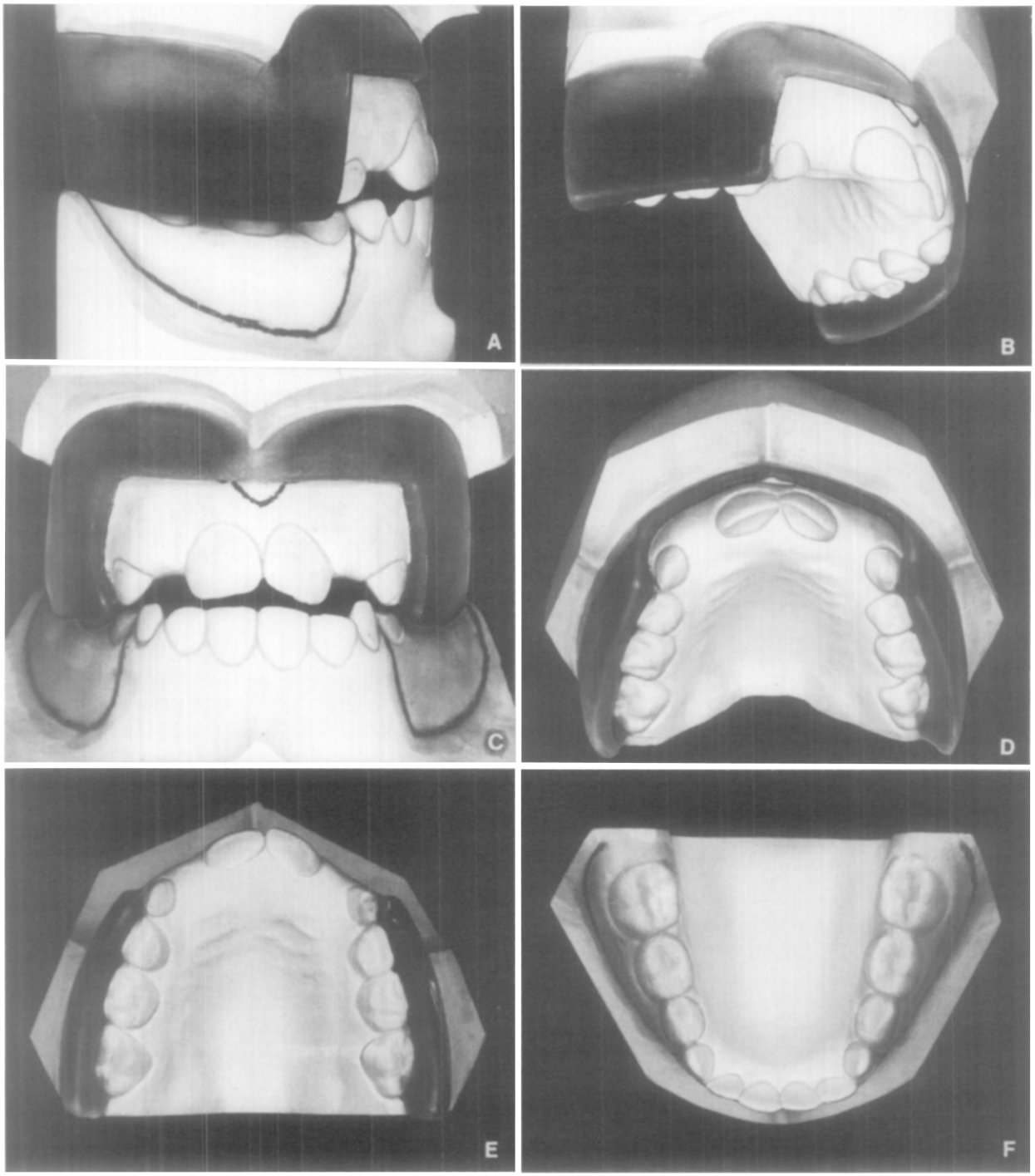

Fig. 6. Placement of wax relief for the vestibular shields and the upper labial pads. **A,** Lateral view. **B,** Oblique lateral view. **C,** Frontal view. **D,** Oblique maxillary view. **E,** Maxillary occlusal view. **F,** Mandibular view. Note the lack of wax relief in the mandibular arch.

the wax bite still in place. After the mounting stone has hardened, the wax bite is removed and the amount of interocclusal space is checked for adequate, but not excessive, separation of the models to allow for construction of the appliance.

Application of wax relief

First, the outlines of the vestibular shields and upper labial pads are drawn on the model with a pencil (Fig. 5). These outlines are used as a guide in the placement of the wax. The models are then separated and wax

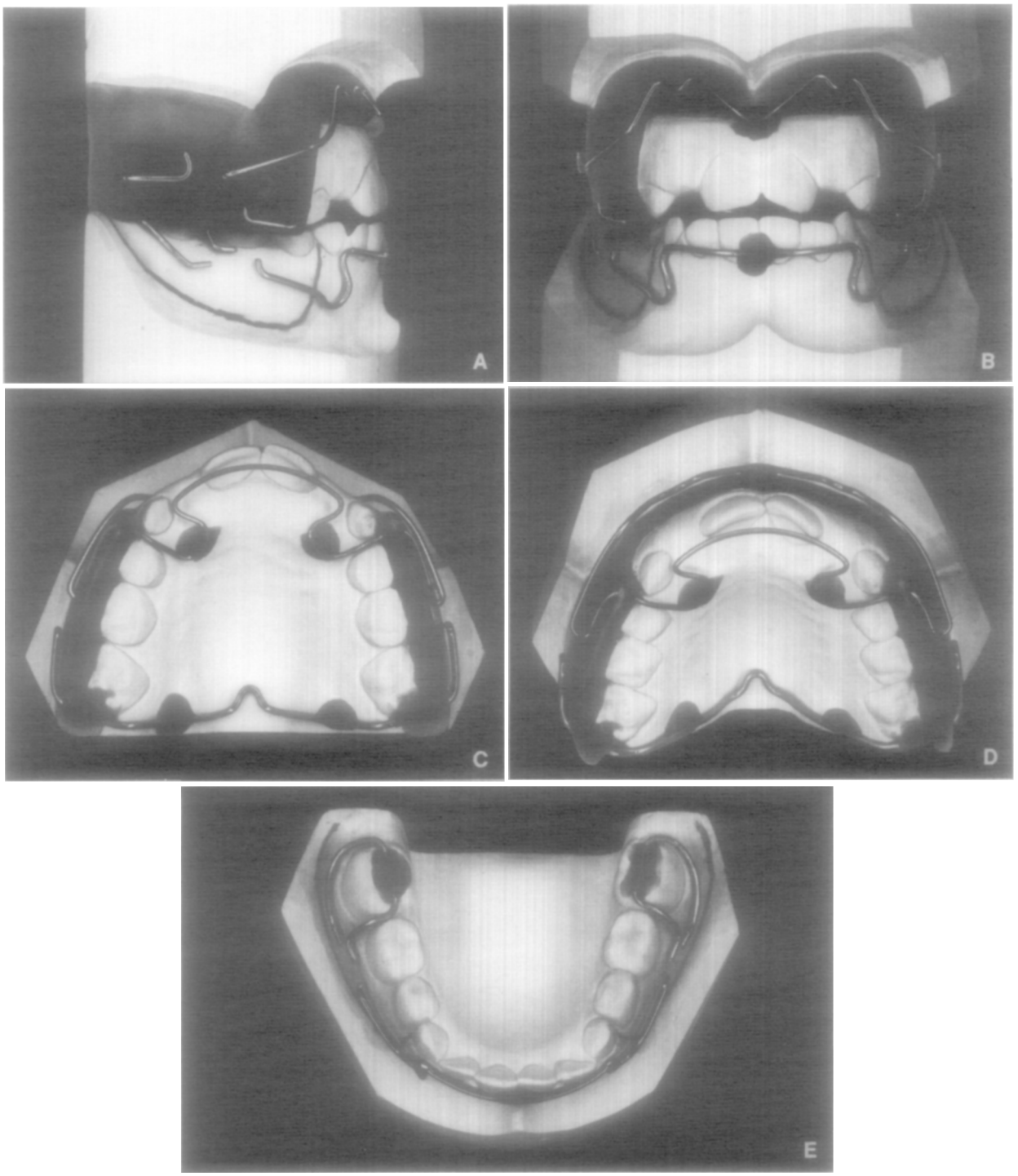

Fig. 7. Completed wax relief and wire work for the FR-3 appliance. **A,** Lateral view. **B,** Frontal view. **C,** Maxillary view. **D,** Maxillary oblique view. **E,** Mandibular view. This appliance does not include an upper occlusal rest.

relief is applied in the posterior and upper anterior regions of the maxillary dental cast as prescribed by the clinician (Fig. 6). Additional wax is then applied in the dental area to establish a smooth contour on the lingual side of the vestibular shield. No wax relief is placed on the mandibular cast, although the gingival margins are carefully waxed out in the region of the vestibular shields to prevent the occurrence of gingival irritation and also to save time in polishing the inside of the shields.

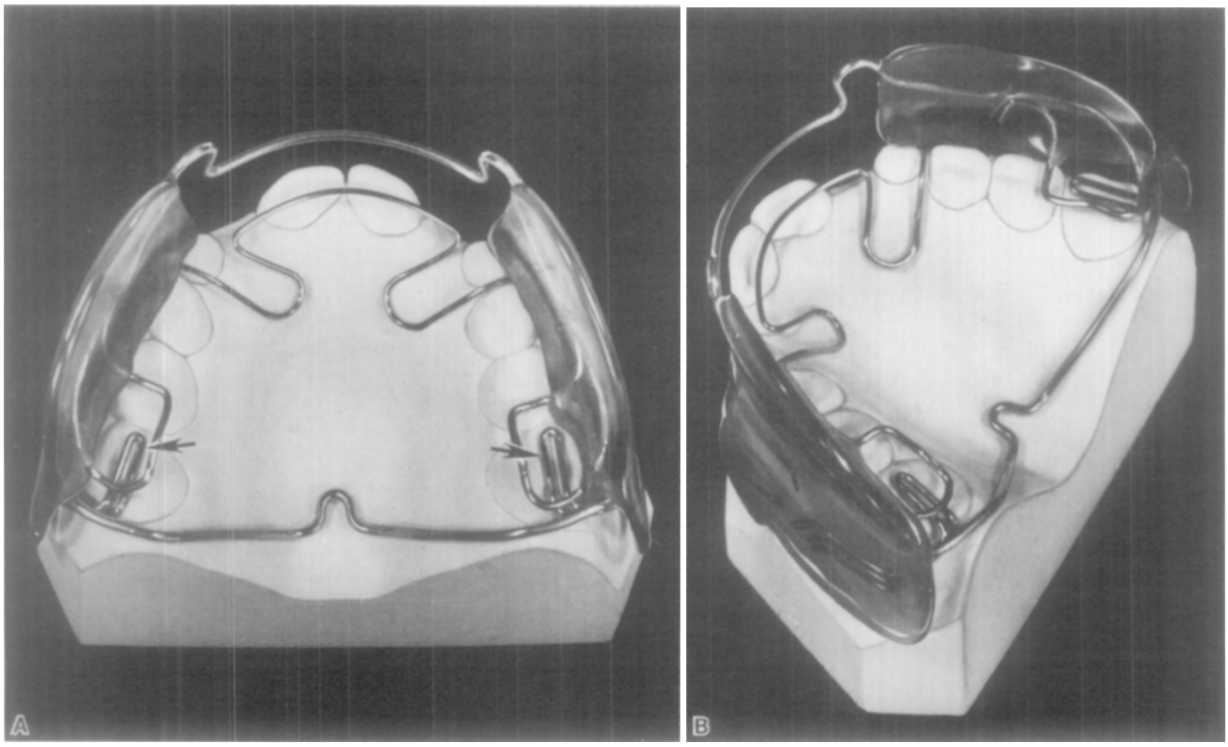

Fig. 8. The relationship of the upper occlusal rest to the lower occlusal rest. **A,** Maxillary view. **B,** Maxillary oblique view.

Wire fabrication

The lower labial support wire. The lower labial support wire is formed from a single piece of 0.040-inch round stainless steel wire. It originates in the area of the future vestibular shield and curves gently downward first and then upward toward the lower incisors (Fig. 7). It crosses the lower incisors along the gingival one third of the facial surface. The lower labial wire is held in position by sticky wax in the central incisor area (Fig. 7, *B*).

The upper labial support wire. The upper labial support wire connects the upper labial pads one to another and to the vestibular shields (Fig. 7). This wire exits the vestibular shields along the upper anterior margin in a slightly upward direction. The wire then curves further upward to the location of the upper labial pads and then downward to accommodate the position of the labial frenum. This wire is constructed of 0.040-inch round stainless steel wire and is fastened to the model with sticky wax just above the lower labial frenum superior to the upper incisor before the acrylic fabrication of the labial pads (Fig. 7, *B*).

It must be stressed that the part of the upper labial support wire inside the vestibular shield must remain straight. If this wire is bent or curved, it will not move during the activation of the upper labial pads (to be covered later). The wire should also be tilted in the shield so that the activation produces a forward and upward movement of the labial shields.[6]

The upper lingual wire. The upper lingual wire is made of 0.028-inch or 0.032-inch stainless steel. It originates in the vestibular shield and traverses the interocclusal area between the upper canine and the upper first deciduous molar (Figs. 3, 4, and 7). It does not touch the maxillary or mandibular dentition. The wire then recurves along the lingual surface of the upper incisors at the level of the cingula. The upper lingual wire can be used to stabilize the incisors during treatment.

Wire bends are made gradual rather than sharp to avoid breakage. This is especially important at the point where the upper lingual wire enters the buccal shield. In cases where the upper lingual wire is fractured repeatedly, the use of separate crossed wires covered by a short sleeve may be considered.[6]

Palatal wire. The 0.040-inch stainless steel palatal wire originates in the posterior aspect of the vestibular shield and traverses the palate posterior to the terminal molar (Figs. 3, 4, and 7). The palate wire is kept slightly off the palatal mucosa to prevent irritation. The eruption of another molar posterior to the palatal wire will usually result in a fracture of the wire. During the repair or fabrication of a new appliance, the wire should be placed behind the erupting tooth.

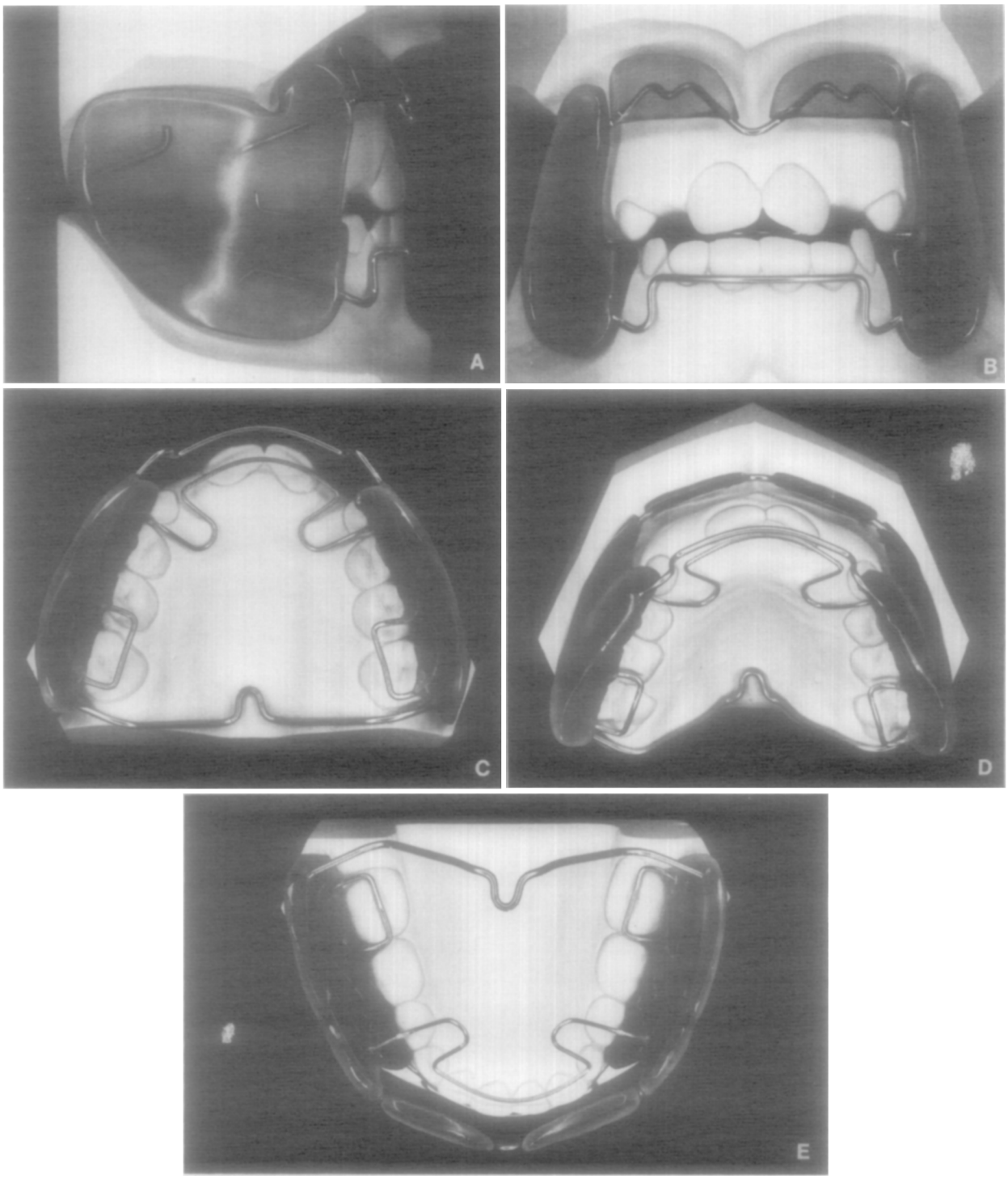

Fig. 9. Finished functional regulator (FR-3). **A,** Lateral view. **B,** Frontal view. **C,** Maxillary occlusal view. **D,** Maxillary oblique view. **E,** Mandibular view. This appliance does not include an upper occlusal rest.

The lower occlusal rest wire. The lower occlusal rest wire (Fig. 7) originates in the lower posterior aspect of the vestibular shield. It curves medially and then anteriorly at the interproximal surface between the mandibular second deciduous molar and first permanent molar. It then curves posteriorly to traverse the central groove of the lower first molar and then recurves laterally to insert once again into the vestibular shield.

This wire is made from 0.030-inch round stainless steel.

The upper occlusal rest wire. As mentioned previously, the upper occlusal rest wire is only used when it is necessary to open the bite anteriorly to allow correction of an anterior crossbite. A doubleback design of 0.036-inch stainless steel is used (Figs. 3 and 8). It originates in the posterior aspect of the vestibular shield, passes anteriorly, and then recurves along the central groove of the upper first molar. If used, this wire is eliminated from the appliance once the anterior crossbite has been corrected.

Acrylic fabrication

The next step in the fabrication of the FR-3 is the application of the acrylic to form the vestibular shield and the upper labial pads. In preparation the upper and lower models are locked together in the articulator. The heels of the models are checked once again to make sure that the bite is still accurate.

The acrylic is applied with alternate applications of monomer and polymer. During this process the name of the patient and date of appliance placement are typed on a small piece of onionskin paper and placed in the acrylic. After the acrylic has hardened slightly, the vestibular shields and the upper labial pads can be trimmed to approximate the final size and shape; the acrylic is then cured under pressure for 15 minutes.

After curing, the appliance is removed from the work models and placed in an ice bath to harden the wax and facilitate its removal. All wires should be gently pried free before the appliance is separated from the models. This is done to avoid distortion of the wires.

Trimming the appliance

After the appliance has been removed from the work model, it is roughly trimmed with a sandpaper arbor. First, the rough outlines of the upper labial pads and the vestibular shields are formed and smoothed. The thickness of the vestibular shields is also reduced to a uniform 2.0 to 2.5 mm in the same manner.

A handpiece and a small burr are used to fine-trim around the wires at the edges of the appliance. Considerable care is to be taken during this procedure because the wires entering the vestibular shield can be greatly weakened if they are nicked or distorted in any way during the trimming process. Then the acrylic parts of the appliance are pumiced and polished on a rag wheel. All edges of the appliance must be smooth to avoid irritation and gingival stripping.

Evaluation of the finished appliance

After the polishing has been completed, the appliance is placed back on the work models (Fig. 9); any distortion from the original fit should be noted. The extensions of the acrylic borders should be checked on the models for accuracy; the fit of the lower labial wire, the upper labial pads (Fig. 10), and the occlusal rest should also be examined. The final adjustments of the appliance, of course, are made by the clinician at the time of delivery of the appliance to the patient.

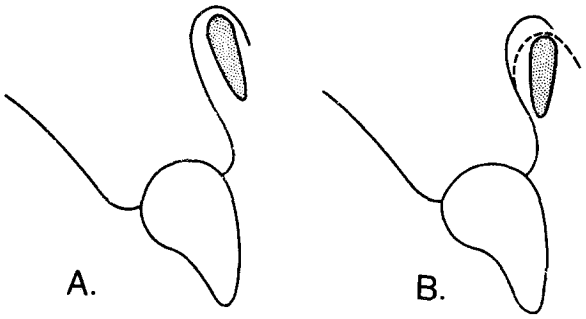

Fig. 10. A, Proper fit of the upper labial pad of the FR-3 appliance. The distance from the linqual surface of the upper labial pad to the maxillary alveolus is approximately 3 mm. **B,** Improper fit of the upper labial pad. Pad is too vertical and placed too low in the maxillary vestibule (after Fränkel[1]).

DELIVERY OF APPLIANCE

At the time of appliance delivery, the clinician checks to see that the contours of the acrylic parts of the appliance extend well into the vestibule and gently blend into the alveolar process. Since there is no forward repositioning of the mandible, little adjustment is needed at time of delivery.

The patient should be instructed that this appliance is a full-time appliance and that it will eventually be worn at all times except during eating, dental hygiene, playing contact sports, language lessons, or playing musical instruments that are held in the mouth. The patient is instructed to read aloud for one-half hour per day until normal speech can be accomplished while wearing the appliance.

During the break-in period, the patient is instructed to wear the appliance on an increasing basis. It is usually recommended that the appliance be worn for a few hours a day for the first few weeks, then gradually increasing wear time until the patient wears it full time. Since there is little change in mandibular position produced by the appliance, the occurrence of sore spots and other clinical problems are less frequent than when the FR-2 appliance is used.

Activating the appliance

After the appliance has been worn on a full-time basis for 3 or 4 months, the distance between the upper labial pads and the underlying alveolus will decrease. Thus, activation of the appliance is necessary to con-

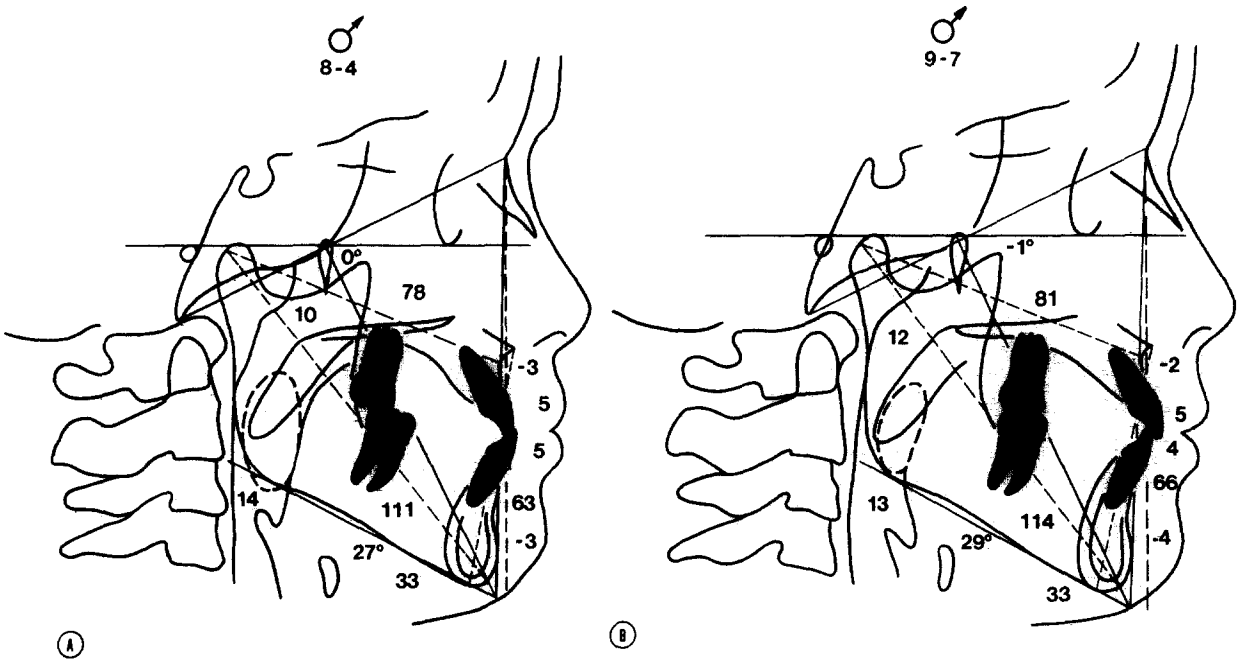

Fig. 11. Case I cephalometric tracings. **A,** Tracing of initial lateral cephalogram. **B,** Tracing of cephalogram taken 15 months later.

tinue treatment. A crosscut fissure burr is used in a low-speed dental handpiece to free the ends of the labial-pad support wires. Enough acrylic is removed around the end of this wire to allow anterior advancement of the wire and maxillary labial pads. The lingual surface of the upper labial pads are kept 3 mm away from the underlying alveolus throughout treatment. After the upper labial-pad adjustment has been checked for patient comfort, the holes in the vestibular shields are refilled with acrylic to secure the labial-pad support wire. In cases of severe maxillary skeletal retrusion, more than one advancement of the maxillary labial pads may be necessary.

CASE REPORTS

In the next section of this article, the skeletal and dental adaptations observed in three patients treated with the functional regulator appliance will be described. Each patient presented with a different morphologic configuration at the beginning of treatment.

CASE I

This patient, an 8-year-old boy, presented with a Class III malocclusion characterized by maxillary skeletal retrusion and an anterior crossbite.

The initial lateral head film (Fig. 11, *A*) was analyzed according to the cephalometric analysis of the senior author.[10] The maxilla was located posteriorly relative to the cranial base. Point A was 3 mm behind the nasion perpendicular (in an idealized mixed-dentition patient, Point A lies on the nasion perpendicular).[10] The effective midfacial length (measured from condylion to Point A) was 78 mm. In a balanced face the corresponding effective mandibular length is 95 to 98 mm.[10] Since the effective mandibular length in this patient was 111 mm, it can be assumed that the patient had a 13 to 16-mm imbalance in the effective lengths of the upper and lower jaws.

The patient's lower anterior facial height was greater than normal (approximately 5 mm over expected values). The mandibular plane angle was within normal limits (27°), as was the facial axis angle (0°). The maxillary central incisors were in a normal position relative to the maxilla with the facial surface of the incisors 5 mm ahead of a line dropped vertically through Point A (ideal 4 to 6 mm).[10] The mandibular central incisors were 5 mm ahead of the A-pogonion line (ideal 1 to 3 mm).

Treatment progress

The impressions and construction bite for the FR-3 appliance were carried out in accordance with the methods previously outlined in this article. The bite registration was taken in the most comfortably retruded mandibular position. With this bite registration, the patient could attain an end-to-end incisal relationship. The appliance was worn on a full-time basis (approximately 20 hours per day) for a period of 12 months.

Analysis of treatment results

As can be observed in the cephalometric tracing of the lateral head film (Fig. 11, *B*) taken 1 year 3 months after the initial head film (Fig. 11, *A*), both skeletal and dental ad-

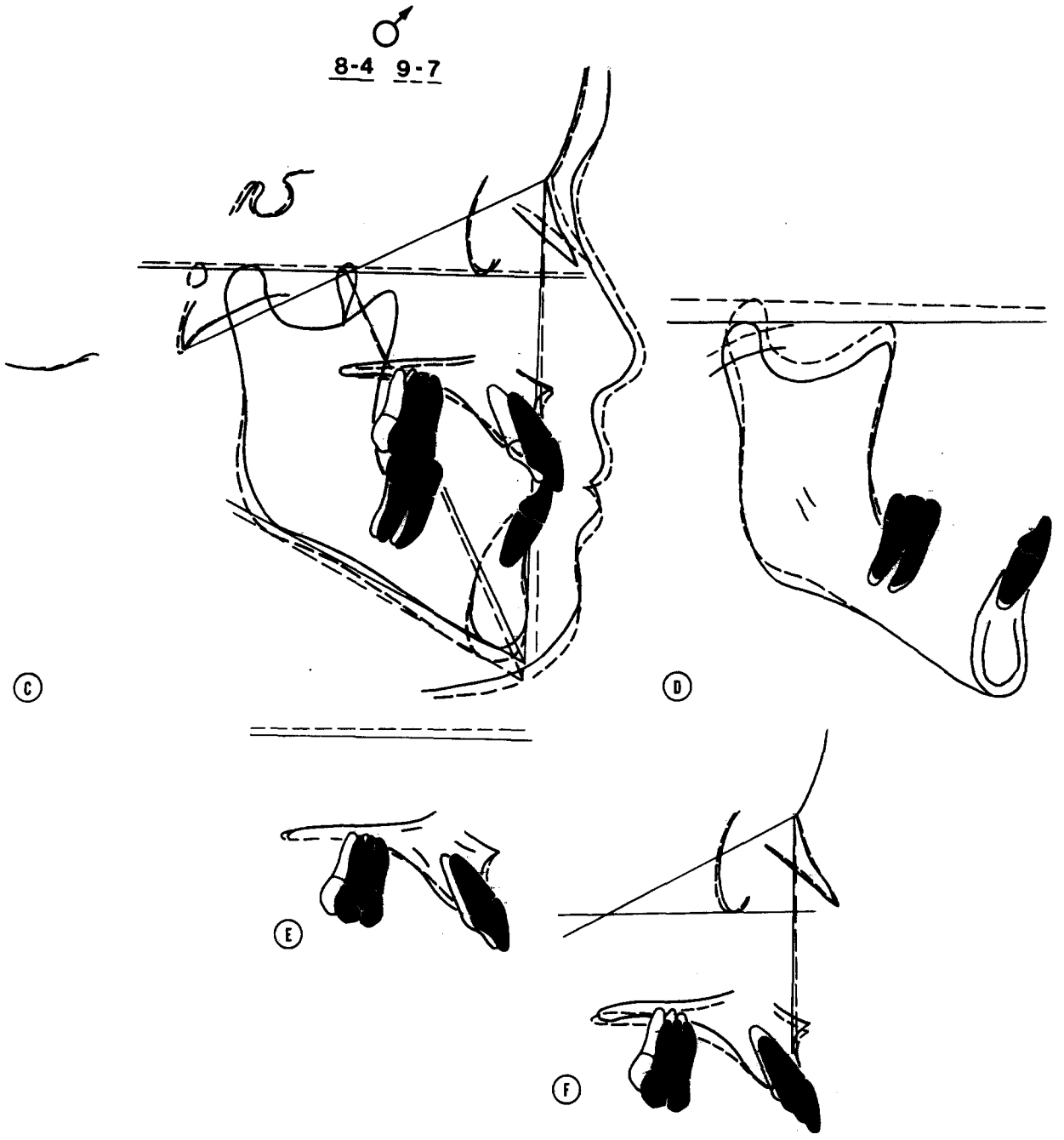

Fig. 11. (Cont'd). Case I cephalometric tracings. **C,** Superimposition of the tracings in **A** and **B** along the basion-nasion line at the pterygomaxillary fissure. **D,** Mandibular superimposition on the internal structures. **E,** Maxillary superimposition on internal structures. **F,** Maxillary displacement. Superimposition is along the basion-nasion line at nasion.

aptations were observed. During 1 year of treatment, there was a 3-mm increase in the length of the midface—about twice as much as would be normally expected in a patient of this age.[10] The maxilla was displaced 1 mm in an anterior direction relative to Point A.

Mandibular length also increased by 3 mm (2 to 3 mm is usually observed in untreated persons), as did the lower anterior facial height (approximately 1 mm per year increase in this dimension is expected). The chin point became more retrusive relative to the nasion perpendicular.

Adaptations in the various regions of the craniofacial complex were analyzed according to the four-point superimposition of Ricketts.[11]

Cranial base superimposition (Fig. 11, *C*). Superimpo-

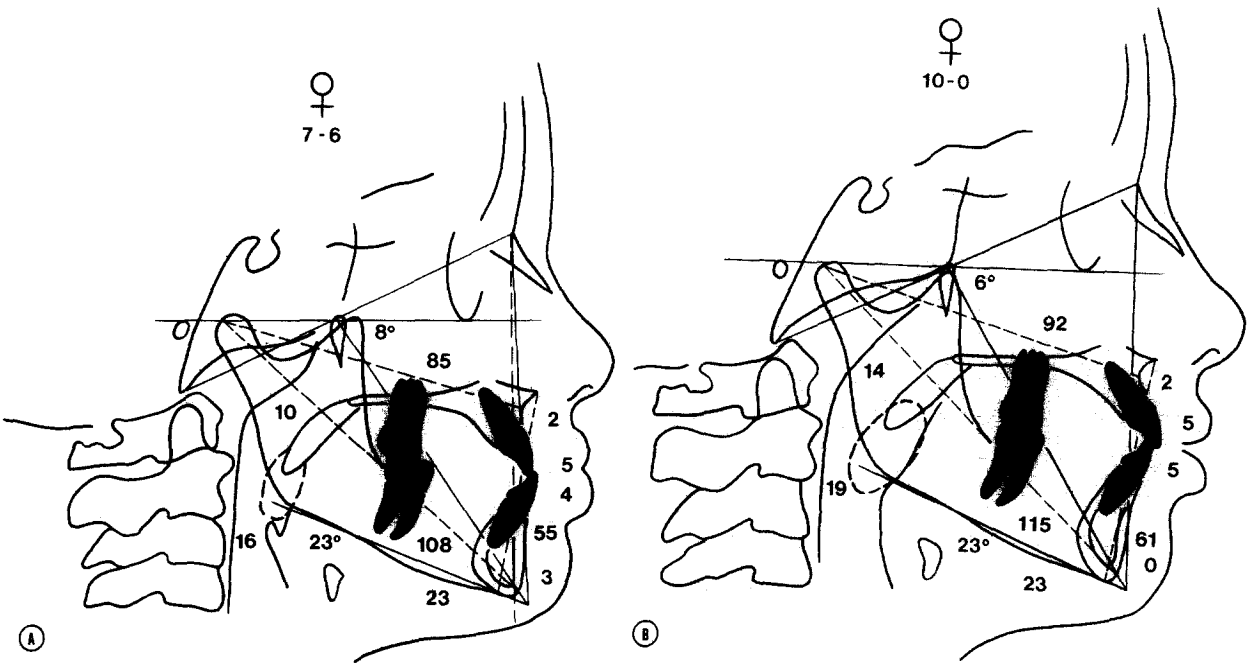

Fig. 12. Case II cephalometric tracings. **A,** Tracing of initial cephalogram. **B,** Tracing of cephalogram taken 2½ years later.

sition along the basion-nasion line at its intersection with the pterygomaxillary fissure indicated that the mandible descended vertically with no change in anteroposterior position. The maxilla moved in a downward and forward direction approximately 3 mm. The position of the lower incisor was relatively unchanged, although the upper incisor moved into a more forward position, eliminating the anterior crossbite. A forward and slight downward movement of the upper molar was also noted.

Mandibular superimposition (Fig. 11, *D*). Superimposition on the internal structures of the mandible (for example, the inferior alveolar canal and the lingual aspect of the symphysis) indicated that mandibular growth was reoriented in a vertical direction with some areas of resorption at the inferior aspect of the gonial angle. The lower molar and the lower incisor erupted vertically with no anteroposterior movement.

Maxillary superimposition (Fig. 11, *E*). Superimposition on the internal structures of the maxilla showed a forward and slight downward movement of the upper incisors and the upper molars. Some changes in the external contour of the maxilla were also evident.

Maxillary displacement (Fig. 11, *F*). Superimposition along the basion-nasion line at nasion showed that the maxilla moved slightly forward during treatment, an adaptation that presumably would not have occurred without treatment. Relative to nasion, the upper incisors moved in a downward and forward direction, as did the upper molars.

Summary

This patient demonstrated both skeletal and dental adaptations during treatment. The maxilla moved in a forward and slightly downward direction with even greater movement observed in the maxillary dentition. The mandible was redirected vertically in its vector of growth with little evidence of anteroposterior repositioning of the chin.

CASE II

The patient, a girl aged 7 years 6 months, had a Class III malocclusion characterized by a Class III molar relationship and an anterior crossbite. In comparison to the patient in Case I, this patient did not have maxillary skeletal retrusion at the beginning of treatment. The evaluation of the initial head film (Fig. 12, *A*) indicated the presence of a normally related maxilla relative to cranial base structures. Point A was 2 mm ahead of the nasion perpendicular. A midfacial length of 85 mm should correspond to a mandibular length of 105 to 108 mm,[10] indicating that the mandible of this patient was normally related to the midface.

A patient with an 85-mm midfacial length should also have a lower anterior facial height of 60 to 62 mm.[10] This patient had a 7-mm deficiency in lower anterior facial height. The mandibular plane angle was normal (23°) and the facial axis angle of 8° indicated a horizontal vector of growth (normal is 0°).

The upper incisor was normally positioned (5 mm ahead of a vertical line dropped through Point A) and the lower incisors were slightly protrusive (4 mm ahead of the A-pogonion line).

Treatment progress

The FR-3 appliance was constructed in accordance with the methods outlined in this article. A second appliance was

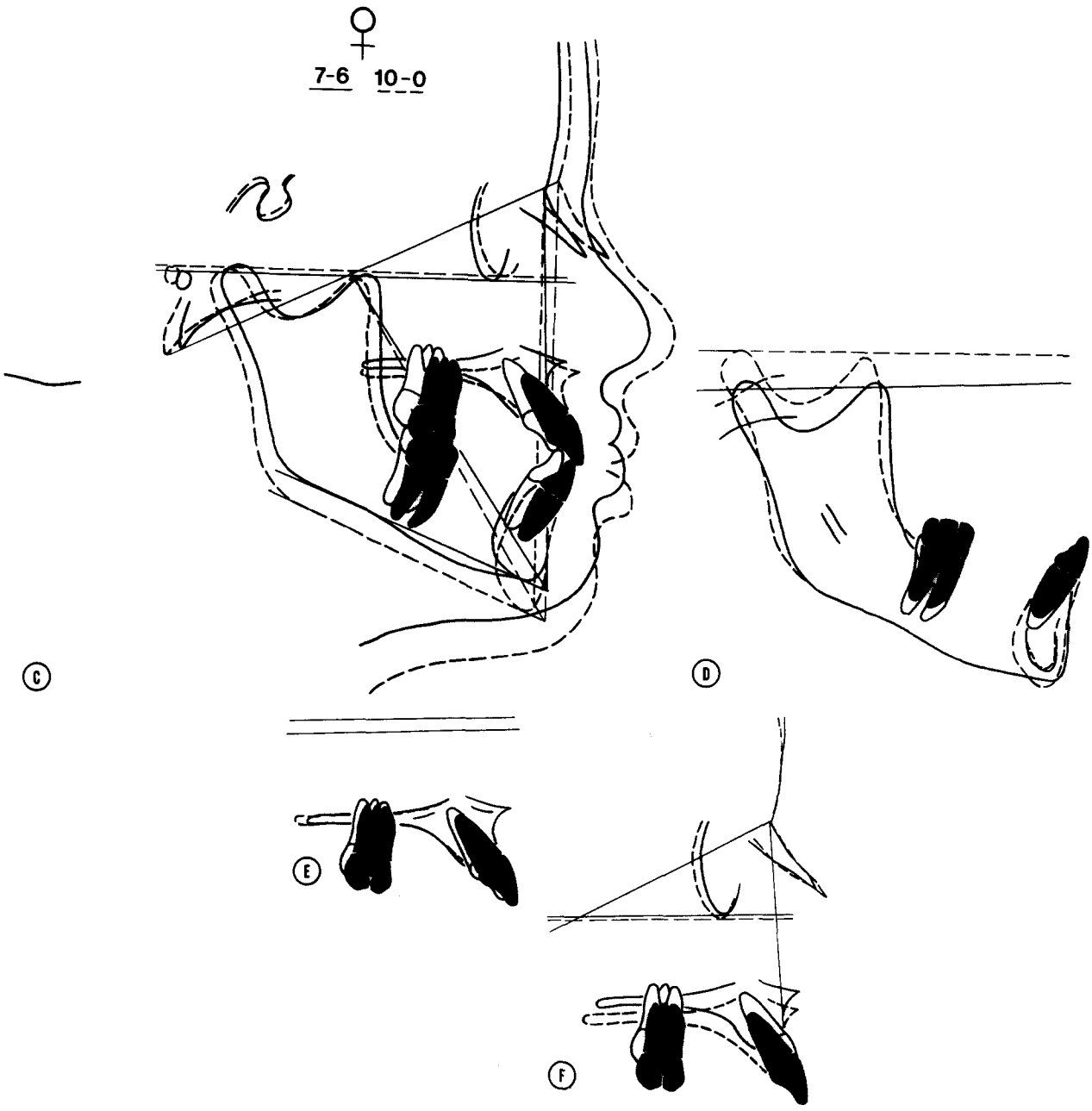

Fig.12 (Cont'd). Case II cephalometric tracings. **C,** Superimposition of the cephalograms in **A** and **B** along the basion-nasion line at the pterygomaxillary fissure. **D,** Mandibular superimposition along internal structures. **E,** Maxillary superimposition along internal structures. **F,** Maxillary displacement. Superimposition is along the basion-nasion at nasion.

made for the patient 14 months after the onset of treatment. The total treatment time was 2 years 3 months with the patient wearing the appliance on an 18 to 20-hour-a-day basis during that time.

Analysis of treatment results

During the 2½ years between the first film (Fig. 12, *A*) and the second film (Fig. 12, *B*), there was a 7 mm-increase in midfacial length, which is greater than normal, as well as a 7-mm increase in mandibular length, a growth increment within normal limits. Lower anterior facial height, which usually increases 1 mm per year,[10] increased by 6 mm. The position of the upper incisors was relatively unchanged anteroposteriorly, whereas the lower incisors became slightly more protrusive relative to the A-pogonion line.

There was no change in the mandibular plane angle which

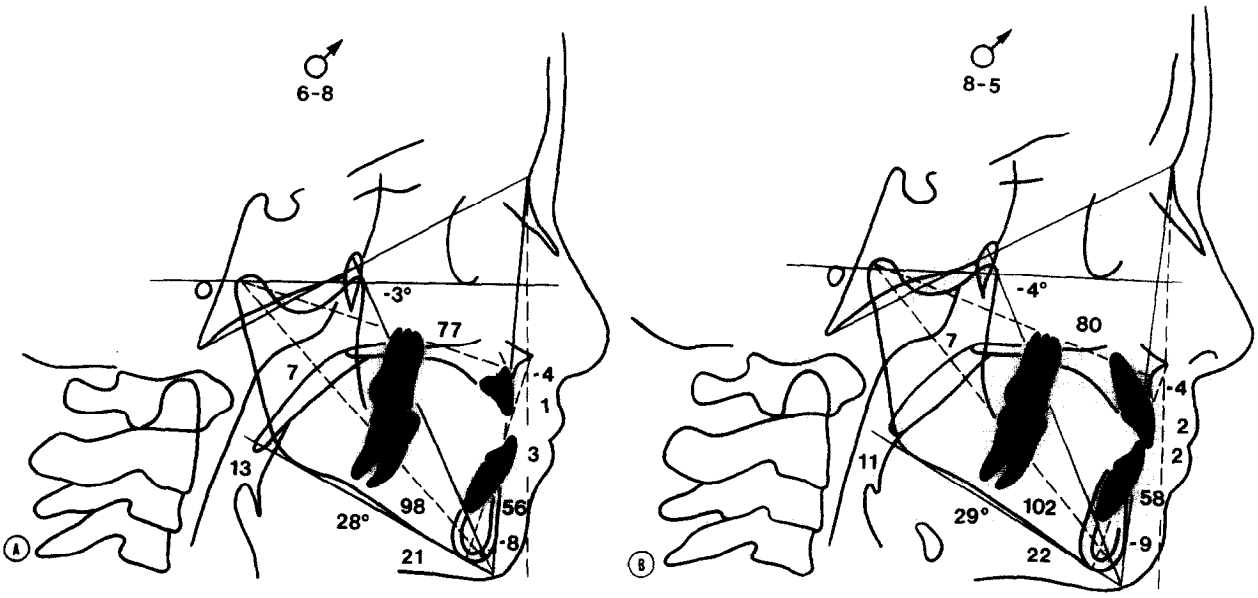

Fig. 13. Case III cephalometric tracings. **A**, Tracing of initial lateral cephalogram. **B**, Tracing of the cephalogram taken 21 months later.

remained at 23°, but there was a decrease of 2° in the facial axis angle.

Cranial base superimposition (Fig. 12, *C*). Superimposing along the basion-nasion line at its intersection with the pterygomaxillary fissure indicated that, as observed in Case I, the direction of mandibular growth was redirected vertically. There was no change in the mandibular plane angle, although there was an opening of the facial axis angle.

The maxilla was displaced anteriorly with some vertical movement observed as well. The anterior crossbite was corrected during the treatment period by a greater forward movement of the maxillary incisors than the mandibular incisors. Changes in the soft-tissue profile were also observed.

Mandibular superimposition (Fig. 12, *D*). Superimposing on the internal structures of the mandible showed an upward and slightly backward direction of condylar growth and some remodeling in the area of the symphysis. Mostly upward movement of the lower molars and lower incisors was noted.

Maxillary superimposition (Fig. 12, *E*). Superimposing on the internal structures of the maxilla revealed less forward movement of the upper teeth than was observed in the patient in Case I. However, the maxillary incisors and molars did move in a downward and forward direction relative to the maxilla.

Maxillary displacement (Fig. 12, *F*). Superimposition of the serial tracings along the basion-nasion line at nasion indicated that there was no forward maxillary displacement relative to nasion during treatment. The palate descended in a downward manner as occurs during normal growth.[10,11]

Summary

This patient showed an increase in midfacial length and an increase in lower anterior facial height over what would be expected during normal growth. In addition, the vector of mandibular growth was redirected more vertically with little anterior chin movement relative to cranial base structures.

CASE III

This patient, a boy aged 6 years 8 months, had a Class III malocclusion characterized by a developing anterior crossbite. Analysis of the initial head film (Fig. 13, *A*) showed a maxilla that was 4 mm in a posterior position relative to cranial base structures. The midfacial length was 77 mm. An idealized midfacial length of 81 mm (adding 4 mm to the actual midfacial length) indicated that effective mandibular length in this patient should be 97 to 100 mm. The patient's actual mandibular length was 98 mm, indicating no major discrepancy if the maxilla were in a normal position.

The patient also presented with a slightly short lower anterior facial height (56 m) that was 1 to 2 mm less than ideal values.[10]

Treatment progress

The patient wore the appliance on a full-time basis for approximately 18 months during which time the occlusal discrepancies were corrected.

Analysis of treatment results

When the initial head film (Fig. 13, *A*) was compared with the posttreatment head film (Fig. 13, *B*) taken 21 months later, significant skeletal and dental adaptations could be observed. Maxillary length increased by 3 mm—a value within normal limits.[10] Mandibular length increased 4 mm and lower anterior facial height increased by 2 mm; again values were within normal limits.

The mandibular plane angle decreased by 1° as did the facial axis angle.

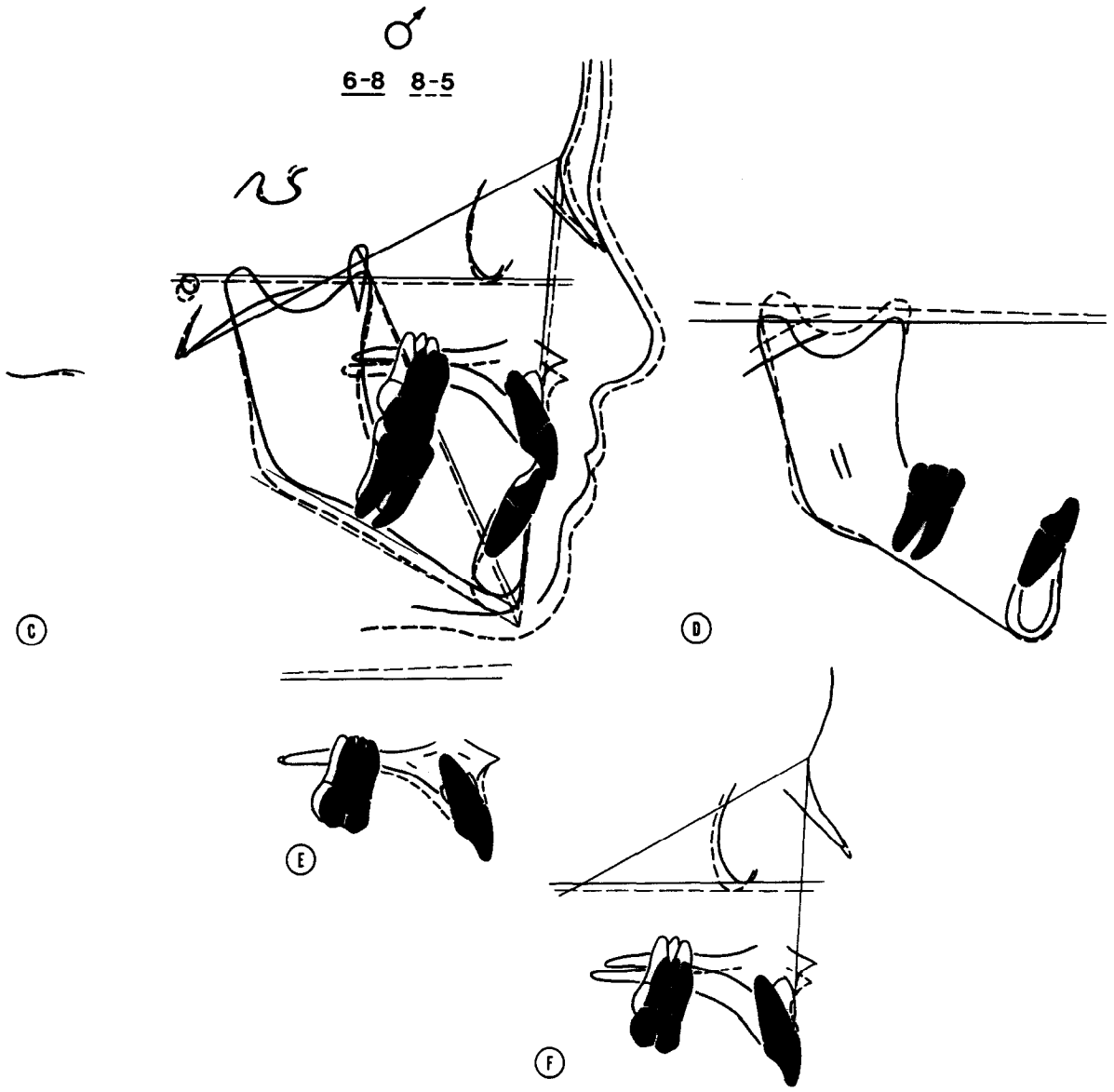

Fig. 13. (Cont'd). Case III cephalometric tracings. **C,** Superimposition of the tracings seen in **A** and **B** along the basion-nasion line at the pterygomaxillary fissure. **D,** Mandibular superimposition on internal structures. **E,** Maxillary superimposition on internal structures. **F,** Maxillary displacement. Superimposition is along the basion-nasion line at nasion.

Slight alterations were observed in the position of the posterior teeth; the attainment of a Class I molar relationship was noted. The potential anterior crossbite was also averted primarily due to the downward and forward movement of the upper incisors.

Cranial base superimposition (Fig. 13, *C*). Superimposing along the basion-nasion line at nasion indicated that once again mandibular growth was redirected inferiorly with a slight opening of the facial axis angle. The maxilla moved in a downward and slightly forward direction.

The largest change in tooth position was observed in the upper molar region. Little change in the contour of the soft-tissue profile was noted.

Mandibular superimposition (Fig. 13, *D*). Superimposing on the internal structures indicated that there was some superior growth at the head of the condyle and slight remodeling in the gonial region. The positions of the lower incisors and lower molars were relatively unchanged.

Maxillary superimposition (Fig. 13, *E*). Superimposing on the internal structures of the maxilla indicated that some remodeling had occurred in this area, particularly along the labial and lingual surfaces of the upper incisors. Some forward and slightly downward movement of the upper molars was also observed.

Maxillary displacement (Fig. 13, *F*). Superimposing along the basion-nasion line at nasion showed that the maxilla

descended in a downward fashion relative to nasion. Little change in the anteroposterior position of this bone was noted.

Summary

Much less skeletal change was observed in this patient than in the patients in Cases I and II. The maxilla moved downward and forward; the mandible was redirected in a more inferior direction. The major dental change appears to have been caused, at least in part, by a downward and forward movement of the upper dentition.

SUMMARY AND CONCLUSIONS

The purpose of this article has been to describe the clinical use of the FR-3 appliance of Fränkel, which has classically been used in cases of Class III malocclusion. The parts of the appliance have been described as have the method of impression taking, bite registration, construction, and appliance delivery.

The three case reports, each of which demonstrated a slightly different morphologic type, indicate that this appliance has a different effect on the growing craniofacial skeleton. The two common findings that were observed in all three patients were the forward movement of the maxillary dentition and the redirection of mandibular growth in a vertical direction. Variable responses in the maxilla were noted.

Before any precise statement can be made regarding the mechanism of action of the Fränkel FR-3 appliance, appropriate prospective clinical trials must be carried out in Class III patients presenting with a wide variety of morphologic types.

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