J Oral Maxillofac Surg
59:635-640, 2001

A Comparison of 3 Methods of Face-Bow Transfer Recording: Implications for Orthognathic Surgery

Jaime Gateno, DDS, MD, Kim K. Forrest, DDS, MS,† and Brian Camp, DDS, MD‡*

Purpose: The purpose of this study was to compare the occlusal plane inclination of models mounted using 3 different systems for face-bow transfer with the actual occlusal plane inclination as measured on a cephalometric radiograph.

Patients and Methods: Twenty-two subjects were enrolled in this study. Three alginate impressions of the maxillary dentition were taken, and 3 stone dental models were produced for each subject. Face-bow recordings were obtained on each subject using the SAM Anatomical Face-bow (Great Lakes Orthodontics Products, Ltd, Tonawanda, NY), the Erickson Surgical Face-bow (Great Lakes Orthodontics Products, Ltd) and a new technique developed by one of the authors (J.G.). For each subject, the dental models were mounted on a SAM articulator using each of the 3 face-bow recordings. Finally, a lateral cephalometric radiograph was obtained for each subject. The occlusal plane inclination was measured on the models and on the cephalometric radiographs. Differences among groups were tested using a 1-way analysis of variance. Bonferroni test was used for post hoc comparison between different pairs of groups.

Results: The average occlusal plane inclination using the SAM Anatomical Face-bow was 7.8° ± 4.2° greater than the actual—a difference that was statistically significant. The mean occlusal plane inclination of the models obtained using the Erickson Surgical Face-bow was 4.4° ± 2.2° greater than the actual—a difference that was also statistically significant. The mean occlusal plane inclination of the models obtained by the new technique was only 0.9° ± 1.2° greater than the actual; this difference was not statistically significant.

Conclusions: The new mounting technique is more accurate than the conventional SAM Face-bow or the Erickson Face-bow for reproducing the actual occlusal plane inclination.

The ability of the surgeon to transfer the desired surgical plan to the patient during orthognathic surgery depends mainly on the accuracy of the surgical splint. The fabrication of an accurate splint requires that the models be mounted to replicate the position of the patient's dentition. Ellis et al[1] demonstrated a significant difference between the inclination of the occlusal plane on the mounted models and the actual occlusal plane as measured on the cephalograms. Their solution for this problem involved modification of the mounting technique used with the Hanau articulator. Unfortunately, this technique cannot be used with the SAM system, because the mounting jigs available for this system do not allow for pin adjustments during mounting.

Working with the SAM system, Erickson et al[2] designed a special surgical face-bow that also addressed the problem of inaccurately mounted models. However, this system did not take into consideration anatomic variations in subjects and, to our knowledge, its accuracy has not been formally tested. One of the authors (J.G.) has developed a new method of face-bow transfer that takes into consideration the individual anatomic variations among subjects. The purpose of this study was to compare the occlusal plane inclination of models mounted using 3 different systems for face-bow transfer with the actual occlusal plane as measured on the cephalogram.

Received from the University of Texas Health Science Center, Houston, TX.

*Assistant Professor, Department of Oral and Maxillofacial Surgery.

†Former Resident, Department of Orthodontics.

‡Former Resident, Department of Oral and Maxillofacial Surgery.

Address correspondence and reprint requests to Dr Gateno: 6550 Fannin, Suite 2237, Houston, TX 77030.

0278-2391/01/5906-0007$35.00/0
doi:10.1053/joms.2001.23374

Patients and Methods

The mounting methods studied involved use of the SAM Anatomical Face-bow (ATB 100) (Great Lakes Orthodontics Products, Ltd, Tonawanda, NY), the Erickson Surgical Face-bow (Great Lakes Orthodontics Products, Ltd) and a new technique developed by one of the authors (J.G.). Each method was designed for use with the SAM2 articulator (Great Lakes Orthodontic Products, Ltd).

FACE-BOW TRANSFER

SAM Anatomical Face-bow (ATB100)

With the SAM Anatomical Face-bow, the first step was to adapt the bite fork to the maxillary teeth. This was done with attention to proper alignment in the sagittal plane. After the bite fork was adapted, it was removed. The face-bow was placed in the ears and was locked in place. The nasion adapter was placed, fitted, and secured. The bite fork was placed back in the mouth, and 2 cotton rolls were placed underneath the bite fork. This allowed the patient to stabilize the bite fork when biting down. Finally, the rods that connect the bite fork to the face-bow were placed and tightened (Fig 1).

Erickson Surgical Face-bow

This face-bow was intended for use with the SAM2 articulator and is based on modifications made to the SAM Anatomical Face-bow. It is equipped with an adjustable nasal rest and an infraorbital pointer. The pointer arbitrarily lowers the anterior part of the face-bow below orbitale by 6.8 mm, thereby reducing the inclination of the occlusal plane (Fig 2).

In using the Erickson Face-bow, the bite fork was adapted and removed as in the previous technique. The face-bow was placed in the ears and was locked in place. The tip of the infraorbital pointer was aligned with the most inferior aspect of the infraorbital rim. With the face-bow in this position, the adjustable nasal rest was adapted and locked. Once the bite fork was placed back in the mouth, the rods that connect the bite fork to the face-bow were placed and tightened (Fig 2).

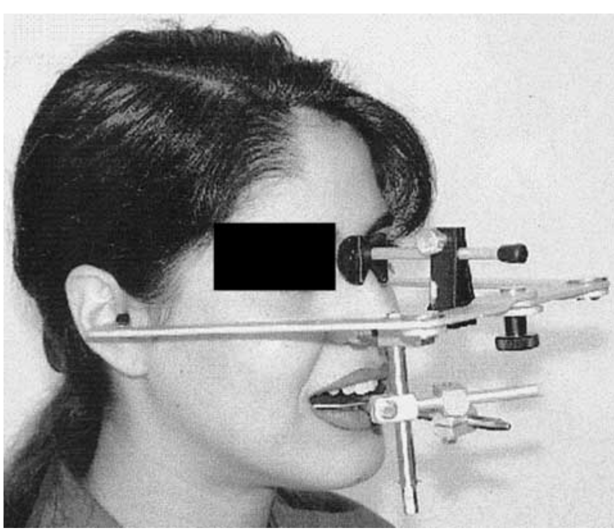

FIGURE 1. SAM Anatomical Face-bow (ATB-100).

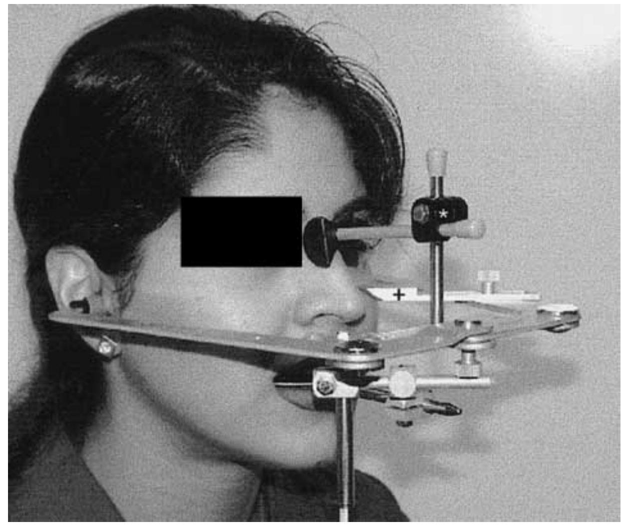

FIGURE 2. Erickson Surgical Face-bow. The infraorbital pointer (+) lowers the anterior end of the face-bow 6.8 mm. (*adjustable nasal rest.)

Author's Technique

The author's technique modified the hardware of the existing SAM Anatomical Face-bow. The use of the nasion locator was eliminated, and a Boley gauge with sharpened points was added. One-millimeter holes were drilled in the most anterior aspect of the bite fork and in the middle of the anterior edge of face-bow. The length of the face-bow (19.5 cm) was measured from its anterior edge to a perpendicular line that passed through the center of both ear rods (Fig 3).

The bite fork was adapted to the maxillary teeth and stabilized using cotton rolls between the bite fork and the mandibular teeth. A cephalometric radiograph was then taken with the bite fork in place. The radiograph cassette was moved anteriorly so that the posterior edge of the cassette was just behind the external auditory canal. This ensured that the full length of the bite fork was captured on the film. Before the radiograph was taken, a wire measuring 30 mm was taped to the dorsum of the nose. This wire was used to calculate the magnification of the x-ray machine. After the radiograph was taken and the bite fork was removed, the cephalogram was used to calculate the appropriate position for the face-bow.

A sheet of acetate paper was laid on the cephalogram, and the following points were located: porion,

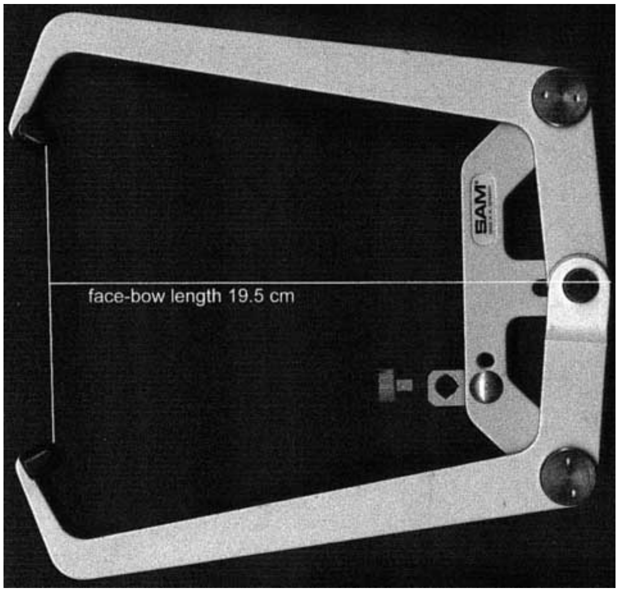

FIGURE 3. SAM Anatomical Face-bow.

orbitale, the middle of the ear rod, and the tip of the bite fork. Porion and orbitale were used to trace Frankfort horizontal. Because the center of the cephalostat's ear rod coincided with the center of the ear rod of the face-bow, the former was used to represent the position of the posterior end of the face-bow. From this point, a horizontal line representing the face-bow was drawn parallel to Frankfort horizontal. The length of the horizontal line was calculated by adding the actual length of the face-bow plus the magnification factor of the x-ray machine. As mentioned earlier, the length of this face-bow was 19.5 cm. The magnification of the cephalometric x-ray machine used in this study was 12.5%. Thus, the horizontal line that represented the face-bow measured 22.0 cm (19.5 + 2.5 cm). Finally, the distance from the anterior end of this line to the tip of the bite fork was measured and recorded. After the magnification factor was subtracted, this distance was used to locate the position of the anterior edge of the face-bow during the actual face-bow transfer. The Boley gauge was set to this distance (Fig 4).

After the tracing was complete and the Boley gauge was set, the face-bow was placed in the ears and locked in place. The bite fork was repositioned on the maxilla and stabilized with cotton rolls. The rods that connect the bite fork to the face-bow were inserted. One tip of the Boley gauge was placed in the hole at the tip of the bite fork, and the other was placed in the hole at the anterior edge of the face-bow. This maneuver positioned the anterior limb of the face-bow at the appropriate location. After this was completed, the screws were securely tightened (Fig 5).

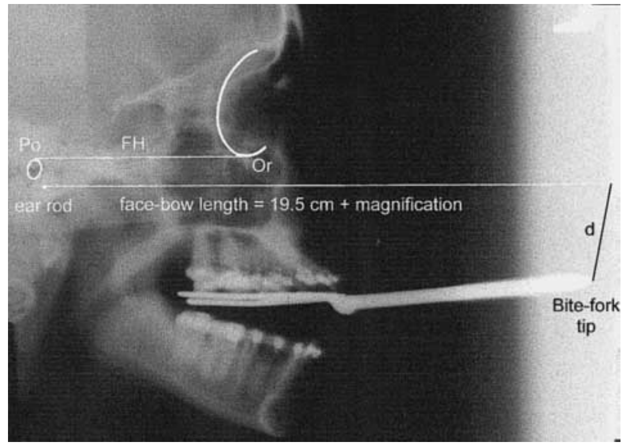

FIGURE 4. Frankfort horizontal (FH) is traced between porion (Po) and orbitale (Or). From the center of the ear rod, a line is drawn parallel to FH. This line measures 22 cm. The distance (d) from the end of this line to the tip of the bite fork is measured and recorded.

SUBJECTS

The protocol for this study was approved by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center in Houston. Twenty-two volunteers were enrolled. Three alginate impressions of the maxillary dentition, and 3 stone dental models were made for each subject. In addition, 3 face-bow recordings were obtained on each subject using each of the previously described techniques. The dental models were mounted on a SAM2 articulator using each of the 3 face-bow recording techniques. Lateral cephalometric radiographs were obtained for each subject. All the impressions, mountings, and radiographs were obtained by a single investigator (K.K.F.).

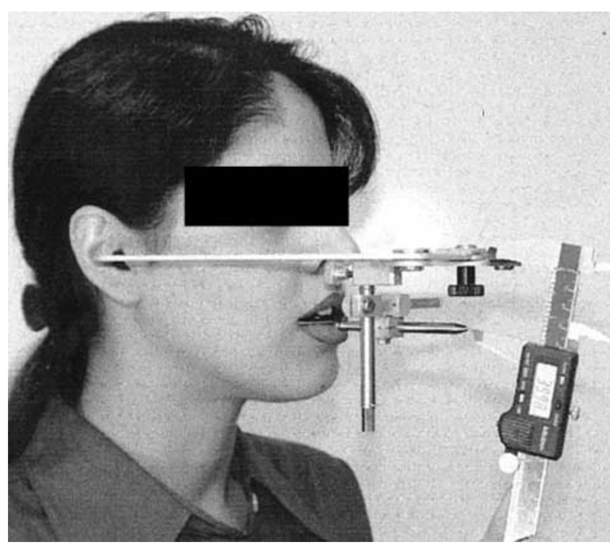

FIGURE 5. One tip of the Boley gauge is placed in the hole at the tip of the bite fork and the other is placed in the hole at the anterior edge of the face-bow. This position of the face-bow is parallel to Frankfort horizontal.

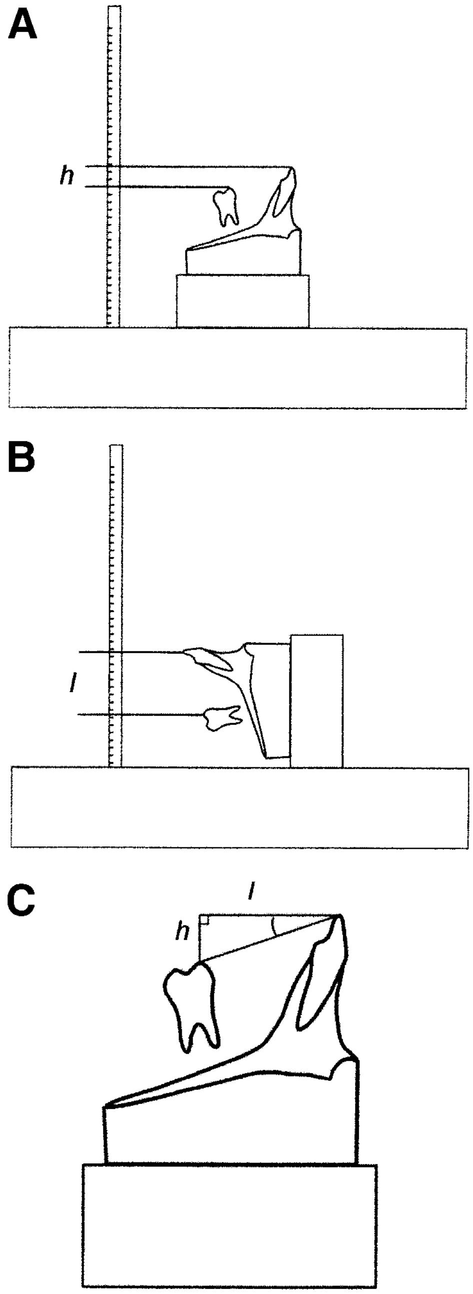

FIGURE 6. Technique used to measure the occlusal plane inclination of the models.

OUTCOME MEASUREMENTS

The models were mounted on an Erickson Model Block and Platform (Great Lakes Orthodontic Products, Ltd), to measure the inclination of the occlusal plane. The middle of the incisal edge of the right central incisor and the tip of the mesiobuccal cusp of the right first molar were marked with a pencil. With the model oriented with the occlusal surfaces of the teeth "looking up," the gauge was placed first on the first molar mark and zeroed. After this, the tip of the gauge was positioned on the incisor mark and the measurement obtained was recorded as "*h*" (Fig 6A). With the model oriented with the labial surfaces of the central incisors facing up, the caliper was first place on the first molar mark and zeroed. Following this, the tip of the gauge was moved to the incisor mark, and the measurement obtained was recorded as "*l*" (Fig 6B). Because *h* and *l* represented the height and length of a right triangle, the occlusal plane inclination θ was calculated using the formula $\theta = \tan^{-1}(h/l)$ (Fig 6C). These measurements were repeated 3 times on 3 different occasions by 2 independent examiners and recorded to the nearest 0.5°.

The occlusal plane inclination was also measured on the cephalometric radiographs. The occlusal plane was traced between the tip of the central incisor and the mesiobuccal cusp of the first molar. The inclination of this plane to Frankfort horizontal was measured. All measurements were repeated 3 times on 3 different occasions by 2 independent examiners.

STATISTICAL ANALYSIS

The intrarater and interrater reliability were calculated using a 1-way analysis of variance. Descriptive statistics were used to summarize the data. Differences among groups were tested using a 1-way analysis of variance. The Bonferroni test was used for post hoc comparison between different pairs of groups.

Results

No statistically significant differences among the 3 measurements made by each examiner or between examiners. These measurements were used to calculate the average occlusal plane inclination for each subject. The occlusal plane inclination measured on the cephalometric radiographs was 6.1° ± 4.5°. The occlusal plane inclination of the models mounted using the SAM Anatomical Face-bow, the Erikson Surgical Face-bow, and the author's new technique were: 13.9° ± 6.7°, 10.5° ± 5.3°, and 7° ± 4.5°, respectively. The analysis of variance test demonstrated a

Table 1. MULTIPLE COMPARISONS BETWEEN GROUPS USING BONFERRONI *t* TEST

Comparisons	Mean Difference (°)	*t*	Significant
SAM vs control	7.8	4.65	Yes
Erickson vs control	4.4	2.7	Yes
New technique vs control	0.9	0.54	No
SAM vs Erickson	3.1	1.1	No

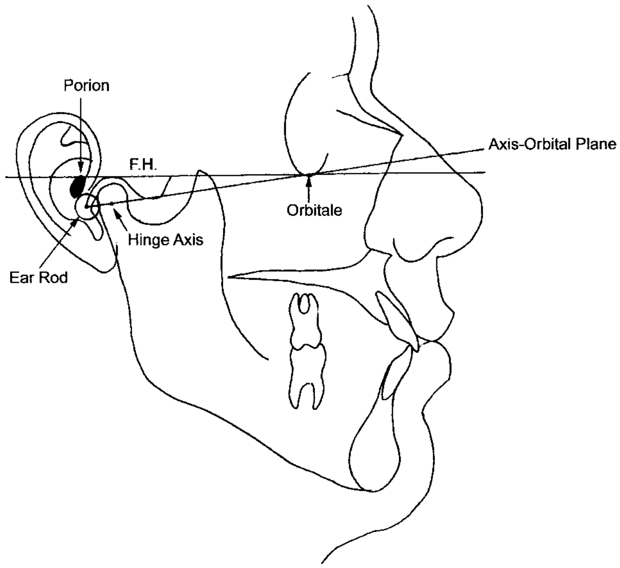

FIGURE 7. The axis-orbital plane passes through the hinge-axis of the mandible. This plane is 7° off Frankfort horizontal (FH).

statistically significant difference among groups at an alpha level of .05. The Bonferroni test was used to test differences between pairs of groups. The results of these comparisons are presented in Table 1.

Discussion

Planning for orthognathic surgery involves integrating diagnostic information from 3 different sources: the patient examination, the cephalometric radiograph, and the dental models. To link this information, a common referrence plane is required, which in most cases is Frankfort horizontal. It is universally accepted that the upper arm of the articulator represents Frankfort horizontal. However, this assumption is erroneous. The semiadjustable articulator used for model surgery was originally created for use in prosthetic dentistry. Its face-bow was designed to transfer the relationship of the maxilla to the terminal hinge-axis of the mandible. To accomplish this, the posterior end of the face-bow was aligned to the terminal hinge axis (middle of the condyle), and the anterior end was aligned to orbitale. These points defined a plane called the axis-orbital plane, which is 7° off Frankfort as shown in Figure 7.

The occlusal plane inclination of the models mounted using the conventional SAM Face-bow was 7.8° greater than the inclination measured on the radiograph. This difference can be explained by the fact that this system aligns the face-bow to the axis-orbital plane, which is approximately 7° off Frankfort

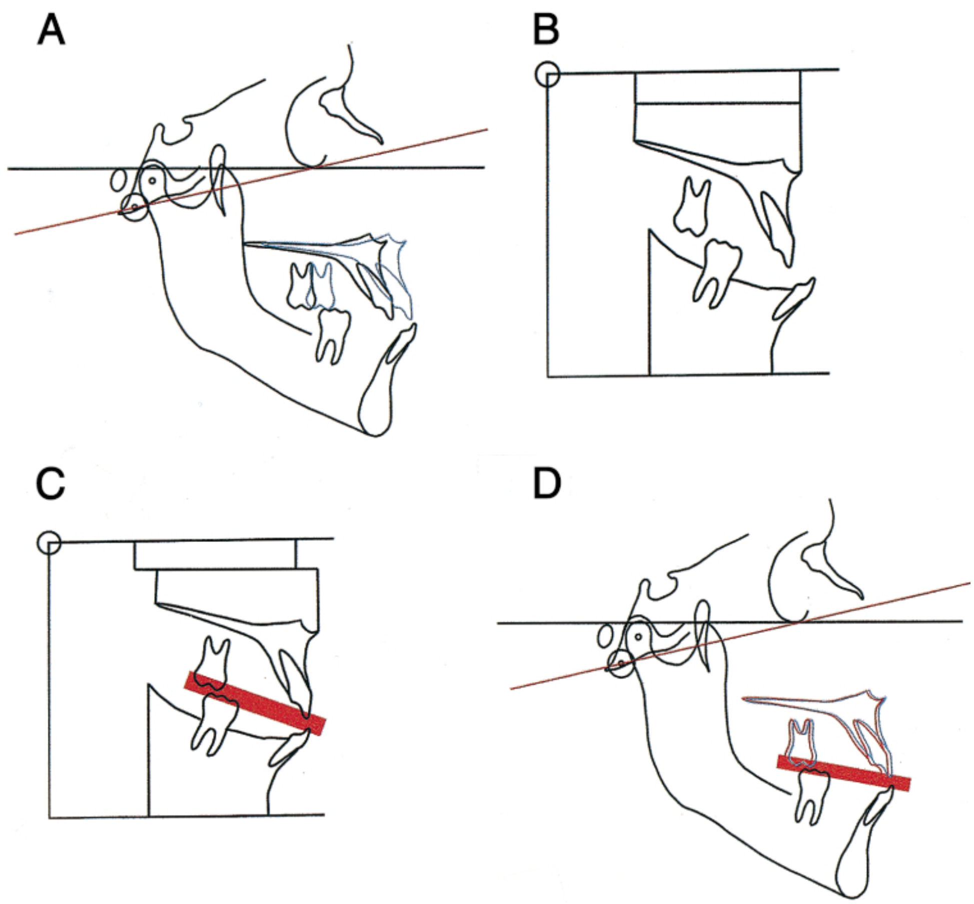

FIGURE 8. *A*, Prediction tracing of a hypothetical patient. The horizontal line in black is Frankfort horizontal. The red line is the axis-orbital plane, which is 12° off Frankfort horizontal. The plan calls for a 10-mm maxillary advancement (*blue line*). *B*, Diagram of the models mounted on an articulator. Note that the occlusal plane inclination of the mounted models is 12° steeper than the actual occlusal plane. *C*, Model surgery. The maxillary model has been advanced 10 mm, and the intermediate splint (red) has been fabricated. *D*, Diagram of the maxillary position at surgery. The blue outline represents the desired position for the maxilla. The red outline represents the actual position at surgery. Note that the actual position is 1.5 mm behind the desired position.

horizontal.[3] These results are comparable to those obtained by Ellis et al, who used a similar face-bow.[1]

The other 2 methods evaluated were the Erickson's Surgical Face-bow and the author's new method. In contrast to the conventional technique, these methods were designed to align the face-bow with Frankfort Horizontal and not the axis-orbital plane. Both methods were found to be more accurate than the conventional SAM Face-bow. However, Erickson's technique produced models whose occlusal plane inclinations were still too steep, whereas the author's new technique produced models whose occlusal plane inclinations were accurately oriented to Frankfort horizontal (Table 1). The principal difference between the 2 techniques was the method used to position the anterior edge of the face-bow. Erickson's method lowered the face-bow by a constant distance, whereas the new technique calculated the position of the face-bow for each patient.

The advantage of using models that are accurately oriented to Frankfort horizontal becomes evident once the implications of using inaccurately mounted models are understood. Figure 8 illustrates the results of using inaccurate models to fabricate an intermediate splint. Figure 8A depicts the cephalometric tracing of a hypothetical patient with mandibular prognathism and maxillary hypoplasia. The surgical plan for this patient calls for a 10-mm maxillary advancement and a 4-mm mandibular setback. In this case, the axis-orbital plane is 12° off the Frankfort horizontal. Figure 8B depicts the articulator on which the models have been mounted using the conventional system. The occlusal plane inclination of the mounted models is 12° greater than that on the cephalometric tracing (Fig 8). In Figure 8C the maxillary model has been advanced 10 mm forward, and the intermediate splint has been fabricated. Figure 8D depicts the planned position for the maxilla and the actual position of the maxilla at the time of surgery. In this hypothetical case, the position of the maxilla at surgery is 1.5 mm behind the planned position, producing a maxillary advancement of only 8.5 mm; 15% less than desired. Although the gains with the author's technique are modest, the surgeon is able to increase the accuracy of the surgical planning and subsequent surgical results. The only drawback to the technique is the necessity of an additional cephalometric radiograph.

Acknowledgment

The author would like to thank Great Lakes Orthodontics, Ltd, Tonawanda, NY, for their support in this study.

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