Cephalometric and clinical diagnoses of open bite tendency

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Pretreatment lateral cephalometric radiographs of patients between 10 and 16 years of age were searched for persons who met criteria commonly used for identifying patients with "open bite tendencies." Results indicate that different measures of open bite tendency identify different patients. Of 50 patients with sella-nasion–mandibular plane angles greater than 40°, only 11 had upper facial height/lower facial height ratios less than 0.70; of 50 patients who had occlusal plane-mandibular plane angles greater than 22°, only 15 had posterior facial height/anterior facial height ratios of less than 0.58. Of the 250 patients who exhibited some well-accepted cephalometric indication for excessive vertical dimension, only 13% had actual anterior open bites. When clinicians ranked their own patients according to the difficulty in controlling excessive vertical growth during treatment, measurements such as the mandibular plane angle, upper to lower facial height ratio, and anterior to posterior facial height ratio did not predict treatment responses. (Am J Orthod Dentofac Orthop 1988;94:484-90.)

How does a clinician decide that a patient has an open bite tendency? The ability to recognize a patient who will exhibit excessive posterior tooth extrusion in response to routine mechanics or excessive vertical growth during treatment is critically important for proper diagnosis and treatment planning. There is a general consensus that patients in this category are among the most consistently difficult challenges faced in orthodontics, and obviously it is highly desirable to be able to identify them before treatment is initiated.

Nevertheless a review of the literature indicates that there is no accepted method to determine the presence of an open bite tendency. Most commonly clinicians evaluate the mandibular plane angle and consider "high angle" cases to be indicative of open bite tendencies. However, a number of investigators have been unable to support this assumed relationship.[1,2] Furthermore, other clinicians use different measurements as an indication of this problem, including the ratio of posterior to anterior facial height[3,4] and the ratio of upper anterior to lower anterior facial height.[5,6]

The purpose of this study is to compare several different commonly used cephalometric indications of "open bite tendency" to determine to what extent they identify the same or different patients. In addition, these measurements are related to actual clinical evaluations of patients exhibiting open bite problems during treatment. These data are used in an attempt to determine whether or not cephalometric variables can produce clinically valid assessments of the tendency for a patient to develop an open bite or exhibit excessive vertical lower facial growth during treatment.

MATERIALS AND METHODS

Pretreatment lateral cephalometric radiographs were obtained on 300 subjects of both sexes between 10 and 16 years of age.

The radiographs were obtained from several different orthodontic practices in Missouri and Kansas. Six different cephalometric measurements were used to select radiographs. For each of these six cephalometric measurements, a value was selected defining patients with an open bite tendency. Records from an office were examined at random and measured for a single variable. When the value for that cephalometric variable met the predetermined criterion for selection as a patient with an open bite tendency, the patient was included in the sample. This selection process continued until 50 patients were chosen. If 50 patients with the necessary value for a particular measurement were not available at one office, a second office was used to continue collecting the same variable.

Once an office was used for data collection of one measurement, it was not used for any other sample. The important characteristic of each group of 50 patients was that no cephalometric or occlusal criterion other than the single variable was used. More than 2500

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radiographs were measured to find the 50 subjects in each of the following 6 groups.

Group 1–SN:MP angle—Mandibular plane to sella-nasion angle 40° or greater. In many previous studies of patients with high mandibular plane angles, a variety of values for this measurement have been used to select cases. Bishara and Augspurger[7] defined high-angle cases as those with values greater than 34.8°; Isaacson and associates[8] used cases greater than 38°. Several studies have found average values close to 40° in groups of open bite patients.[9,10] Since mean values for normal samples have been found to be 28° ± 3.4°[7] and 33.7° ± 4.8°,[11] the value of 40° is at least one standard deviation higher than the mean. In this study the mandibular plane was defined as the line connecting menton with constructed gonion.

Group 2–OP:MP angle—Mandibular plane to occlusal plane angle 22° or greater. Schudy[12] first described the use of the OP:MP angle to identify vertical differences among patients. Both Schudy[12] and Kim[11] found an average value for normal patients of 16° for the measurement with standard deviations of 4.0° and 3.8°, respectively. Schudy's mean value for a group of 50 patients with long anterior facial heights was 22°.[9] In the present study, the occlusal plane was established by Schudy's method, which involves bisecting the vertical overlap of the distobuccal cusps of first molars and bisecting the vertical open bite (or overbite) of the central incisors. Schudy[12] used the terminology of "OM angle" for this measurement.

Group 3–PP:MP angle—Mandibular plane to palatal plane angle 32° or greater. Nahoun, Horowitz, and Benedicto[5] and Kim[11] observed the PP:MP angle as part of their studies of patients with long lower faces or excessive vertical dimension. In their samples of normal patients, average values for this angle were found to be 20.7° and 25.6°, respectively. In Class II patients with open bites, Nahoun, Horowitz, and Benedicto[5] reported an average value of 37.1°. Kim[11] found a mean value of 32.5° in 56 open bite patients. Bimler[13] used this angle as a key measurement to describe differences in facial types. He defined 0° to 15° PP:MP angles as dolichoprosopic facial types, 15° to 30° as mesoprosopic, and more than 30° as leptoprosopic. Palatal plane was defined as the line connecting ANS and PNS.

Group 4—Anterior open bite. This was determined from cephalometric radiographs and defined as a vertical space between maxillary and mandibular incisors perpendicular to the occlusal plane. Patients were included in this group if they exhibited any detectable vertical open bite.

Group 5–PFH/AFH—Posterior facial height (PFH) to anterior facial height (AFH) ratio (Jarabak ratio) of 58% or less. Jarabak and co-workers[3,4] defined hypodivergent growers as patients having PFH to AFH ratios of 64% or greater; hyperdivergent growth patterns were defined as PFH to AFH ratios of 58% or less. Fifty-nine percent to 63% was defined as the neutral range. AFH was defined as nasion to menton and PFH as sella to constructed gonion. In this study the ratio is reported as a decimal rather than following multiplication by 100% (for example, 0.58 rather than 58%).

Group 6–UFH/LFH—Upper facial height (UFH) to lower facial height (LFH) ratio of 0.700 or less. Nahoun[5,6,14,15] has extensively evaluated UFH to LFH ratios as an indication of open bite tendency. He reported[5] that in patients with "good faces," the UFH to LFH ratio averaged 0.810. Open bite patients had an average UFH to LFH ratio of 0.686, and deep bite patients exhibited UFH to LFH ratios of 0.900 and above. The division between the upper face and lower face was determined by a perpendicular through ANS from the nasion-menton line. Upper facial height was measured as nasion to the ANS perpendicular and lower facial height from the ANS perpendicular to menton.

After all radiographs were collected, the preceding six measurements were digitized for every patient in all groups on an IBM PC Numonics 400 digitizer with numeric coprocessor, using the Orthodig digitizing program developed at Washington University.[16] Resulting data were analyzed on an IBM-AT computer with the Systat Package.[17]

A seventh measurement, which was not collected as a specific group of patients, was measured also. This measurement was the overbite depth indicator.[11] The overbite depth indicator (ODI) is defined as the angle of the A-B plane to the mandibular plane combined with the angle of the palatal plane to Frankfort horizontal. If the latter angle is positive, it is added to the former angle. If it is negative, it is subtracted from the former angle. Frankfort horizontal was measured from anatomic porion to orbitale. Lower values of the ODI indicate open bite tendency. Kim[11] reported a mean value of 74.5° and standard deviation of 6.07° for a sample of patients with normal occlusions. A value of 68° or less (one standard deviation below the mean) was used as an indication of open bite tendency.

Although the main objective of this study was to compare and contrast the cephalometric measurements often used to evaluate excessive vertical dimension, collection of these data provided the opportunity to test the relationship between clinical treatment results and pretreatment cephalometric measurements. Thus it was possible to ask if these patients, cephalometrically identified as having an open bite tendency, were actually

Table I. Means and standard deviations for all variables, separately for each group

	Measurement													
	SN : MP		*OP : MP*		*PP : MP*		*Open bite*		*PFH/AFH ratio*		*UFH/LFH ratio*		*ODI*	
Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
SN : MP >40° (N = 50)	43.3	2.66	24.4	3.56	35.2	4.15	−3.0	2.03	0.56	0.023	0.76	0.065	66.9	8.07
OP : MP >22° (N = 50)	38.8	4.76	25.9	2.60	33.1	4.38	−3.2	2.17	0.60	0.036	0.75	0.059	68.8	7.11
PP : MP >32° (N = 50)	39.4	3.47	23.1	3.25	35.7	2.61	−3.1	2.18	0.60	0.027	0.72	0.054	64.3	6.37
Open bite (N = 50)	38.1	5.65	17.9	3.80	33.8	5.62	3.0	1.60	0.62	0.037	0.71	0.066	64.6	7.65
PFH/AFH ratio <0.58 (N = 50)	44.2	3.87	24.8	3.52	35.4	4.58	−2.14	2.50	0.56	0.018	0.76	0.070	66.3	7.24
UFH/LFH ratio <0.700 (N = 50)	38.6	6.19	23.4	4.63	34.6	6.05	−1.07	2.49	0.61	0.046	0.65	0.030	64.7	7.46
Total (N = 300)	40.4	5.17	23.2	4.41	34.6	4.75	−1.59	3.08	0.59	0.040	0.73	0.070	65.9	7.42

Table II. Number of patients in each group meeting the criteria of "open bite tendency" for other measurements

	Measurement						
Group	*SN : MP >40°*	*OP : MP >22°*	*PP : MP >32°*	*Open bite*	*PFH/AFH <0.58*	*UFH/LFH <0.700*	*ODI <68°*
SN : MP >40°	—	38	38	3	41	11	32
OP : MP >22°	21	—	27	3	15	8	23
PP : MP >32°	22	33	—	3	12	20	35
Open bite	18	6	27	—	10	19	31
PFH/AFH <58%	45	41	40	9	—	12	32
UFH/LFH <0.700	20	31	31	15	16	—	37

found by clinicians to exhibit this problem during treatment. In this second part of the study, the clinicians whose offices were used for collection of data were given a list of patients from their offices. Clinicians were asked to rank these patients according to whether or not they actually encountered problems with an open bite tendency during treatment. Patients were ranked from 1 to 5. A value of 1 indicated no problem at all—perhaps even a deep bite problem; a value of 5 suggested severe open bite problems during treatment. Patients who were assigned values of 1 or 2 were patients we would *not* want to identify as having an open bite problem; patients assigned values of 4 and 5 were those we would want to identify. Clinicians made these judgments without any reference to the cephalometric radiograph or cephalometric measurements of their patients. This evaluation was made for 164 of the 300 patients for whom cephalometric radiographs were obtained. Patients were excluded if an evaluation of open bite tendency with routine mechanics could not be made. Therefore, for example, no patients treated surgically were included in this part of the analysis. The cephalometric values for patients ranked at each level were then compared to see whether or not there were cephalometric differences among patients who were actually judged to be different on the basis of clinical criteria that were independent of the cephalometric radiograph.

RESULTS

Table I lists the means and standard deviations for all seven measurements taken on each group of 50 subjects and overall averages for the combined group of 300 persons. For example, in the group of 50 patients selected for mandibular plane to sella-nasion angles greater than 40°, the average upper facial height to lower facial height ratio was 0.76. Thus the average patient meeting the criterion of open bite tendency because of a mandibular plane angle of 40° or greater does not appear cephalometrically to have an open bite tendency with the criterion of UFH/LFH ratio since this is generally considered to require a value of 0.70 or less. Similarly, for the 50 patients selected because they had UFH/LFH ratios of 0.70 or less, the average mandibular plane angle was 38.6°.

These interrelationships among variables are easier

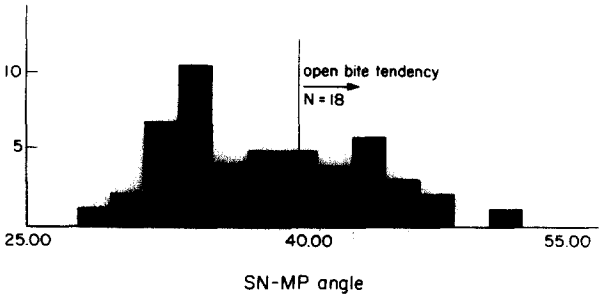

Fig. 1. Sella-nasion to mandibular plane angle. Eighteen of the 50 open bite patients (36%) had values for this measurement greater than 40°. (All histograms show the distribution of cephalometric values in the group of 50 patients with anterior open bites.)

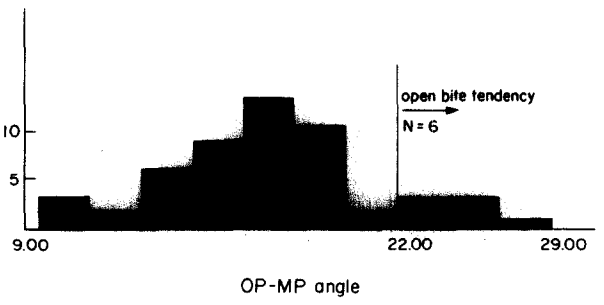

Fig. 2. Occlusal plane to mandibular plane angle. Only six patients (12%) had values of 22° or greater.

Table III. Correlation coefficients between variables for the combined sample of 300 patients

	SN : MP	*OP : MP*	*PP : MP*	*Open bite/ overbite*	*PFH/AFH*	*UFH/LFH*	*ODI*
SN : MP	—	0.457	0.673	0.103	0.903	0.089	0.259
OP : MP		—	0.411	0.560	0.416	0.007	0.067
PP : MP			—	0.086	0.555	0.387	0.600
Open bite				—	0.165	0.314	0.403
PFH/AFH					—	0.181	0.344
UFH/LFH						—	0.209

to interpret if we look directly at the number of patients in each group who met the criterion for open bite tendency in other measurements (Table II). Only 11 of the 50 patients with SN:MP angles greater than 40° had UFH/LFH ratios of 0.70 or less, and only three of these 50 patients actually had open bites before treatment. The number of patients with open bites was identical in the SN:MP group, OP:MP group, and PP:MP group. The largest number of open bites was found in the 50 patients selected for UFH/LFH ratios of 0.70 or less. In this group of 50 patients, 15 (30%) had overt open bites before treatment. Excluding the open bite group, of 250 patients selected because they had some cephalometric criterion for open bite tendency, only 33 (13%) had open bites.

Several trends are evident when examining measurements in Table II. The ODI column is relatively high for all groups. This implies that cases selected for any of the criteria used in this study often will appear to be open bite tendencies when the ODI is used. The UFH/LFH column indicates the opposite trend. All values here are low, indicating that cases selected as having open bite tendencies by most of the measurements used in this study often would not be selected as open bite problems by clinicians using an UFH/LFH ratio of 0.70 or less as their cephalometric criterion.

Table III, which shows the correlation coefficients between measurements for the combined sample of 300 patients, further clarifies the relationships between these different cephalometric criteria for open bite tendency. The highest correlation in the table is 0.903, between the mandibular plane angle and the Jarabak ratio. This confirms the very high concordance in patients selected by these two criteria in Table II in which 41 of 50 SN:MP patients met the Jarabak criterion of 0.58 or less, and 45 of the 50 Jarabak group patients met the SN:MP criterion of 40° or more. The magnitude of overbite had very low correlations with the SN:MP angle and PP:MP angle (0.103 and 0.086, respectively) and much higher correlations with the OP:MP angle, PFH/AFH, and ODI. Excluding the open bite group itself, there is a clear tendency for the UFH/LFH ratio to have the lowest correlations with all other measurements.

The distribution of cephalometric measurements in the 50 patients from the open bite group is shown in Figs. 1 through 6. Most patients with open bites do not meet cephalometric criteria for having an open bite tendency. Only 18 of the 50 open bite patients had mandibular plane angles greater than 40° (Fig. 1), and only 19 had UFH/LFH ratios of less than 0.70 (Fig. 5). For the PFH/AFH ratio, 21 of the 50 open bite

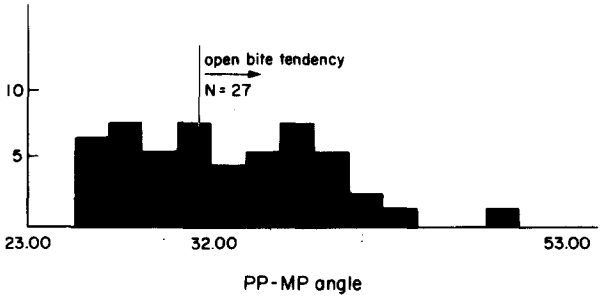

Fig. 3. Palatal plane to mandibular plane angle. Twenty-seven patients (54%) had values of 32° or greater.

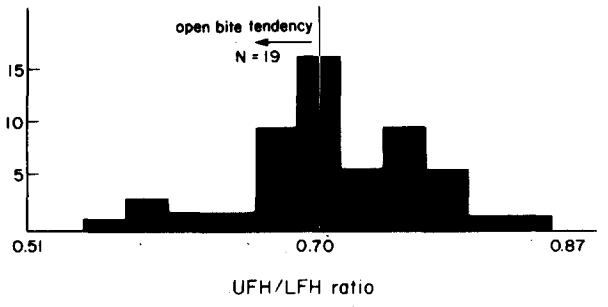

Fig. 5. Upper facial height/lower facial height ratio. Nineteen patients (38%) had values of 0.70 or less.

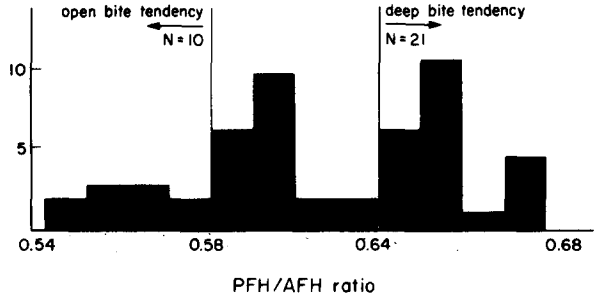

Fig. 4. Posterior facial height/anterior facial height ratio. Only 10 patients (20%) had values of 0.58 or less.

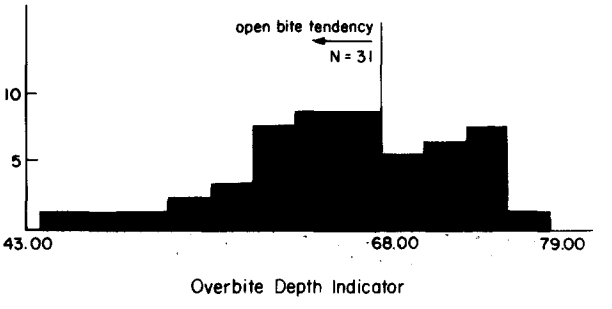

Fig. 6. Overbite depth indicator. Thirty-one (62%) of the patients in the open bite group met the criterion for open bite tendency with this measurement.

patients had values greater than 0.64, Jarabak's criterion for deep bite (Fig. 4).

Table IV lists the results of the analyses of the 164 patients classified by the five orthodontists who treated them according to the extent to which an open bite tendency was exhibited during treatment. The patients classified in groups 1 and 2 (that is, exhibiting no open bite tendency) were combined and compared with the patients in groups 4 and 5 (those exhibiting strong open bite tendencies). As shown in Table IV, there was no significant difference between these groups for the mandibular plane angle or Jarabak ratio. For the mandibular plane angle, the difference between groups 1 and 5 was a negligible 1.3°; with the Jarabak ratio, the lowest values (indicating open bite tendency) were found in groups 1 and 2. Although results for the occlusal plane/mandibular plane angle are statistically significant, they are in fact in the opposite direction to the values expected in that groups 1 and 2 have a significantly larger OP:MP angle than groups 4 and 5. The differences among groups for PP:MP angle and the UFH/LFH do not reach statistical significance, but tend toward values in the expected direction. The only statistically significant and interpretable differences among groups occur for the actual incidence of open bites and for the overbite depth indicator. Patients with no open bite tendency had an average overbite of approximately 3 mm; those scored by clinicians as having an open bite tendency had an average overbite of zero. The overbite depth indicator averaged 68.0° in patients without open bite tendencies and approximately 63.0° in those with open bite tendencies.

DISCUSSION

The results of this study suggest that most patients with open bites do not have cephalometric criteria that are suggestive of open bites, and that most patients who have cephalometric measurements considered to be suggestive of open bites do not in fact have open bites.

There is no doubt that some patients have a tendency for characteristics such as mandibular vertical growth, extrusion of posterior teeth with light forces, and anterior open bites highly resistant to closure and retention. Cephalometric studies have confirmed repeatedly that patients with anterior open bites differ from a random population in having characteristics such as a steep mandibular plane angle, a low upper facial height/lower facial height ratio, and a number of other tendencies including those examined in this study.[8,9,10,18-21] From these observations, it has been widely assumed that these cephalometric variables can be used to identify

Table IV. Cephalometric values in groups defined by clinicians' evaluations of open bite tendency

	Groups					*t test—Groups 1 and 2 combined versus groups 4 and 5 combined*	
Measurement	*1* *N = 14*	*2* *N = 62*	*3* *N = 45*	*4* *N = 23*	*5* *N = 32*	*T ratio*	*Probability*
SN : MP	39.5	39.6	39.2	40.1	40.8	1.22	0.226
OP : MP	22.1	24.3	23.4	21.7	21.2	3.54	0.001
PP : MP	34.0	33.9	34.3	34.7	35.1	1.45	0.150
Open bite	−2.6	−3.6	−1.4	−0.6	0.4	7.33	0.000
PFH/AFH ratio	0.59	0.59	0.61	0.60	0.60	1.67	0.097
UFH/LFH ratio	0.74	0.74	0.72	0.71	0.73	0.77	0.441
ODI	68.0	68.0	65.9	62.7	63.6	3.80	0.000

patients who will have open bite tendencies during treatment. However, this is not a logically valid assumption. The form of the argument is as follows:

1. Most open bite patients have steep mandibular plane angles.
2. I have a patient with a steep mandibular plane angle; therefore he probably has (or will have) an open bite.

The error in this logic is apparent from another example:

1. Most roses are red.
2. I have a red flower; therefore it is probably a rose.

The results of this study clearly indicate that this assumption is incorrect. We do not yet know how to cephalometrically identify patients with open bite tendencies. Particularly unexpected was the very small number of actual open bites in patients in the steep MP:SN, PP:MP, and OP:MP groups. The critical question in interpreting this observation is the relationship between patients who exhibit actual open bites before treatment and patients who have overbites before treatment but exhibit treatment responses typical of open bite tendency. Our working hypothesis is that the biologic distinctions between these two groups of patients are minimal. Those patients with open bite tendencies probably differ from a group of patients who actually have open bites in subtle combinations of anterior and posterior eruption. The other possibility, of course, is that the balance of forces during growth that results in an open bite is biologically different than the characteristics that result in open bites during application of orthodontic forces. This is an important question that requires further study.

In evaluating the specific measurements used in this study, it is evident that they can be separated into two groups. The MP:SN, PP:MP, and OP:MP are highly correlated with each other and clearly are related anatomically. The Jarabak ratio also belongs in this group as evidenced by the high correlations in Table III. An anatomic basis is apparent here also because it is the mandibular plane that forms the inferior point for both posterior facial height and anterior facial height. The single measurement related to a relatively independent anatomic relationship is the UFH/LFH ratio. A clinician wishing to use cephalometric measurements to evaluate open bite tendency should therefore select one of the four measurements related to the mandibular plane and the UFH/LFH ratio. Whatever it is that we are attempting to assess with these measurements, the results indicate that there are clear differences in the patients identified if a mandibular plane angle or a UFH/LFH ratio is used.

An important limitation of the present experimental design was the selection of cutoff values for the indication of open bite tendency. For example, we might find that selecting patients for a high SN:MP angle would identify a very large number of open bites if we used a minimum angle of 50° instead of one of 40°. The values selected represent typical clinical criteria and generally are supported by the literature.

The results of this study lead to questions regarding the role of cephalometric analysis in orthodontic diagnosis and treatment planning. We do not need a cephalometric radiograph to tell us that a patient has an anterior open bite or a long lower face. These are straightforward clinical observations. Most cephalometric analyses consist of measurements that allow the clinician to evaluate the morphologic basis for these simply observed conditions (for example, does a patient have a Class II malocclusion because the maxilla is forward or because the mandible is back?). This is a useful objective. Nevertheless description of existing morphology is not helpful for the other (and potentially more important) diagnostic role of the cephalometric radiograph—namely, predicting what will happen either as a result of treatment or of growth. Prediction of growth has something of a mixed reputation, and the

results of the second section of this study presented in Table IV would suggest that prediction of treatment response, at least in the area of open bite tendency, should be viewed with similar skepticism. However, it is possible that the problems found here with the prediction of open bite tendencies are caused by use of the wrong cephalometric variables. In growing patients an open bite tendency is in large part synonymous with a backward rotation to mandibular growth, as defined by Björk.[22,23] Indeed, as Björk[23] has stated, "In the case of backward rotation, opening of the bite is difficult to prevent."

Björk[22] has listed seven cephalometric features related to significantly abnormal growth rotations: (1) inclination of the condylar head, (2) curvature of the mandibular canal, (3) shape of the lower border of the mandible, (4) inclination of the symphysis, (5) interincisal angle, (6) interpremolar or intermolar angle, and (7) anterior lower facial height. It is somewhat surprising that popular cephalometric analyses developed subsequent to Björk's work have not included these variables.[24-26] Only lower anterior facial height and interincisal angle are commonly used, and in general these measurements are viewed more as static morphologic features rather than as dynamic indications of growth rotation tendencies. The frequency of patients with open bites in this study tends to confirm Björk's[22] conclusion that the mandibular plane "does not help" in evaluation of rotational patterns.

If we are interested in predicting how patients will respond to treatment rather than solely in describing existing morphology, perhaps attention should be directed to the features Björk has identified instead of to the traditional cephalometric variables that have been the focus of attention in most of the literature on open bite patients. It also would be appropriate to consider cephalometric measurements as multivariate sets, rather than as the single isolated variables that characterize most modern clinical cephalometric analyses. Finally, many of the biologic factors that contribute to open bite tendency may be related to individual differences in tongue posture, chewing patterns, and respiration that cannot be quantified on a cephalometric radiograph.

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