J Oral Maxillofac Surg
43:92–105, 1985

Components of Adult Class II Open-bite Malocclusion

EDWARD ELLIS, III, DDS, MS,* JAMES A. McNAMARA, JR., DDS, PHD,† AND TIMOTHY M. LAWRENCE, DDS‡

In an effort to identify the frequency and distribution of the dental and skeletal components of adult Class II malocclusion with and without open-bite, 124 adults, half of whom had an anterior open-bite, were evaluated. Significant differences ($P < 0.05$) between the open-bite and non-open-bite groups were found for the following measurements: the posterior maxilla exhibited vertical excess in the open-bite group; the maxillary occlusal plane was less steep in the open-bite group; the mandibular occlusal plane was more steep in the open-bite group; the gonial angle was higher in the open-bite group; the mandibular plane angle was higher in the open-bite group; the mandibular ramus was positioned in a more downward and backward (clockwise) location in the open-bite group; the total and lower anterior facial height were increased in the open-bite group; and the mandible was less protrusive in the open-bite group. No significant intergroup differences were noted in the cranial base, the anteroposterior position of the maxilla or of the upper and lower incisors, the palatal plane, posterior facial height, mandibular ramus height, or mandibular body length. The results of this analysis indicate that the average Class II open-bite malocclusion is characterized by aberrations in both the maxilla and the mandible. Therapy, therefore, may frequently require surgical intervention in both jaws to successfully correct this deformity.

The diagnosis and planning of treatment for patients who have maxillofacial deformities can be complex and challenging. A particularly frustrating deformity is one in which a skeletal open-bite is superimposed on an anteroposterior malrelationship of the teeth and jaws. The open-bite component compounds the deformity, and, frequently, more extensive intervention is required to ensure a satisfactory result. Historically, neither orthodontic or surgical treatment of skeletal open-bite deformities has been very successful, even when used in combination. However, the results of combined surgical and orthodontic treatment have improved considerably due to increased diagnostic capabilities, a better understanding of the interaction between the neuromuscular components of the masticatory system with the craniofacial skeleton, and the ability to tailor treatment to the individual patient.[1–7]

The management of adult patients who have an open-bite component to their Class II malocclusion remains a controversial issue. Anterior maxillary and mandibular surgery,[1,2,8–13] mandibular ramus surgery,[14–18] surgery in the mandibular body,[1–4] posterior maxillary surgery,[8,19–22] total maxillary surgery,[23–25] and various combinations of the same have been used in the treatment of skeletal open-bite. The many and varied treatments reflect the confusion that surrounds open-bite deformity, in-

---

* Assistant Professor, Department of Oral and Maxillofacial Surgery, Co-director, Dentofacial Program, and Research Investigator, Center for Human Growth and Development, The University of Michigan, Ann Arbor, Michigan.

† Professor, Departments of Orthodontics and Anatomy and Cell Biology, and Research Scientist, Center for Human Growth and Development, The University of Michigan.

‡ Former resident, Department of Oral and Maxillofacial Surgery, The University of Michigan; currently in private practice in Toledo, Ohio.

Supported in part by United States Public Health Service Grant DE-03610.

Address correspondence and reprint requests to Dr. Ellis: Department of Oral and Maxillofacial Surgery, University of Michigan School of Dentistry, Ann Arbor, Michigan 48109.

cluding considerable differences of opinion regarding the site of the problems.

Several studies have attempted to evaluate the differences in the craniofacial complex that occur with both Class II malocclusion[26-33] and open-bite deformity.[7,34-39] Because we have previously reviewed the literature on the anteroposterior dysplasia of Class II malocclusion,[33] the following review will focus on the nature of the open-bite component of the craniofacial deformity.

Review of the Literature

Cranial Base

Most previous studies have indicated that deformities in the anterior cranial base region were not evident when skeletal open-bite patients were compared with controls.[7,34,35,37] However, Subtelny and Sakuda[35] did find that the distance between sella and basion was less in their open-bite sample, indicating a shortened posterior cranial base.

Maxilla

There is no universal agreement regarding the relationship of the palatal plane to the anterior cranial base in an individual who has an open-bite deformity. Sassouni and Nanda[34] and Nahoum[36] found that the angle between the sella–nasion plane and the palatal plane was significantly less in their open-bite samples, indicating that in skeletal open-bite cases the anterior nasal spine is located more superiorly, that the posterior nasal spine is located more inferiorly, or that there can be a combination of the two. Conversely, Subtelny and Sakuda,[35] Enunlu,[38] Frost et al.,[7] and Lowe[39] found no significant difference in this angle, indicating that the open-bite deformity arises inferior to the palatal plane. Similarly, Subtelny and Sakuda[35] and Frost et al.[7] found no significant difference in the angle between the palatal plane and the Frankfort plane in their open-bite and normal samples.

Occlusal Plane

Approaches to evaluating the relationship between the occlusal plane to anterior cranial base have varied. Those investigators who have constructed the occlusal plane in a conventional manner[7,34,35,38-40] report a statistically significant increase in the angle between the sella–nasion plane and the occlusal plane. Other investigators[37,38] have constructed two occlusal planes (mandibular and maxillary) in the belief that using one occlusal plane drawn midway between the incisors to the mesial cusps of the first molar teeth is inadequate when analyzing cases of skeletal open-bite malocclusion. Their studies showed no significant difference in the maxillary occlusal plane angle; however, the average mandibular occlusal plane angle was significantly greater in their open-bite cases than in their controls. The latter finding suggests that the open-bite deformity arises below the maxillary dentition.

Mandible

Most investigators who have studied skeletal open-bite agree that the average mandibular plane angle of skeletal open-bite patients is consistently larger than that of controls.[7,34-39,41-47] This increase can be an expression of a backward rotation of the mandible or a difference in the shape. Richardson[48] found increased S–Art–Go angles in his open-bite sample, indicating that the larger mandibular plane angle was due to a downward and backward position of the mandibular ramus. Sassouni and Nanda[34] found that the mandibular condyle was located in a superior position, thereby indirectly decreasing effective ramus height and producing a larger mandibular plane angle.

Variations in mandibular morphology have been shown to occur in open-bite cases. The gonial angles of patients who have skeletal open-bite are significantly larger than those of controls,[34,35,37,38,48] and are associated with large mandibular plane angles. Posterior facial heights of patients who have an open-bite are shorter than those of normal patients.[7,34,35,37,38] Even with a normal gonial angle, a shortened ascending ramus would tend to produce a larger mandibular plane angle. Thus, the high mandibular plane angle present in the average open-bite patient can be a result of an increased gonial angle, a downward and backward position of the mandibular ramus, and a shortened posterior facial height.

Dentoalveolus

Although traditional orthodontic treatment has been directed at extrusion of the incisor teeth, many investigations have proven the inappropriateness of this mode of therapy. Nahoum et al.[37] found that the maxillary dentoalveolus was not underdeveloped in their open-bite population, and Sassouni and Nanda[34] and Subtelny and Sakuda[35] found that it may even be overdeveloped. These findings fail to incriminate undereruption of the anterior teeth as a cause of open-bite deformity.

An increase in maxillary posterior dentoalveolar height is another commonly cited causal factor in open-bite cases.[7,34,35,43,45] However, Nahoum et al.[37] did not find any significant differences in the

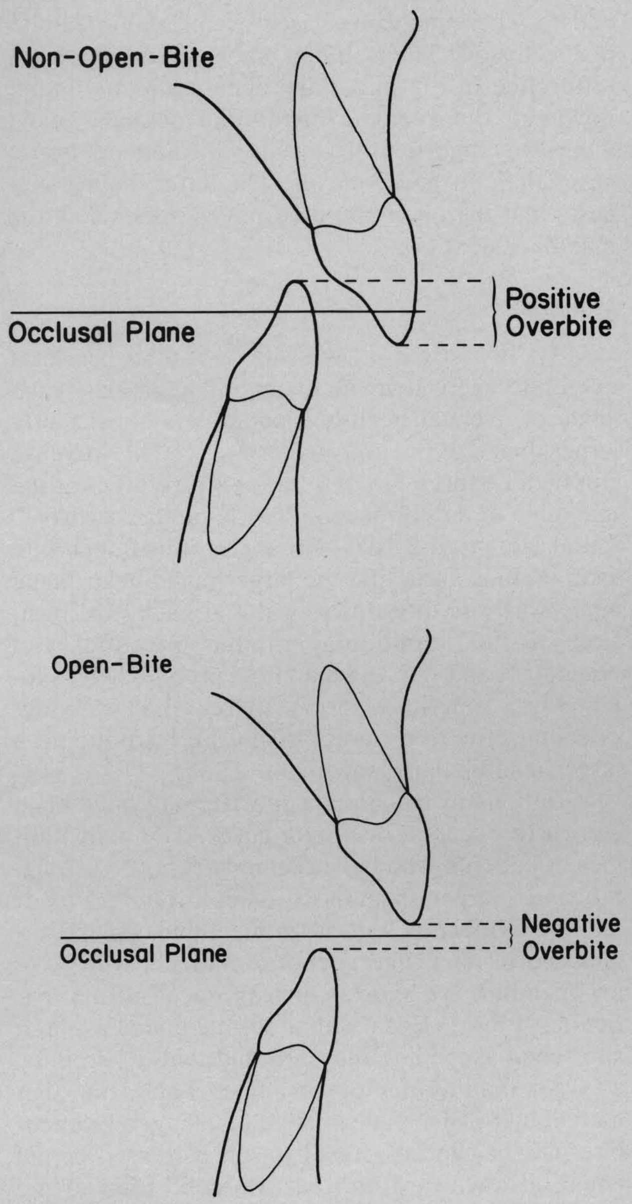

FIGURE 1. Illustration showing the method used to calculate the dental overbite for the non-open-bite and open-bite groups. The measures were all made by computer using the bisected occlusal plane for orientation. A negative incisal overbite was defined as an open-bite.

posterior maxillary dentoalveolar heights of their open-bite and normal samples. Therefore, no concensus exists as to the relationships of posterior dentoalveolar hyperplasia to open-bite.

Another factor that could contribute to an open-bite is the over-eruption of the mandibular molar teeth, which could cause a clockwise rotation of the mandible. However, Subtelny and Sakuda[35] noted no significant difference between open-bite and control samples, and Sassouni and Nanda[34] and Nahoum et al.[37] noted a decrease in distance between the mandibular molars and the mandibular plane.

Vertical Dysplasia

One of the most distinguishing features of the skeletal open-bite population is that total anterior facial heights are greater than those of a normal population.[7,34,35,41,48–52] Most studies show that this increase occurs primarily in the lower anterior facial height or in the area below the anterior nasal spine,[7,34,36,37,41,42,44,47,48,53] and not in the upper anterior facial height, which remains normal[34,35,41] or is shorter.[36,38,39] This indicates that most of the deformity occurs below the level of the palate. The posterior facial height, the distance between sella and gonion, is usually shorter in open-bite patients than in normal subjects.[7,34,35,37,38,45]

Purpose of the Present Study

A basic therapeutic principle in the treatment of patients who have maxillofacial deformities is, in general, to correct rather than camouflage the existing deformity (i.e., the aberrant structures). Since a proper diagnosis is paramount to the implementation of successful treatment, identification of the aberrations that exist within a given population of patients who exhibit a maxillofacial deformity is essential.

Several studies have compared components of a Class II malocclusion with those of Class I normal occlusion;[26–33] similarly, several studies have compared open-bite subjects with normal subjects.[7,34–39] This has allowed identification of the aberrant components of the craniofacial complex, so that correction can be accomplished at the site of the aberration, if technically feasible. Very little information is available, however, that identifies the differences in the dental and skeletal components of patients who have Class II open-bite malocclusion versus those who have Class II malocclusion without an open-bite deformity. The purpose of this article is twofold: 1) to present the results of a cephalometric investigation into the frequency and distribution of dental and skeletal components of a large sample of adults who had Class II malocclusion with and without open-bite, and 2) to discuss the clinical implications of these results. Our analysis of the anteroposterior components of this sample of adult Class II patients has been documented[33] and will not be extensively dealt with here.

Materials and Methods

Lateral cephalometric radiographs of 253 adults, 76 males and 177 females 17 years or older, were evaluated. One hundred and four patients had already undergone presurgical orthodontic treatment;

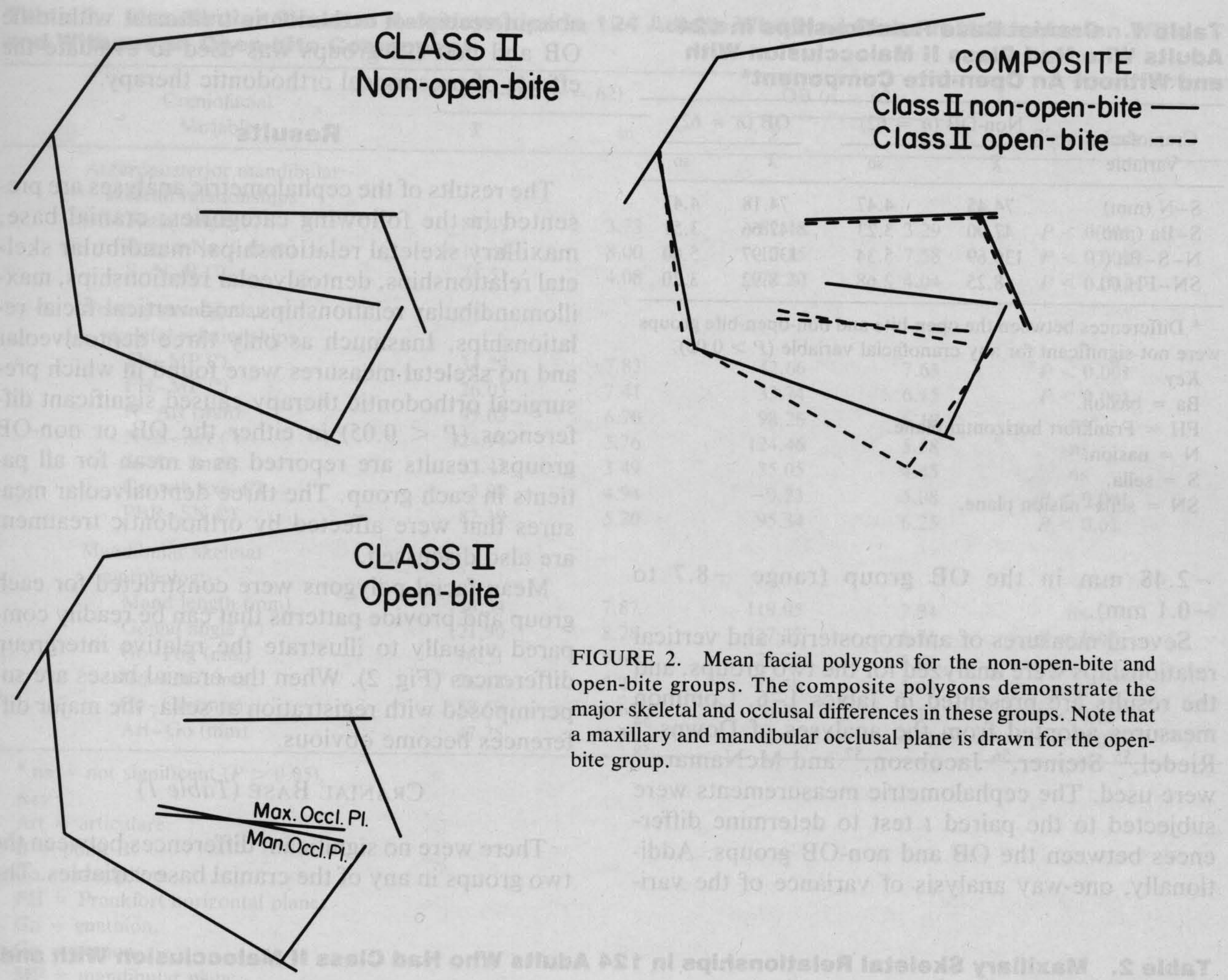

FIGURE 2. Mean facial polygons for the non-open-bite and open-bite groups. The composite polygons demonstrate the major skeletal and occlusal differences in these groups. Note that a maxillary and mandibular occlusal plane is drawn for the open-bite group.

the remaining 148 had not. The cephalograms were obtained from two private orthodontic offices, a private oral and maxillofacial surgery office, and The University of Michigan Department of Oral and Maxillofacial Surgery.

One hundred-twenty-four patients who had Class II malocclusion, 62 of whom had and 62 of whom did not have open-bite deformity, were selected from this group. The criterion for inclusion of a subject in the initial group of 253 adults was the presence of at least an end-to-end Class II molar and canine relationship as determined from the lateral cephalogram. No skeletal criteria were used. No cases of craniofacial syndromes were included in this study.

Each film was traced by one investigator and checked by a second investigator to verify the accuracy of the tracing. The tracings were then digitized at the Center for Human Growth and Development, translating the landmark points into an *X*–*Y* coordinate system. The dental overbite was calculated for each lateral cephalogram by measuring the vertical distance between the incisal edges of the maxillary and mandibular incisors parallel to the bisected occlusal plane (Fig. 1). Any case that demonstrated a negative overbite was placed into the open-bite (OB) group. Those with a positive overbite were placed into the non-open-bite (non-OB) group. There were 58 males and 133 females (total = 191) in the non-OB group and 18 males and 44 females (total = 62) in the OB group.

The lengths of the anterior cranial base (S–N) for males and females were determined for the entire sample. One standard deviation above and below the mean was used to define a neutral range; any case with an S–N distance below this neutral range was considered low, and any case with an S–N distance above was considered high. Each OB case was randomly paired with a non-OB case by sex, orthodontic treatment, and anterior cranial base length (low, neutral, high). Using these criteria, all 62 of the OB cases were paired with a non-OB case. There were 18 males and 44 females in each group. Twenty-six subjects had had orthodontic treatment and 36 had not. The mean overbite was 4.23 mm in the non-OB group (range 0.1 to 11.4 mm), and

Table 1. Cranial Base Relationships in 124 Adults Who Had Class II Malocclusion With and Without An Open-bite Component*

Craniofacial Variable	Non-OB (n = 62)		OB (n = 62)	
	$\bar{X}$	SD	$\bar{X}$	SD
S–N (mm)	74.45	4.47	74.18	4.43
S–Ba (mm)	47.90	3.23	47.66	3.51
N–S–Ba (°)	130.69	5.34	130.97	5.60
SN–FH (°)	8.25	2.68	8.92	3.20

* Differences between the open-bite and non-open-bite groups were not significant for any cranofacial variable ($P > 0.05$).

Key

Ba = basion.
FH = Frankfort horizontal plane.
N = nasion.
S = sella.
SN = sella–nasion plane.

−2.48 mm in the OB group (range −8.7 to −0.1 mm).

Several measures of anteroposterior and vertical relationships were analyzed for the two groups, and the results are presented in Tables 1–6. Common measures adopted from the analyses of Downs,[54] Riedel,[55] Steiner,[56] Jacobson,[57] and McNamara[58] were used. The cephalometric measurements were subjected to the paired t test to determine differences between the OB and non-OB groups. Additionally, one-way analysis of variance of the variable of receipt of orthodontic treatment within the OB and non-OB groups was used to evaluate the effects of presurgical orthodontic therapy.

Results

The results of the cephalometric analyses are presented in the following categories: cranial base, maxillary skeletal relationships, mandibular skeletal relationships, dentoalveolar relationships, maxillomandibular relationships, and vertical facial relationships. Inasmuch as only three dentoalveolar and no skeletal measures were found in which presurgical orthodontic therapy caused significant differences ($P < 0.05$) in either the OB or non-OB groups, results are reported as a mean for all patients in each group. The three dentoalveolar measures that were affected by orthodontic treatment are also discussed.

Mean facial polygons were constructed for each group and provide patterns that can be readily compared visually to illustrate the relative intergroup differences (Fig. 2). When the cranial bases are superimposed with registration at sella, the major differences become obvious.

CRANIAL BASE (*Table 1*)

There were no significant differences between the two groups in any of the cranial base variables. The

Table 2. Maxillary Skeletal Relationships in 124 Adults Who Had Class II Malocclusion With and Without an Open-bite Component*

Craniofacial Variable	Non-OB (n = 62)		OB (n = 62)	
	$\bar{X}$	SD	$\bar{X}$	SD
Anteroposterior maxillary skeletal position				
S–N–A (°)	80.78	3.85	79.66	4.14
A pt to Na ⊥ (mm)	−1.10	3.44	−1.63	3.73
Vertical maxillary skeletal relationships				
SN–PP (°)	8.08	3.67	8.07	3.84
FH–PP (°)	−0.17	3.59	−0.85	3.07
S–PNS (mm)	49.63	3.90	49.73	3.91
ERP–PNS (mm)	50.79	3.70	51.30	3.85
PNS–SN ⊥ (mm)	47.32	3.75	47.72	3.73
PNS–FH ⊥ (mm)	26.21	2.99	26.30	2.60

* Differences between the open-bite and non-open-bite groups were not significant for any cranofacial variable ($P > 0.05$).

Key

A = point A.
A pt = point A.
ERP = ethmoid registration point.
FH = Frankford horizontal plane.
N = nasion.
Na ⊥ = nasion perpendicular.
PNS = posterior nasal spine.
PP = palatal plane.
S = sella.
SN = sella–nasion plane.

Table 3. Mandibular Skeletal Relationships in 124 Adults Who Had Class II Malocclusion With and Without an Open-bite Component

Craniofacial Variable	Non-OB (n = 62) $\overline{X}$	Non-OB (n = 62) SD	OB (n = 62) $\overline{X}$	OB (n = 62) SD	Significance
Anteroposterior mandibular skeletal relationships					
Facial angle (°)	84.49	3.73	82.18	3.29	$P < 0.001$
Pog to Na ⊥ (mm)	−11.34	8.00	−17.15	7.58	$P < 0.001$
S–N–B (°)	74.51	4.08	72.20	4.04	$P < 0.001$
Vertical mandibular skeletal relationships					
SN–MP (°)	34.29	7.83	42.66	7.63	$P < 0.001$
FH–MP (°)	26.03	7.41	33.74	6.15	$P < 0.001$
N–Art (mm)	99.03	6.70	98.26	6.18	ns*
N–S–Art (°)	124.94	5.76	124.46	5.58	ns
S–Art (mm)	35.43	3.49	35.05	4.45	ns
Growth axis (°)	−3.98	4.94	−9.23	5.08	$P < 0.001$
PBR–SN (°)	82.39	5.20	95.34	6.25	$P < 0.01$
Mandibular skeletal morphology					
Mand length (mm)	118.34	7.87	119.05	7.84	ns
Gonial angle (°)	121.90	8.28	127.32	6.71	$P < 0.001$
Go–Pog (mm)	76.51	5.68	75.60	5.86	ns
Go–Gn (mm)	76.14	5.47	75.58	5.99	ns
Co–Go (mm)	58.59	6.66	56.78	5.11	$P < 0.05$
Art–Go (mm)	47.25	6.36	45.63	4.81	$P < 0.05$

* ns = not significant ($P > 0.05$).

Key

Art = articulare.
B = point B.
Co = condylion.
FH = Frankfort horizontal plane.
Gn = gnathion.
Go = gonion.
MP = mandibular plane.
N = nasion.
Na ⊥ = nasion perpendicular.
PBR = posterior border of mandibular ramus.
Pog = pogonion.
S = sella.
SN = sella–nasion plane.

posterior cranial base (S–Ba) was similar in dimension, as was the cranial base angle (N–S–Ba). Nor was there any significant difference in the angle between the sella–nasion plane (S–N) and the Frankfort horizontal plane (FH) between the two groups. The anterior cranial base (S–N) was also similar in dimension, although this was, of course, expected, since the groups were paired on this dimension.

MAXILLARY SKELETAL RELATIONSHIPS (*Table 2*)

The position of the maxilla as it related to the cranium was evaluated. The variables used to measure the anteroposterior position of the maxilla were not significantly different in the two groups. The mean S–N–A value was 80.8° for the non-OB group and 79.7° for the OB group. The distance from Point A to the nasion perpendicular was −1.1 mm for the non-OB group and −1.6 mm for the OB group.

There was no significant difference in the palatal plane angles (SN–PP, FH–PP) of the non-OB and OB groups. The values for the linear distances sella to posterior nasal spine (S–PNS) and ethmoid registration point to PNS (ERP–PNS), and the perpendicular distances between PNS and the S–N and FH planes (PNS–SN⊥, PNS–FH⊥) were not significantly different between the groups, indicating that the posterior nasal spine is in a similar vertical location in both groups. The measures between the cranial base and anterior nasal spine are presented under the heading of vertical facial relationships.

Table 4. Dentoalveolar Relationships in 124 Adults Who Had Class II Malocclusion With and Without an Open-bite Component

Craniofacial Variable	Non-OB ($n = 62$) $\bar{X}$	Non-OB ($n = 62$) SD	OB ($n = 62$) $\bar{X}$	OB ($n = 62$) SD	Significance
Anteroposterior relationships					
U1–Pt A vert (mm)	5.30	4.10	4.64	4.45	ns*
U1–NA (°)	25.12	10.31	24.92	7.23	ns
U1–NA (mm)	5.64	4.25	5.21	4.33	ns
IMPA (°)	96.99	8.80	94.98	9.37	ns
L1–NB (°)	25.78	8.37	29.84	8.61	$P < 0.01$
L1–NB (mm)	6.79	4.32	8.97	4.73	$P < 0.01$
Vertical relationships					
SN–OP (°)	16.30	5.12	18.27	4.88	$P < 0.001$
SN–MxOP (°)	—	—	15.46	4.99	—
SN–MnOP (°)	—	—	19.42	5.46	—
FH–OP (°)	8.05	4.45	10.35	3.93	$P < 0.001$
FH–MxOP (°)	—	—	6.54	4.48	—
FH–MnOP (°)	—	—	10.50	4.52	—
U6–SN ⊥ (mm)	74.53	4.74	78.02	5.57	$P < 0.001$
U6–FH ⊥ (mm)	50.40	3.83	53.38	4.47	$P < 0.001$
UIE–ANS (mm)	30.51	3.41	31.75	3.70	ns
U6–PP ⊥ (mm)	24.25	2.44	27.40	2.99	$P < 0.001$
OP–PP (°)	8.21	4.86	11.20	4.43	$P < 0.001$
MxOP–PP (°)	—	—	7.39	4.37	—
L1–Me (mm)	44.71	3.98	46.01	4.45	$P < 0.05$
L6–MP ⊥ (mm)	32.96	3.06	34.96	3.46	$P < 0.001$
OP–MP (°)	17.99	5.80	23.39	5.19	$P < 0.001$

* ns = not significant ($P > 0.05$).

Key

ANS = anterior nasal spine.
FH = Frankfort horizontal plane.
IMPA = angle between the lower incisor and mandibular plane.
L1 = lower incisor.
L6 = lower molar.
Me = menton.
MnOP = mandibular occlusal plane.
MP = mandibular plane.
MxOP = maxillary occlusal plane.
NA = nasion–point A plane.
NB = nasion–point B plane.
OP = occlusal plane (bisected).
PP = palatal plane.
Pt A vert = point A vertical.
SN = sella–nasion plane.
U1 = upper incisor.
U6 = upper molar.
UIE = incisal edge of upper incisor.

MANDIBULAR SKELETAL RELATIONSHIPS (*Table 3*)

The position of the mandible as it relates to the cranial base and the size and shape of the mandible were evaluated. All of the variables used to evaluate the anteroposterior position of the mandible relative to the cranium—the facial angle, pogonion to the nasion perpendicular, and the S–N–B angle—had significantly higher values in the non-OB group. This indicates that the mandible was more protrusive in the non-OB group than in the OB group.

Values for the mandibular plane (MP) angle were significantly larger in the OB group for both the SN–MP and FH–MP angles. For instance, the SN–MP angle averaged 34.5° for the non-OB group and 42.7° for the OB group—over 8° larger in the OB group. The angle between the posterior border of the mandibular ramus (PBR) and the cranial base

Table 5. Maxillomandibular Relationships in 124 Adults who Had Class II Malocclusion With and Without an Open-bite Component

Craniofacial Variable	Non-OB (n = 62) $\bar{x}$	SD	OB (n = 62) $\bar{x}$	SD	Significance
A–N–B (°)	6.28	2.12	7.45	2.42	$P < 0.01$
WITS (mm)	6.13	3.02	6.86	3.46	ns*
Overjet (mm)	9.79	3.42	9.36	3.37	ns
U1–L1 (°)	122.82	12.86	117.79	11.50	$P < 0.05$

* ns = not significant ($P > 0.05$).

Key

A = point A.
B = point B.
L1 = lower incisor.
N = nasion.
U1 = upper incisor.

(PBR–SN) was significantly greater in the OB group, indicating a backward and downward (clockwise) position of the mandibular ramus. There was also a significant difference in the mean values for the growth axis angle, that of the OB group being −9.2°, versus −4.0° for the non-OB group. This indicates that gnathion is in a more inferior and backward position in the OB group.

There was no significant difference in the relative position of articulare (S–Art and N–Art), nor in the saddle angle (N–S–Art), indicating that the location of the temporomandibular joint is similar in both groups. The gonial angles of the OB group were significantly larger than those of the non-OB group. The mean gonial angle for the OB group was 127° versus 122° for the non-OB group.

The length of the mandibular body (Go–Gn and Go–Pog) and the effective length of the mandibular (Co–Pog) were not significantly different between the two groups. The length of the mandibular ramus (Co–Go and Art–Go) was, however, significantly longer in the non-OB group.

DENTOALVEOLAR RELATIONSHIPS (*Table 4*)

There was no significant difference in the anteroposterior position of the maxillary incisor in the two groups, either in angulation or in relation to the

Table 6. Vertical Facial Relationships in 124 Adults Who Had Class II Malocclusion With and Without an Open-bite Component

Craniofacial Variable	Non-OB (n = 62) $\bar{x}$	SD	OB (n = 62) $\bar{x}$	SD	Significance
AFH (mm)	123.96	7.83	132.45	10.00	$P < 0.001$
UFH (mm)	55.57	4.03	56.00	4.31	ns*
LFH (mm)	70.98	6.31	79.85	7.47	$P < 0.001$
UFH/LFH	0.79	0.08	0.70	0.06	$P < 0.001$
UFH/AFH	0.45	0.02	0.42	0.02	$P < 0.001$
LFH/AFH	0.57	0.03	0.60	0.02	$P < 0.001$
N–A (mm)	61.60	4.41	62.48	4.95	ns
A–Gn (mm)	61.63	5.19	69.77	6.49	$P < 0.001$
NA/AGn	1.00	0.08	0.90	0.07	$P < 0.001$
PFH (mm)	78.67	7.37	77.48	7.19	ns
PFH/AFH	0.64	0.06	0.59	0.05	$P < 0.001$

* ns = not significant ($P > 0.05$).

Key

A = point A.
AFH = anterior facial height (N–Me).
AGn = point A–gnathion.
Gn = gnathion.
LFH = lower facial height (ANS–Me).
N = nasion.
NA = nasion–point A.
PFH = posterior facial height (S–Go).
UFH = upper facial height (N–ANS).

maxilla and cranium (U1–NA(°), U1–NA(mm), U1–point A vertical). There was also no significant difference in the angle between the lower incisor and the mandibular plane (IMPA). However, values for L1–NB (°) and L1-NB (mm) were significantly greater in the OB group than in the non-OB group. This apparent conflict was due to the change in the angulation of the two lines (L1–NB) when the mandible was positioned clockwise and not to differences in the angulation between the incisor and the mandible (IMPA). Thus, the relationship of the lower incisor to the mandible was not different in the OB and non-OB populations. The 26 subjects who had had orthodontic treatment in the OB group had significantly greater ($P < 0.05$) values for the L1–NB angle and IMPA than the 36 subjects who had not had treatment. No such differences were noted in the non-OB group.

The bisected occlusal plane angle (SN–OP) was significantly larger in the OB group, being 18.3°, versus 16.3° in the non-OB group. The maxillary occlusal plane angle (SN–MxOP) in the OB group was only 15.5°, which was less than the SN–OP values of either group. The mandibular occlusal plane angle in the OB group (SN–MnOP) was 19.4°, which was much greater than the SN–OP values of either group. Similar results occurred when the Frankfort plane was used to determine the occlusal plane angles (FH–OP, FH–MxOP, and FH–MnOP).

The distance from the incisal edge of the upper incisor to the anterior nasal spine (UIE–ANS) was not significantly different in the two groups. The OB group, however, demonstrated an increase of more than 1 mm more than the non-OB group for this measurement. The perpendicular distance between the mesial cusp tip of the maxillary first molar and the palatal plane, the sella–nasion plane, and the Frankfort horizontal plane (U6–PP⊥, U6–SN⊥, U6–FH⊥) were significantly greater in the OB group, indicating a greater posterior dentoalveolar hyperplasia of the maxilla in the OB group. The mean occlusal plane to palatal plane angle (OP–PP) of the OB group was also significantly (3°) greater than that of the non-OB group. When MxOP–PP was evaluated, values were found to be lower than those for the OP–PP angle in the non-OB group.

Anterior mandibular dentoalveolar heights (L1–Me) were significantly greater in the OB group, indicating anterior mandibular dentoalveolar hyperplasia. Posterior mandibular dentoalveolar heights (L6–MP) were also significantly greater in the OB group, as was the angle between the bisected occlusal plane and the mandibular plane (OP–MP).

MAXILLOMANDIBULAR RELATIONSHIPS (*Table 5*)

Based on the analysis of the A–N–B angle, there was a significantly greater discrepancy in the relative anteroposterior relationship of the maxilla and the mandible in the non-OB group than in the OB group. However, the Wits analysis demonstrated no significant difference between the groups.

The relative anteroposterior positions of the maxillary and mandibular incisors, based on analysis of the incisor overjet, were not significantly different in the two groups. There was a significantly smaller value ($P < 0.05$) for the incisor overjets of the 26 subjects in the OB group who had had orthodontic treatment as compared with the 36 who had not. No such differences were found in the non-OB group. The mean interincisal angle (U1–L1) was significantly greater in the non-OB group, averaging 123° versus 118° in the OB group.

VERTICAL FACIAL RELATIONSHIPS (*Table 6*)

The values for anterior facial height (N–Me), lower facial height (ANS–Me), and AGn were all significantly greater in the OB group ($P < 0.001$). The ratios of the various vertical measures were also significant. Posterior facial height (S–Go), N–A, and upper facial height (N–ANS) were the only vertical mesures that showed no significant difference between the two groups.

SUMMARY OF RESULTS

The OB group, compared with the non-OB group, had a larger gonial angle, a downward and backward positioning of the mandible, a larger mandibular plane angle, a longer lower facial height, vertical maxillary excess, and a divergent occlusal plane angle.

Discussion

Although the incidence of open-bite in the general population is not known, the results of this study clearly indicate that it is not a rare phenomenon in the population of surgical patients being treated for adult Class II malocclusion. Approximately one-fourth of the subjects in an overall sample of 253 cases of Class II malocclusion had an open-bite component.

The data from the present study indicate that the open-bite component of a Class II malocclusion arises below the cranial base. All measures of the cranial base in the OB group were similar to those in the non-OB group. These findings contrast with

those of Subtelny and Sakuda,[35] who noted a shortened posterior cranial base in their open-bite sample.

The major areas of difference in the measurements of the OB and non-OB groups are found in the posterior maxillary and mandibular dentoalveolar regions and in the mandible. These findings are very similar to those of a previous study comparing components of adult Class III malocclusion to adult Class III open-bite malocclusion.[59]

Dentoalveolar Regions

That posterior maxillary dentoalveolar hyperplasia with over-eruption of the maxillary molars occurred in the OB group is indicated by various measures. The angle between the bisected occlusal plane and the sella-nasion plane (SN–OP; Table 2) was significantly greater in the OB group, which indicates that the bisected occlusal plane of the OB group was much steeper than that of the non-OB group. However, examination of the maxillary occlusal plane angle in the OB group (MxOP–SN; Table 2), showed that it was smaller than the bisected occlusal plane angle of the non-OB group (15.5° versus 16.3°), which indicates that the maxillary occlusal plane angle of the OB group was less steep than that of the non-OB group. The decreased maxillary occlusal plane in the OB group is the result of inferiorly positioned maxillary molars as verified by the significantly greater values for U6–SN⊥ and U6–FH⊥.

The fact that the distance between the mandibular first molar cusp tip and the mandibular plane is greater in the OB group indicates the presence of posterior mandibular dentoalveolar hyperplasia, which could greatly contribute to the open-bite deformity. This would be especially detrimental when taken in concert with posterior maxillary dentoalveolar hyperplasia.

One possible cause for an open-bite deformity is under-eruption of the anterior teeth. However, in this study, the anterior maxilla did not demonstrate an inadequate vertical dimension or under-eruption of the maxillary incisors. In fact, the OB group had a greater, although not significant, amount of anterior maxillary dentoalveolar height than did the non-OB group. The OB group also had significantly greater anterior mandibular dentoalveolar hyperplasia. These findings suggest that the malocclusion of the OB group was not due to an underdevelopment of the dentoalveolus in this area, but rather that adaptations may have occurred in an attempt to compensate for the open-bite by over-eruption of the maxillary and mandibular incisors.

Mandible

The mandible is the other major site of aberration in the average open-bite deformity. The actual mandibular dimensions in the two groups are of interest. Although the length of the mandibular body and the effective mandibular length were not significantly different in the two groups (Table 3), the mandibular ramus was significantly longer in the non-OB group. The similar overall length of the mandible in the face of a longer mandibular ramus in the non-OB group was caused by an increase in the gonial angle in the OB group and indicates that there is a gross difference in mandibular morphology between the two groups.

Although the oblique gonial angle considered by itself can contribute to an open-bite deformity, it was only one aspect of the altered mandibular morphology found in the OB group. Another variable was the downward and backward (clockwise) positioning of the mandibular ramus. Taken together, these two variables contributed most significantly to the open-bite deformity and gave rise to the marked increase in mandibular plane angle that was found in the OB group.

Another consequence of the backward and downward positioning of the mandibular ramus in the OB group was to make the anteroposterior discrepancy of the Class II component of the malocclusion more obvious. This was exemplified by the larger A–N–B values found in the OB group, and also accounts for the more retrusive position of the mandible and the smaller growth axis variable.

Vertical Facial Relationships

The 9-mm increase in lower anterior facial height noted for the OB group corresponds with the findings of other investigators.[7,34,36,37,41,42,44,47,48,53] This indicates that the largest increase in vertical facial dimension occurs in lower facial height. Total anterior facial height was, as one would expect, markedly greater in the OB group, a finding which also agrees with those of other studies.[7,34,36,37,41,42,44,47,48,53] No significant differences in upper anterior facial heights were noted between the groups.

There was no significant difference in the posterior facial heights of the two groups. However, several other studies show a decrease in the posterior facial heights of their open-bite samples.[7,34,35,37,38,45] The reason for this discrepancy may be related to the nature of our sample. While most investigators agree that posterior facial height is less in open-bite patients than in Class I controls, few have examined

this variable in Class II open-bite and Class II non-open-bite populations.

Clinical Implications

In devising a therapeutic regimen for the patient who has a Class II open-bite malocclusion, treatment must address the following specific problems in addition to the routine aspects of the malocclusion: 1) the presence of posterior maxillary dentoalveolar hyperplasia; 2) a steep mandibular plane angle; 3) an oblique gonial angle; 4) the downward and backward position of the mandibular ramus; 5) a long lower anterior face, and; 6) the Class II anteroposterior malrelationship.

Because this study did not analyze the spectrum of skeletal and dental components of the Class II open-bite malocclusion and instead provided only mean differences between the open-bite and non-open-bite groups, we are unable to make categorical statements about the most appropriate treatment for this deformity. However, we can discuss techniques to treat the average Class II open-bite malocclusion, realizing that treatment of each case must be individually planned based on the particular dental and skeletal aberrations present in a given patient.

Orthodontic corrections of open-bite deformities are prone to failure, as they do not address the underlying causes. In fact, the open-bite patient has a greater anterior maxillary and mandibular dentoalveolar height than does a patient without this deformity. Thus, orthodontic extrusion of the anterior teeth is clearly inappropriate treatment in most instances.

Not all surgical procedures for correcting open-bite malocclusions have been universally successful. Results of surgery in the mandibular ramus have been unstable, with varying amounts of postoperative relapse reported.[60–62] This is not surprising when one examines the biomechanics of this procedure. Figure 3 demonstrates the effects of correcting a Class II open-bite deformity via a mandibular ramus osteotomy. In its new position, the body of the mandible is rotated in such a fashion that two powerful groups of muscles, the elevators and suprahyoids, are stretched. The posterior aspect of the mandible is now in a more inferior position than it was preoperatively, thereby stretching the elevator musculator (the masseter, medial pterygoid, and temporalis muscles).§ The mandibular symphysis is rotated to a more superior location, stretching the suprahyoid musculature. Thus, the distal molar serves as a fulcrum for tilting the mandibular body by the two powerful and opposing muscle groups.

Experimental documentation of the adverse affects of stretching the elevator musculature is offered by Carlson and Schneiderman[63], who cemented bite-opening splints onto the occlusal surfaces of the teeth of adult rhesus monkeys and analyzed the effects on the craniofacial complex. Stretching the elevator muscles in this fashion caused an anterosuperior displacement of the entire maxilla, severe intrusion of the dentition, and a tendency for the masseter muscle to return to its original resting length. Thus, stretching of elevator muscles should be avoided whenever possible. The stretched musculature may be the primary reason why closing an open-bite via a mandibular ramus operation produces unstable results.

In contrast, correction of open-bite via an anterior segmental surgical procedure has been shown to be very stable.[13] The stability of these procedures probably relates directly to the noninvolvement of the muscles of mastication in the biomechanics of the surgical change. However, anterior segmental osteotomies have limited utility in cases of gross skeletal open-bite or gross anteroposterior malrelationships.

The total mandibular alveolar osteotomy, proposed by McIntosh,[3,4] also avoids the alteration of the muscles of mastication and produces good stability. However, the technical difficulty of and incidence of morbidity from this procedure preclude its use for routine correction of open-bite deformities.[64] The operation also does not correct the posterior maxillary dentoalveolar hyperplasia or the aberrant maxillary occlusal plane angle.

After examining the various aspects of the Class II open-bite malocclusion, one can clearly see that this deformity is not confined to one particular anatomical structure but instead involves various aspects of both the maxilla and mandible. It is not surprising, therefore, that treatment may involve surgery in both jaws. The treatment that would correct the average Class II open-bite deformity would include surgery to intrude the posterior maxilla via either segmental or total maxillary surgery. This would correct both the posterior maxillary dentoalveolar hyperplasia and the aberrant maxillary occlusal plane angle. Posterior maxillary intrusio would also allow the mandible to autorota counter-clockwise, partially correcting the hi mandibular plane angle and decreasing the low anterior facial height, while at the same time i proving the mandibular retrusion. This wo permit the mandible to be advanced via a mand ular ramus osteotomy without stretching the

---

§ This is of less importance, however, when a modified, sagittal split osteotomy is performed, with the split just posterior to the mandibular foramen. With this operation, the gonial angle and its associated musculature remain in the preoperative posi-

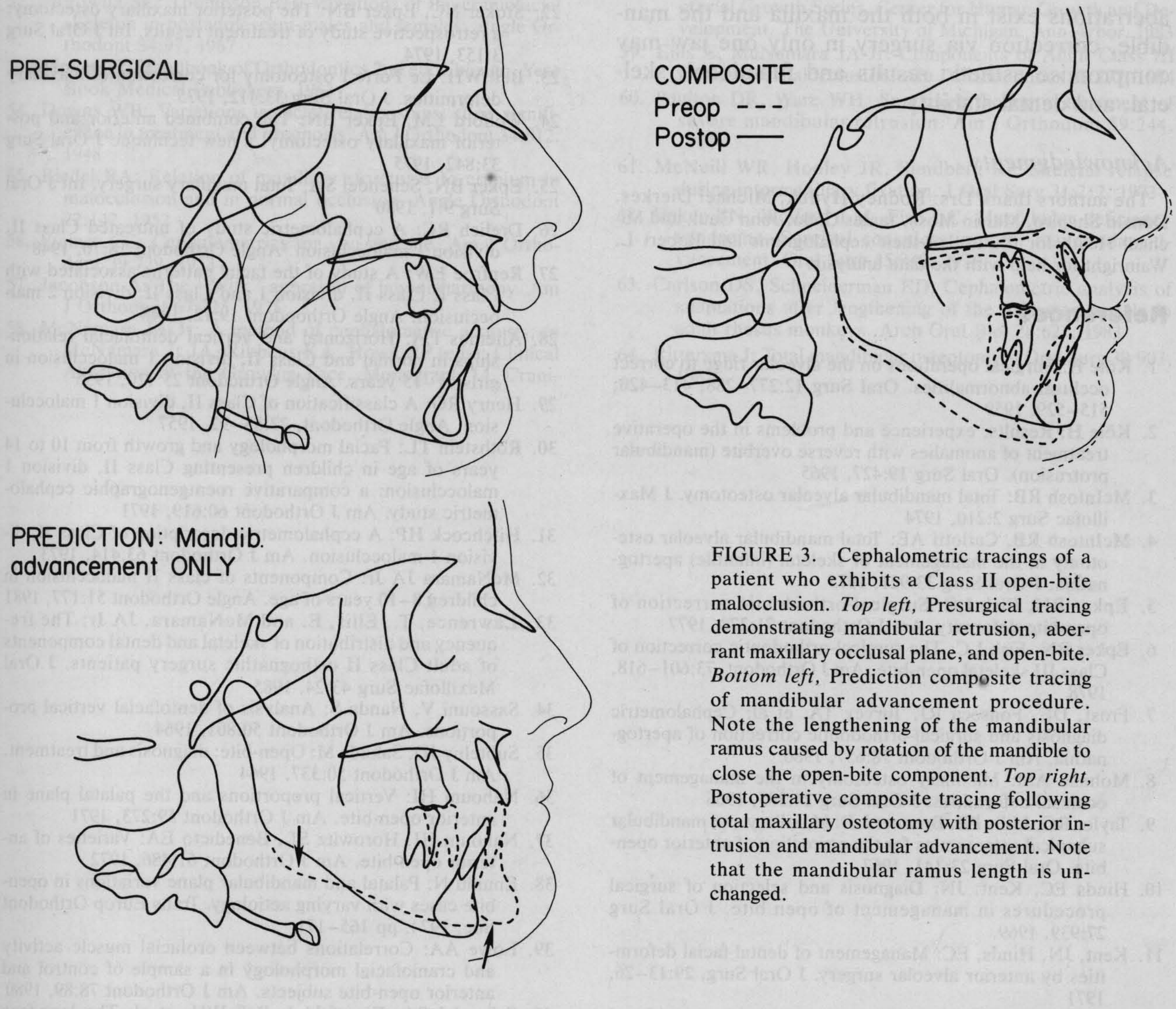

FIGURE 3. Cephalometric tracings of a patient who exhibits a Class II open-bite malocclusion. *Top left,* Presurgical tracing demonstrating mandibular retrusion, aberrant maxillary occlusal plane, and open-bite. *Bottom left,* Prediction composite tracing of mandibular advancement procedure. Note the lengthening of the mandibular ramus caused by rotation of the mandible to close the open-bite component. *Top right,* Postoperative composite tracing following total maxillary osteotomy with posterior intrusion and mandibular advancement. Note that the mandibular ramus length is unchanged.

vator masticatory musculature (Fig. 3). It would also decrease the absolute amount of mandibular advancement needed to correct the Class II occlusal discrepancy.

Combined maxillary and mandibular surgery is, in our opinion, the most appropriate and stable method of correcting the majority of cases of Class II open-bite malocclusion. Not only does it return the dental and skeletal elements of the maxillofacial complex to their proper location, but it does so without upsetting the delicate balance between the soft tissue elements, particularly the musculature, and the skeletal elements. As Carlson and Schneiderman[63] have demonstrated very effectively, in the continuing struggle between the soft and hard tissues caused by an alteration of homeostasis, the soft tissues will certainly win.

Conclusions

Lateral cephalograms of 253 adults who had Class II malocclusion were studied to determine the frequency of open-bite deformity. Differences in the skeletal and dental components of those who had and those who did not have open-bite as a part of their deformity were evaluated in two groups of 62 patients. The following observations were made:

First, 25% of the entire adult Class II malocclusion sample exhibited an open-bite component.

Secondly, patients who had an open-bite component exhibited, in comparison with those who did not: 1) a larger mandibular plane angle; 2) a larger gonial angle; 3) downward and backward positioning of the mandibular ramus; 4) a shorter mandibular ramus length; 5) increased mandibular retrusion; 6) posterior maxillary and mandibular dentoalveolar hyperplasia; 7) anterior maxillary and mandibular dentoalveolar hyperplasia; 8) a longer total anterior facial and lower anterior facial height; and 9) no difference in cranial base.

It was concluded that proper diagnosis and treatment of a significant number of cases of adult Class II open-bite malocclusion may require the surgical correction of both jaws. Since, in the average case,

aberrations exist in both the maxilla and the mandible, correction via surgery in only one jaw may compromise esthetic results and functional, skeletal, and dental stability.

Acknowledgments

The authors thank Drs. Rodney Hyduk, Michael Dierkes, Donald Shapiro, Martin Moss, James Gallo, John Gaul, and Michael Heath for the use of their cephalograms and Robert L. Wainright for help with the data analysis.

References

1. Köle H: Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg 12:277–288; 413–420; 515–529, 1959
2. Köle H: Results, experience and problems in the operative treatment of anomalies with reverse overbite (mandibular protrusion). Oral Surg 19:427, 1965
3. McIntosh RB: Total mandibular alveolar osteotomy. J Maxillofac Surg 2:210, 1974
4. McIntosh RB, Carlotti AE: Total mandibular alveolar osteotomy in the management of skeletal (infantile) apertognathia. J Oral Surg 33:921, 1975
5. Epker BN, Fish LC: Surgical-orthodontic correction of open-bite deformity. Am J Orthodont 71:278, 1977
6. Epker BN, Fish LC: The surgical-orthodontic correction of Class III skeletal open-bite. Am J Orthodont, 73:601–618, 1978
7. Frost, DE, Fonseca RJ, Turvey TA, et al: Cephalometric diagnosis and surgical-orthodontic correction of apertognathia. Am J Orthodont 78:657, 1980
8. Mohnac AM: Maxillary osteotomy in the management of occlusal deformities. J Oral Surg 24:305, 1966
9. Taylor RG, Mills PB, Brenner LD: Maxillary and mandibular subapical osteotomies for the correction of anterior open-bite. Oral Surg 23:141, 1967
10. Hinds EC, Kent, JN: Diagnosis and selection of surgical procedures in management of open bite. J Oral Surg 27:939, 1969.
11. Kent, JN, Hinds, EC: Management of dental facial deformities by anterior alveolar surgery. J Oral Surg, 29:13–26, 1971
12. Bell WH: Correction of skeletal type anterior open-bite. J Oral Surg 29:706, 1971
13. Bell WH, Dann JJ: Correction of dentofacial deformities by surgery in the anterior part of the jaws. Am J Orthodont 64:162, 1973
14. Kostecka F: A contribution to the surgical treatment of open-bite. Int J Orthodont 20:1082, 1934
15. Pichler H, Trauner R: Mund und Kieferchirurgie, vol. 1. Vienna, Urban and Schwarzenberg, 1948, pp 626–634
16. Shira RB: Surgical correction of open-bite deformities by oblique sliding osteotomy. Oral Surg 19:275, 1961
17. Alfaro R, Othon LG, Levine B, et al: Correction of mandibular prognathism with associated apertognathia by intraoral sagittal osteotomy of rami. Oral Surg 27:285, 1969
18. Kline SN, Shensa DR, Kahn M: Skeletal open-bite—surgical management: report of case. J Oral Surg 28:791, 1970
19. Schuchardt K: Experiences with surgical treatment of some deformities of the jaws: prognathia, micrognathia and open bite, *in* Wallace AB (ed): Transactions of Second Congress of International Society of Plastic Surgeons. Edinburgh, Scotland, E & S Livingstone, 1961, pp 73–78
20. Kufner J: Experience with a modified procedure for correction of open bite, *in* Walker RV (ed): Transactions of the Third International Conference on Oral Surgery. Edinburgh and London, E & S Livingstone, 1970, pp 18–23
21. West RA, Epker BN: The posterior maxillary ostectomy: its place in the treatment of selected dentofacial deformities. J Oral Surg 30:562, 1972
22. Stoker NC, Epker BN: The posterior maxillary ostectomy: a retrospective study of treatment results. Int J Oral Surg 3:153, 1974
23. Bell WH: Le Forte I osteotomy for correction of maxillary deformities. J Oral Surg 33:412, 1975
24. Wolford LM, Epker BN: The combined anterior and posterior maxillary ostectomy: a new technique J Oral Surg 33:842, 1975
25. Epker BN, Schendel SA: Total maxillary surgery. Int J Oral Surg 9:1, 1980
26. Drelich RC: A cephalometric study of untreated Class II, division 1 malocclusion. Angle Orthodont 18:70, 1948
27. Renfroe EW: A study of the facial patterns associated with Class I, Class II, division 1 and Class II, division 2 malocclusion. Angle Orthondont 19:12, 1948
28. Altemus LA: Horizontal and vertical dentofacial relationships in normal and Class II, division 1 malocclusion in girls 11–15 years. Angle Orthodont 25:120, 1955
29. Henry RG: A classification of Class II, division 1 malocclusion. Angle Orthodont, 27:83–92, 1957
30. Rothstein TL: Facial morphology and growth from 10 to 14 years of age in children presenting Class II, division 1 malocclusion: a comparative roentgenographic cephalometric study. Am J Orthodont 60:619, 1971
31. Hitchcock HP: A cephalometric description of Class II, division 1 malocclusion. Am J Orthodont 63:414, 1973
32. McNamara JA Jr: Components of class II malocclusion in children 8–10 years of age. Angle Orthodont 51:177, 1981
33. Lawrence, T., Ellis, E. and McNamara, JA Jr: The frequency and distribution of skeletal and dental components of adult Class II orthognathic surgery patients. J Oral Maxillofac Surg 43:24, 1985
34. Sassouni V, Nanda S: Analysis of dentofacial vertical proportions. Am J Orthodont 50:801, 1964
35. Subtelny JD, Sakuda M: Open-bite: diagnosis and treatment. Am J Orthodont 50:337, 1964
36. Nahoum HI: Vertical proportions and the palatal plane in anterior open-bite. Am J Orthodont 59:273, 1971
37. Nahoum HI, Horowitz SL, Bénedicto EA: Varieties of anterior open-bite. Am J Orthodont 61:486, 1972
38. Enunlu N: Palatal and mandibular plane variations in open-bite cases with varying aetiology. Trans Europ Orthodont Soc, 1974, pp 165–171
39. Lowe AA: Correlations between orofacial muscle activity and craniofacial morphology in a sample of control and anterior open-bite subjects. Am J Orthodont 78:89, 1980
40. Schendel SA, Eisenfeld J, Bell WH, et al: The long-face syndrome: vertical maxillary excess. Am J Orthodont 707:398, 1976
41. Hapak FM: Cephalometric appraisal of the open-bite case. Angle Orthodont 34:65, 1964
42. Schudy FF: Vertical growth versus anteroposterior growth as related to function and treatment. Angle Orthodont 34:75, 1964
43. Björk A: Prediction of mandibular growth rotation. Am J Orthodont 55:585, 1969
44. Sassouni V: A classification of skeletal facial types. Am J Orthodont 55:109, 1969
45. Isaacson JR, Isaacson RJ, Speidel TM et al: Extreme variation in vertical facial growth and associated variation skeletal and dental relations. Angle Orthodont 41:219, 1971
46. Kim YH: Overbite depth indicator with particular reference to anterior open-bite. Am J Orthodont 65:586, 1974
47. Arvystas MG: Treatment of anterior skeletal open-bite deformity. Am J Orthodont 72:147, 1977
48. Richardson A: Skeletal factors in anterior open-bite and deep open-bite. Am J Orthodont 56:114, 1969
49. Björk A: The face in profile. Svensk Tandl Tidskr 40:suppl 5B, 1947
50. Prakash P, Margolis HI: Dento-craniofacial relations in varying degress of openbite. Am J Orthodont 38:657, 1952
51. Atherton JD: The influence of the face height upon the incisor occlusion and lip posture. Dent Pract 15:227, 1965

52. Horowitz SL: Thompson RH: Variations of the craniofacial skeleton in postadolescent males and females. Angle Orthodont 34:97, 1967
53. Moyers R: Handbook of Orthodontics 2nd ed. Chicago, Year Book Medical Publishers, 1963
54. Downs WB: Variations in facial relationships: their significance in treatment and prognosis. Am J Orthodont 34:812, 1948
55. Riedel RA: Relation of maxillary structures to cranium in malocclusion and in normal occlusion. Angle Orthodont 22:142, 1952
56. Steiner CC: Cephalometrics for you and me. Am J Orthodont 39:729, 1953
57. Jacobson A: The ''Wits'' appraisal of jaw disharmony. Am J Orthodont 67:125, 1975
58. McNamara JA Jr: A method of cephalometric analysis, *in* McNamara Jr JA, Ribbens KA, Howe RP (eds): Clinical Alteration of the Growing Face. Monograph 14, Craniofacial Growth Series, Center for Human Growth and Development, The University of Michigan, Ann Arbor, 1983
59. Ellis E, McNamara JA Jr: Components of Adult Class III Open–bite malocclusion. Am J Orthodontics 86:277, 1984
60. Poulton DR, Ware WH: Surgical-orthodontic treatment of severe mandibular retrusion. Am J Orthodont 59:244, 1971
61. McNeill WR, Hooley JR, Sundberg RI: Skeletal relapse during intermaxillary fixation. J Oral Surg 31:212, 1973
62. Epker BN, Wolford LM, Fish LC: Mandibular deficiency syndrome. Surgical considerations for mandibular advancement. Oral Surg 45:349, 1978
63. Carlson DS, Schneiderman ED: Cephalometric analysis of adaptations after lengthening of the masseter muscle in adult rhesus monkeys. Arch Oral Biol 28:627, 1983
64. Rittersma J: Total mandibular osteotomy. J Oral Surg 39:903, 1981