Class II malocclusion: mandibular retrusion or maxillary protrusion?

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An analysis of maxillary and mandibular skeletal positions is essential in planning dentofacial orthopedic treatment or orthognathic surgery. The skeletal nature of a child's malocclusion may have a bearing on the choice of appliance and the evaluation of the treatment result.

The present study was undertaken to further investigate the nature of Class II malocclusions and the validity of some of the sagittal skeletal cephalometric indicators used in orthodontic diagnosis. Some of the questions for this study were:

1. Are most Class II skeletal patterns retrognathic?
2. What percent of Class II skeletal patterns are maxillary protrusive?
3. What is the best cephalometric indicator for mandibular retrognathism?
4. What is the best cephalometric indicator for maxillary protrusion?

Literature review

In orthodontics there is a long history of considering Class II mandibles as retrognathic. McNamara,[1] in his paper on the components of Class II malocclusion, listed 12 studies that supported the skeletal position of Class II mandibles as retrognathic and only four that found them neutral. Almost all studies supporting

Abstract

This study was undertaken to evaluate whether the majority of Class II skeletal patterns are mandibular retrusive or maxillary protrusive and also to compare four maxillary sagittal cephalometric indicators and four mandibular sagittal cephalometric indicators in a skeletal Class II sample. The Fishman SMA method was used to stratify the subjects into 11 maturity levels. Computerized cephalometric programs selected the subjects and compared the different indicators for each subject. The results indicate a wide diversity in the evaluation of maxillary protrusion and mandibular retrusion in these subjects. The Downs facial angle indicated that only 27.0% of the sample had mandibular retrusion. The angle NA-FH indicates that 56.3% of the sample had maxillary protrusion. These findings are in marked contrast to those evaluated by some of the other indicators.

Preliminary data from this study was presented at a combined meeting of the Orthodontic Society of the Cote D'Azur and the North Atlantic Component of the E.H. Angle Society of Orthodontists, Nice, France, October 1990 and at the annual meeting of the North Atlantic Component of the E.H. Angle Society of Orthodontists, Philadelphia, April 1991.

Key Words

Malocclusion • Computerized cephalometrics • Sagittal indicators • Comparative analysis

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Table I
Chronologic ages for adolescent skeletal maturity indicators–SMIs from Fishman

SMI No.	Female Mean	Female S.D.	Male Mean	Male S.D.	Diff.
1	9.94	.96	11.01	1.22	1.07
2	10.58	.88	11.68	1.06	1.09
3	10.88	.99	12.12	1.00	1.23
4	11.22	1.11	12.33	1.09	1.11
5	11.64	.90	12.98	1.12	1.35
6	12.06	.96	13.75	1.06	1.69
7	12.34	.90	14.38	1.08	2.04
8	13.10	.87	15.11	1.03	2.01
9	13.90	.99	15.50	1.07	1.61
10	14.77	.96	16.40	1.00	1.62
11	16.07	1.25	17.37	1.26	1.30

retrognathic mandibles in Class II malocclusions used sella-nasion-based indicators or were limited by small sample size or by samples based on chronologic age or without age selection.

McNamara concluded that only a small percentage of his subjects showed maxillary skeletal protrusion. He found that mandibular skeletal retrusion was the most common single characteristic of his Class II sample.

McNamara's study included 277 subjects 8 to 10 years of age. He apparently used chronologic age instead of skeletal age, made no selection based on the severity of the malocclusion or its skeletal nature, used several linear measurements, and based part of his maxillary analysis on the angle SNA. His separation of the sample into 10 groups based on 77 combinations of skeletal and dental characteristics relied entirely on linear measurements.

Because of the high incidence of mandibular skeletal retrusion he found, McNamara concluded that, "It appears that in designing the ideal treatment regime, those approaches which might alter the amount and direction of mandibular growth could be more appropriate in many cases than those which restrict maxillary development."

Amoric's[2] study of 100 French subjects did not support McNamara's conclusions. Amoric analyzed McNamara's linear measurements for the maxilla and mandible and Ricketts's facial axis and found statistically significant differences in the means and distribution of his results. Amoric's mean was more protrusive for point A and less retrusive for pogonion than McNamara's. No data were given on the age of the subjects or the degree of skeletal dysplasia in the sample.

As noted by Amoric, McNamara's sample had excessive anterior vertical dimension. Amoric's sample consisted of more horizontal growers than McNamara's, thus leading to less mandibular retrusion.

Blair[3] studied 40 Class I subjects; 40 Class II, division 1, subjects; and 20 Class II, division 2, subjects. Selection was by chronologic age with a range of 10 to 14 years. The only mandibular difference was a greater gonial angle in the Class I males. There were no differences in the females. There were no differences in mandibular position between Class I and Class II. Blair noted great varation in the subjects and the possibility of a forward position of the maxilla in Class II.

Altemus[4] studied 40 girls—20 Class II, division 1, and 20 controls—and found that the Class II maxillae were more protrusive and that the mandibles were normal in size, but he did not adequately test mandibular position.

Rothstein's[5,6] computer comparison of 335 Class II, division 1, subjects with 273 normal subjects in three skeletal age groups, done under the guidance of W.M. Krogman and G.F. Walker, is a superb example of meticulous research in this field. Using skeletal base superimpositions and a variety of measurements, Rothstein found that, "The mandible was most often within the range of normal for size, form and positional characteristics, as was the position of the mandibular first permanent molar." Using six age and gender groups for comparison he found that "the morphologic basis of Class II, division 1, malocclusion is consistent with a forward (mesial) position of the maxillary dentition." He found associated differences in the cranial base, orbito-malar complex, and palatal inclination. He found that the angular indicators SNA, NAPg, SNB, and SNPg gave completely erroneous findings on maxillary and mandibular anteroposterior jaw position.

Fishman[7,8,9] published a series of papers categorizing facial skeletal development into 11 skeletal maturity indicator (SMI) stages based on analysis of hand-wrist radiographs (Table I). By relating skeletal measurements to distinct developmental stages, more clear-cut cor-

relations between skeletal measurements and age have been obtained than by methods using chronlogic age.

Materials and methods

The material for this study was derived from same-day cephalometric and hand radiographs taken from a database of subjects from two private practices. The radiographs were taken at a standard 8% enlargement and were digitized using a Houston Instruments HiPad digitizer and a computerized cephalometric program developed by the author. A database of the coordinates, cephalometric measurements and vital data was maintained.

This computer database was searched by severity of facial convexity as indicated by the Downs'[10] angle of convexity and of the Class II tendency of the facial skeletal pattern as indicated by the Kim[11] anteroposterior dysplasia indicator—the APDI. The first search was for subjects whose values for either of these was more than one standard deviation from a population standard. For facial convexity the search was for convexity values greater than 8.5 degrees. The APDI search was for values less than 77.61, indicating the Class II side of the APDI reference mean.

The Fishman SMA method was used to assess the hand radiographs for the level of skeletal maturation and to assign a numeric skeletal maturation indicator (SMI) to each subject. The subjects were then grouped into three SMI levels, as will be explained below. All grouping was by SMI without regard to chronologic age. The sample was Caucasian except for one Vietnamese and one African-American.

The four sets of indicators for the anteroposterior skeletal positions of the maxilla and the mandible for this study were derived from various cephalometric analyses. These sagittal cephalometric measurements indicated maxillary protrusion, mandibular retrusion or combinations of these in 103 Class II subjects having moderate to severe facial convexity in the SMI categories 1 through 11. One additional subject who did not have a hand film was included in the regression analysis of the indicators.

The cephalometric standards used for comparison were pooled male and female standards at the appropriate chronologic ages of the three groups of subjects and were derived from reference standards or the authors cited.

These four sets of indicators and the defining parameters for the differential evaluation of these indicators are shown in Table II.

Table II
Indicators and limits used for evaluation of maxillary protrusion and mandibular retrusion

	Means of male and female standards		
Maxillary Protrusion greater than one standard deviation protrusive			
SMI	1-3	4-7	8-11
NA-FH (Lande)	90.75	90.35	91.00
Ba-A:Ba-N (Coben)	100.40	100.60	101.50
SNA (Riedel)	85.58	85.10	85.70
A-NaPp (McNamara)	2.50	2.50	3.25
Mandibular Retrusion greater than one standard deviation retrusive			
SMI	1-3	4-7	8-11
NPg-FH (Downs)	83.22	84.23	85.08
Ba-Pg:Ba-N (Coben)	83.72	86.60	90.41
SNB (Riedel)	76.96	77.58	78.11
Pg-NaPp (McNamara)	-8.50	-4.50	-5.25

The first set of indicators was the facial angle for the mandible from the Downs Analysis[10] and a similar maxillary indicator (NA-FH) from Lande's[12] work. This angle, NA-FH, has been used for over 30 years in the orthodontic department of the Eastman Dental Center. It has also been used by Ricketts[13] and by Wylie, Fish, and Epker.[14] Lundstrom and Lundstrom[15] used a variant of it to the postural horizontal plane.

A pair of measurements from Coben's[16,17] work provided indicators of the proportional anteroposterior contribution to the facial profile by the maxilla and mandible. These proportional indicators (B-A:B-N and B-Pg:B-N) are expressed as a percentage of the basion-to-nasion distance measured parallel to Frankfort horizontal.

McNamara[1,18] used the horizontal distance of point A from a perpendicular to Frankfort horizontal at nasion as a maxillary indicator and the distance of pogonion from the nasion perpendicular as a mandibular indicator. The linear standards are given at 8% enlargement, but of course linear measurements do not compensate for differences in the size of individuals as angles and proportions do.

The fourth set of sagittal indicators consisted of Riedel's[19,20] angles SNA and SNB, as used in the Steiner[21,22] analysis and in many papers analyzing the characteristics of Class II malocclusion.

Table III
Distribution of subjects in the three SMI groups and ages used for each SMI group for comparison with published reference data.

SMI	Male		Female		
	Age	N	Age	N	Total
1-3	12	20	11	19	39
4-7	14	13	12	23	36
8-11	16	03	15	25	28
Totals		36		67	103

As recommended by Ricketts,[13] the Frankfort horizontal plane used was the skeletal anatomic one. The use of wooden earrods and supports in the cephalometer gave generally good imaging of porion. A wire marker aided in the verification of orbitale.

Reference standards for this study were obtained from the *Bolton Standards of Dentofacial Developmental Growth*,[23] from the *Michigan Atlas of Craniofacial Growth*,[24] from McNamara's[1,18] papers on Class II malocclusion and his method of cephalometric evaluation, and from reference sheets of Coben's standards.[17]

The limits for comparison were one standard deviation in the direction studied, such as a protrusive maxilla measuring more than one standard deviation from the reference mean, or a retrognathic mandible measuring less than one standard deviation from the reference mean.

Mean values were derived from the reference material to determine these limiting values. Combined male and female reference values were used. The values combined were at the same SMI level, not at the same chronologic age. Fishman[7] showed a 1- to 2-year chronologic age difference for a given SMI for males and females.

The McNamara limits were less precise than the other indicators. The standard deviations were given only for an adult sample. The limits used for the SMI 1-3 group were those used by McNamara[1] in his analysis of Class II malocclusion.

Subjects in the SMI categories were combined into groups at related levels of growth velocity. In another study using SMI sorting, Kopecky and Fishman[25] combined their material into three groups. The three groups were those in SMIs 1 to 3 which covers the range to the beginning of the pubertal growth spurt—a period of accelerating growth velocity, those in SMIs 4 to 7 that are in the peak of the pubertal growth spurt, and those in SMIs 8 to 11 that are in the decelerating phase of growth. The same combinations were used in this study.

Reference values appropriate to the SMI for each gender were used. The reference values used were from chronologic ages standards corresponding to the mean age for the males and females in the SMI group. These were then averaged to obtain the reference means and standard deviations for this study.

Table III shows the gender distribution of the subjects in this study in the three SMI ranges described and the chronologic ages for these three SMI ranges used for comparison with published reference data. Some adults were included in the SMI 8-11 group.

Results

Several computer programs developed by the author were used to select subjects for the study and to provide data and indication of maxillary protrusion or mandibular retrusion. The data were then exported to a spreadsheet program for sorting, frequency analysis, and graphing (Quattro Pro 5.0).

Maxilla

For the first group of subjects with SMIs 1 to 3, Table IV shows the summary data with the mean, standard deviation, standard error, coefficient of variation, and minimum and maximum reading for each of the four maxillary indicators studied. A fifth column shows the McNamara linear indicator with 90 added to the measurements of all the subjects. This allows the calculation of a coefficient of variation for a mean close to that of the facial angle and the plotting of the data in the same area of a graph as for the other indicators. It has no effect on the other statistics reported. The coefficient of variation is not valid for data with mixed positive and negative values.

The Lande angle (NA-FH) indicated that 51.3% of the subjects were maxillary protrusive, and the Coben ratio indicated that 56.4% were protrusive. According to the angle SNA, only 23.1% of the subjects were protrusive while McNamara's linear measurement indicated that 38.5% were protrusive.

The Lande and Coben measurements indicated that 63.9% of the 36 subjects (13 male, 23 female) in the SMI 4-7 group were protrusive. The McNamara measurement indicated 44.4% protrusive and SNA found only 19.4% protrusive.

The 28 subjects (3 male, 25 female) in the SMI 8-11 group showed similar results. The Lande

Table IV
Summary data for analysis of maxillary protrusion with percent of subjects reported by each indicator

	NA-FH	Ba-A%	SNA	A-NaPp	A-NaPp+90
SMI 1-3 n=39					
mean	91.13	101.12	82.31	1.01	91.01
s.dev.	3.25	3.37	3.87	3.11	3.11
s.error	0.52	0.54	0.62	0.50	0.50
c.var.	3.56	3.33	4.70	*n.a.	3.42
max	98.95	109.24	90.09	8.30	98.30
min	83.72	93.14	74.61	-6.60	83.40
limit	90.75	100.40	85.58	2.50	
#>limit	20	22	9	15	
%>limit	51.3	56.4	23.1	38.5	
SMI 4-7 n=36					
mean	91.65	101.79	82.04	1.58	91.58
s.dev.	3.47	3.77	3.12	3.51	3.51
s.error	0.58	0.63	0.52	0.59	0.59
c.var.	3.79	3.71	3.80	*n.a.	3.84
max	98.90	109.44	88.89	8.50	98.50
min	84.10	93.95	73.92	-6.10	83.90
limit	90.35	100.60	85.10	2.50	
#>limit	23	23	7	16	
%>limit	63.9	63.9	19.4	44.4	
SMI 8-11 n=28					
mean	91.47	101.59	81.38	1.44	91.44
s.dev.	2.94	3.35	3.49	3.02	3.02
s.error	0.56	0.63	0.66	0.57	0.57
c.var.	3.22	3.30	4.29	*n.a.	3.31
max	98.78	110.43	87.98	8.50	98.50
min	85.39	93.97	72.94	-5.90	84.10
limit	91.00	101.50	85.70	3.25	
#>limit	15	14	3	9	
%>limit	53.6	50.0	10.7	32.1	
Summary n=103 mean % indication of protrusion	56.27	56.77	17.73	38.33	

*n.a. result not valid because of mixed positive and negative values

angle showed 53.6% protrusive, the Coben ratio showed 50% protrusive, and the McNamara linear measurement showed 32.1% protrusive. The angle SNA indicated only 10.7% protrusive.

The mean percent indications of maxillary protrusion are shown in the bottom row of Table IV with both NA-FH (Lande's angle) and Ba-A% (Coben) showing over 56% protrusion. The SNA angle gave the lowest indication of maxillary protrusion at 17.7%. The data for the SMI groups are graphically displayed in Figure 1.

A report using asterisks was also obtained to show concurrence or nonconcurrence in the evaluation of each subject for protrusion or retrusion by the various sagittal indicators. Table V shows the maxillary measurements for the 18 subjects in SMI 5 along with the asterisk indicators of maxillary protrusion for the

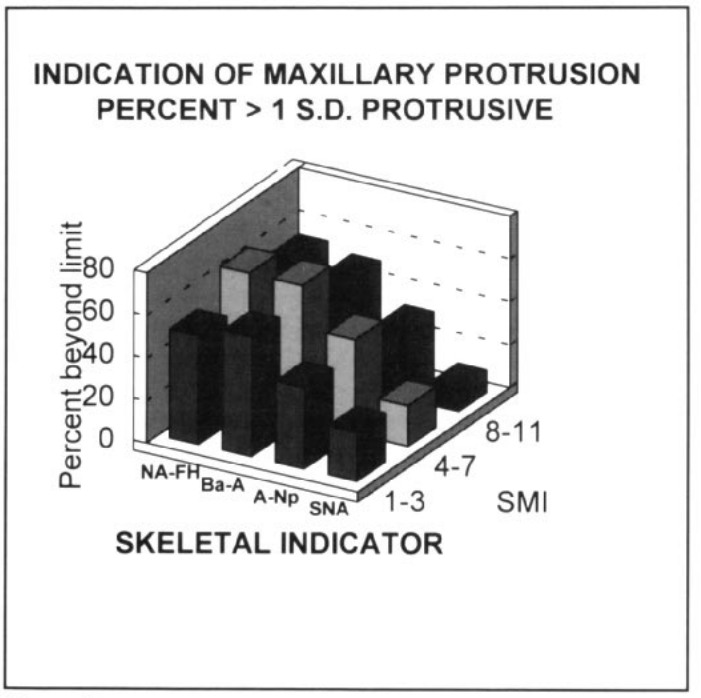

Figure 1

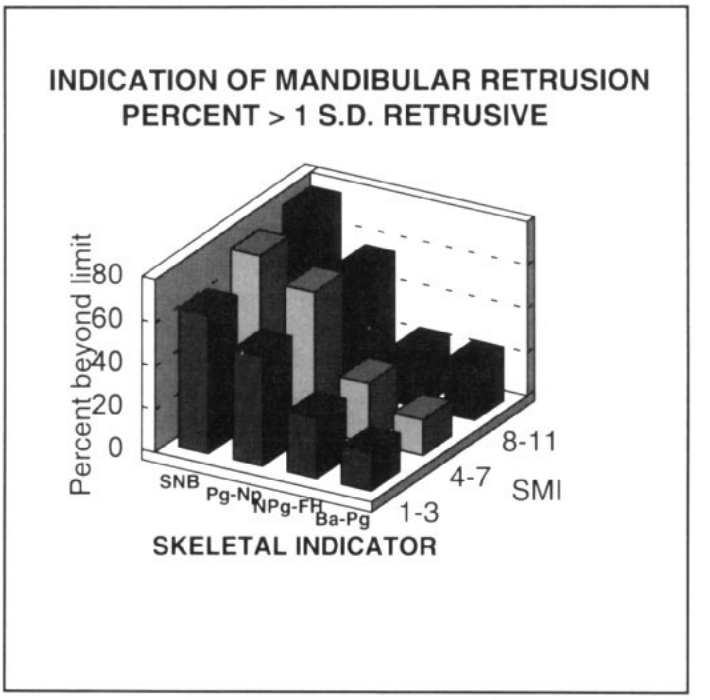

Figure 2

Figure 1
Percent indication of maxillary protrusion at the three levels of maturity according to each sagittal indicator.

Figure 2
Percent indication of mandibular retrusion at the three levels of maturity according to each sagittal indicator.

Table V
Maxillary analysis example for SMI 5, showing individual measurements for the four maxillary indicators. Gender, molar occlusion and asterisk indication of maxillary protrusion as reported by each sagittal indicator are also shown. Subjects arranged by increasing size of angle NA-FH.

SMI 5, n=18						Indication of maxillary protrusion			
Subj #	Sex	NA-FH	Ba-A%	SNA	A-NPp	NA-FH	Ba-A%	SNA	A-NPp	Class
75	M	86.6	95.8	76.1	-4.1					II
73	M	86.9	96.9	82.6	-3.0					II
65	F	88.2	98.1	80.2	-1.8					II
35	F	88.3	98.2	81.8	-1.7					II
84	F	88.4	97.6	76.3	-2.0					E O
37	M	88.5	98.5	80.2	-1.5					II
74	F	89.8	99.8	80.8	-0.2					II
66	F	91.3	101.4	78.9	1.3	*	*			II
95	F	92.7	102.9	82.8	2.5	*	*			II
72	M	92.8	102.9	82.3	2.8	*	*		*	II
62	F	93.3	103.4	83.2	3.3	*	*		*	E O
98	M	93.7	103.9	84.3	3.8	*	*		*	II
78	F	93.8	103.9	80.8	3.9	*	*		*	II
7	F	94.3	104.5	82.1	3.9	*	*		*	II
107	M	94.4	104.9	79.7	4.8	*	*		*	II
59	M	95.1	105.8	83.5	5.3	*	*		*	II
10	M	96.0	107.0	80.9	6.0	*	*		*	E O
42	F	96.1	106.4	81.1	5.6	*	*		*	II

Table VI
Summary data for analysis of mandibular retrusion with percent of subjects reported by each indicator.

	NPg-FH	Ba-Pg%	SNB	Pg-NPp	Pg-NPp+90
SMI 1-3 n=39					
mean	85.41	90.72	75.76	-8.68	81.32
s.dev.	3.12	6.61	3.81	6.19	6.19
s.error	0.50	1.06	0.61	0.99	0.99
c.var.	3.65	7.29	5.04	71.36	7.61
max	90.96	102.15	84.23	1.90	91.90
min	78.69	74.37	67.54	-24.50	65.50
limit	83.22	83.72	76.96	-8.50	
#>limit	11	7	25	20	
%>limit	28.2	17.9	64.1	51.3	
SMI 4-7 n=36					
mean	86.15	92.17	75.87	-7.44	82.56
s.dev.	2.96	6.29	3.17	6.06	6.06
s.error	0.49	1.05	0.53	1.01	1.01
c.var.	3.43	6.83	4.18	81.46	7.34
max	91.99	104.11	83.59	3.90	93.90
min	78.22	77.30	69.55	-22.90	67.10
limit	84.23	86.60	77.58	-4.50	
#>limit	10	6	27	23	
%>limit	27.8	16.7	75	63.9	
SMI 8-11 n=28					
mean	86.43	92.21	75.13	-7.37	82.63
s.dev.	2.20	5.69	3.09	5.30	5.30
s.error	0.42	1.07	0.58	1.00	1.00
c.var.	2.55	6.17	4.11	72.00	6.42
max	90.23	100.31	80.28	0.30	90.30
min	80.93	77.46	67.61	-20.80	69.20
limit	85.08	90.41	78.11	-5.25	
#>limit	7	7	22	16	
%>limit	25	25	78.6	57.1	
Summary n=103					
mean %> 1 s.d.					
retrusive	27.00	19.87	72.57	57.43	

same subjects. According to Fishman,[8] SMI 5 occurs a short time before the peak growth rate for S-A and S-Gn for males and females.

Sorting based on the angle NA-FH showed that three of the four indicators were in agreement on the most protrusive subjects. The Lande and Coben indicators detected maxillary protrusion in 11 of 18 subjects and were in agreement for each of these 11 subjects. The McNamara measurement indicated maxillary protrusion in nine subjects, while angle SNA did not detect maxillary protrusion in any of the subjects.

Mandible

Table VI gives summary data for the mandible for the three SMI groups. The same type of data are shown as for the maxilla. Figure 2 graphically displays the data for the mandible for all three SMI ranges.

In the 39 subjects in the SMI 1 to 3 group, the

Table VII
Mandibular analysis example for SMI 5 showing individual measurements for the four mandibular indicators. Sex, molar occlusion and asterisk indication of mandibular retrusion as reported by each sagittal indicator are also shown. Subjects arranged by increasing size of angle NPg-FH (Downs facial angle).

SMI 5, n=18						Indication of mandibular retrusion				
Subj #	Sex	NPg-FH	Ba-Pg%	SNB	Pg-NPp	NPg-FH	Ba-Pg%	SNB	Pg-NPp	Class
84	F	81.5	79.8	69.9	-16.9	*	*	*	*	EO
73	M	81.7	83.5	76.2	-15.9	*	*	*	*	II
75	M	82.0	81.6	70.1	-17.8	*	*	*	*	II
65	F	83.1	87.5	73.2	-11.8	*		*	*	II
37	M	83.4	86.6	73.9	-13.3	*		*	*	II
35	F	83.6	87.9	77.0	-11.7	*		*	*	II
95	F	85.7	90.4	76.1	-8.4			*	*	II
62	F	86.3	93.2	75.9	-6.7			*	*	EO
66	F	86.7	93.4	74.1	-6.0			*	*	II
74	F	86.9	94.3	76.6	-5.5			*	*	II
78	F	87.2	94.6	72.9	-5.5			*	*	II
72	M	88.4	96.8	76.6	-3.1			*		II
7	F	88.6	97.0	75.5	-2.6			*		II
42	F	88.6	96.8	73.2	-2.8			*		II
98	M	88.8	97.6	77.7	-2.4					II
107	M	89.1	97.7	73.7	-2.3			*		II
59	M	90.6	101.7	78.6	1.5					II
10	M	91.0	102.0	75.1	1.7			*		EO

facial angle found that only 28.2% of the subjects had retrusive mandibles. The Coben ratio found only 17.9% while SNB found 64.1% and the McNamara mandibular linear skeletal indicator found 51.3% retrusion.

In the 36 subjects in the SMI 4 to 7 group, the facial angle found 27.8% mandibular retrusion and the Coben ratio found 16.7% retrusion. The SNB angle, however, found 75.0% and the McNamara linear indicator found 63.9% mandibular retrusion.

Of the 28 subjects in the SMI 8 to 11 group, only 25% were retrusive by the facial angle or the Coben ratio, but 78.6% were retrusive by the angle SNB and 57.1% were retrusive by the McNamara linear indicator.

The mean percent indications of mandibular retrusion are given at the bottom of Table VI and show that the Downs facial angle and the Coben ratio indicated that only 27.0% or 19.9% of these patients had mandibular retrusion,

Table VIII
Regression analysis for the maxillary and mandibular sagittal indicators.

Maxilla	
Independent variable: NA-FH	
Dependent variables	R square
A-NPp	0.992924
Ba-A%	0.991866
SNA	0.444593
Mandible	
Independent variable: NPg-FH	
Dependent variables	R square
Pg-NPp	0.980583
Ba-Pg%	0.975599
SNB	0.336544

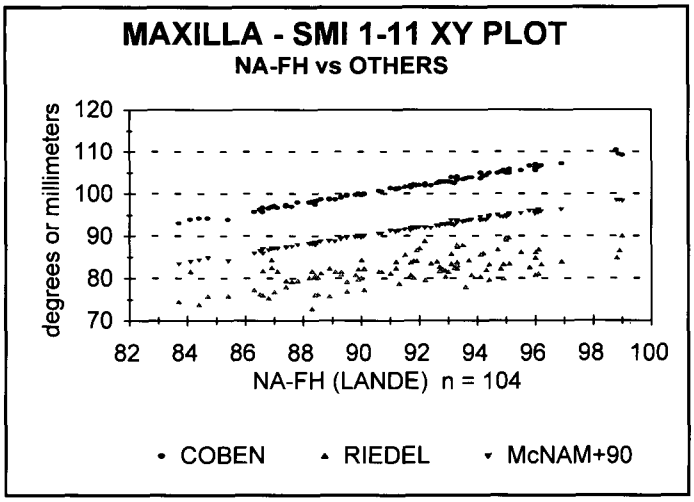

Figure 3

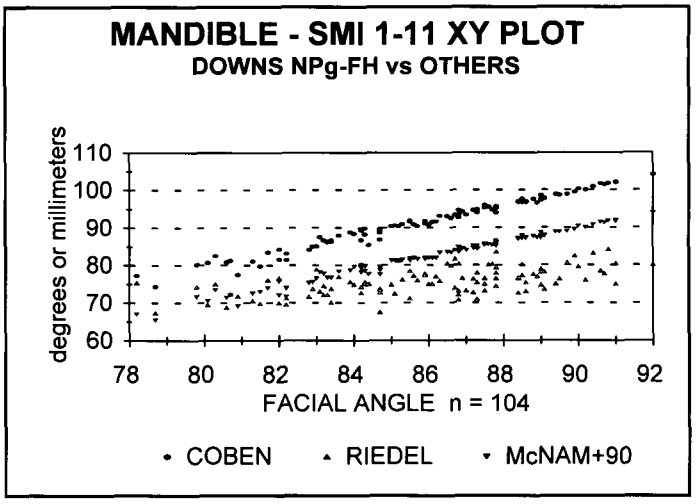

Figure 4

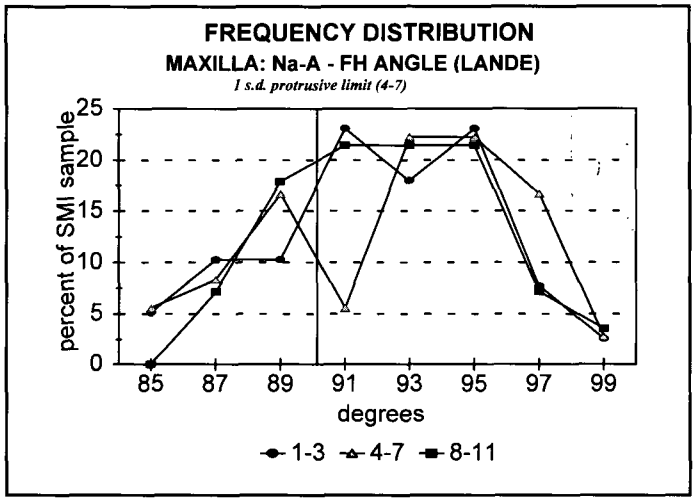

Figure 5A

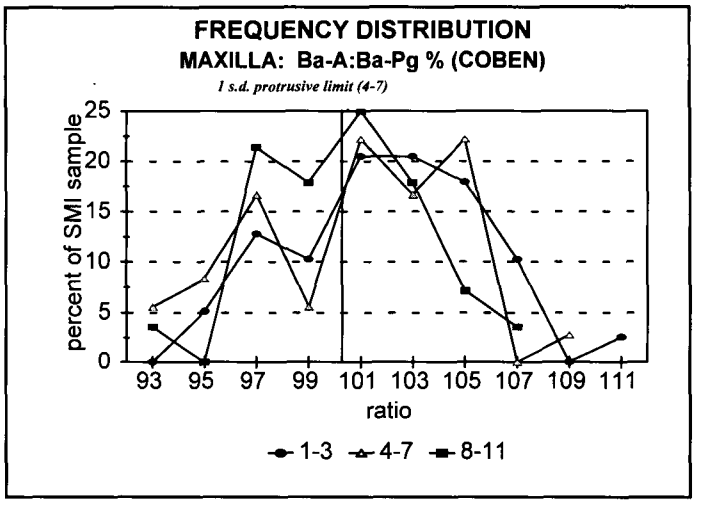

Figure 5B

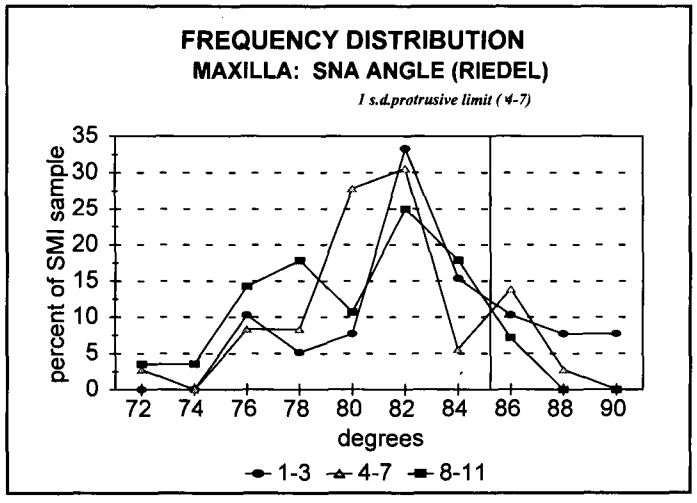

Figure 5C

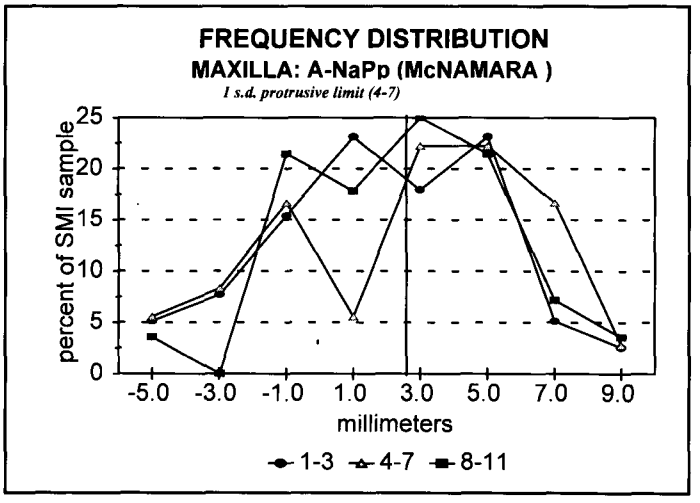

Figure 5D

Figure 3
Regression plot of three maxillary sagittal indicators as compared with the angle NA-FH as the independent variable for the entire sample.

Figure 4
Regression plot of three mandibular sagittal indicators as compared with the angle NPg-FH as the independent variable for the entire sample.

Figure 5A-D
Frequency distribution of maxillary sagittal indicators with the one standard deviation protrusive limit from the reference mean shown for the SMI 4-7 group.

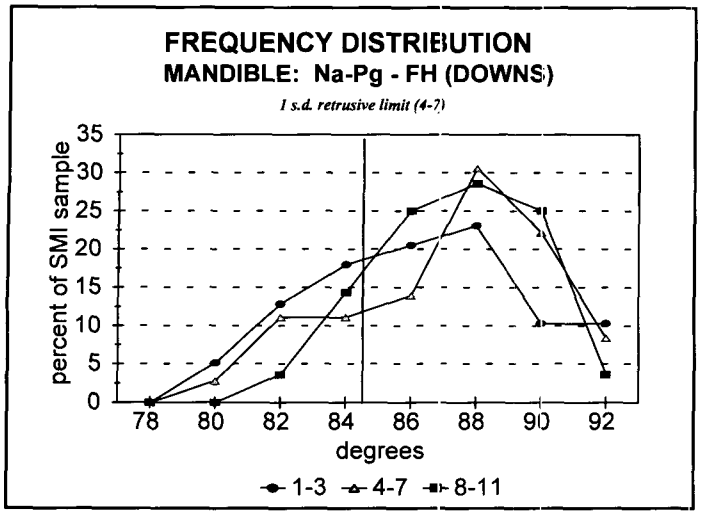

Figure 6A

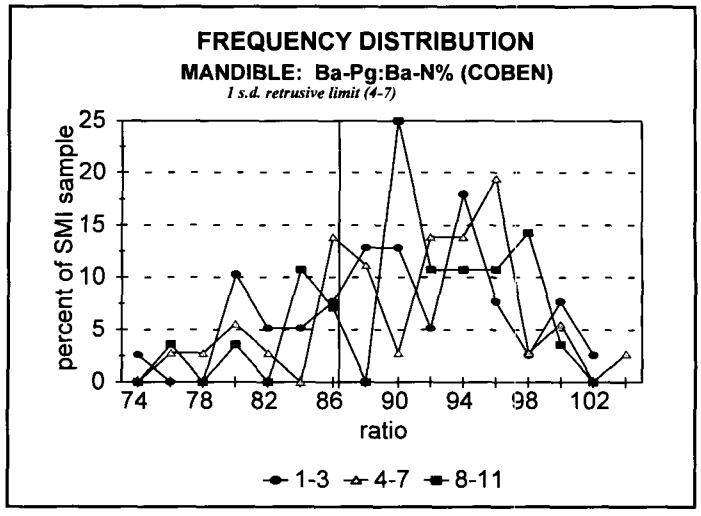

Figure 6B

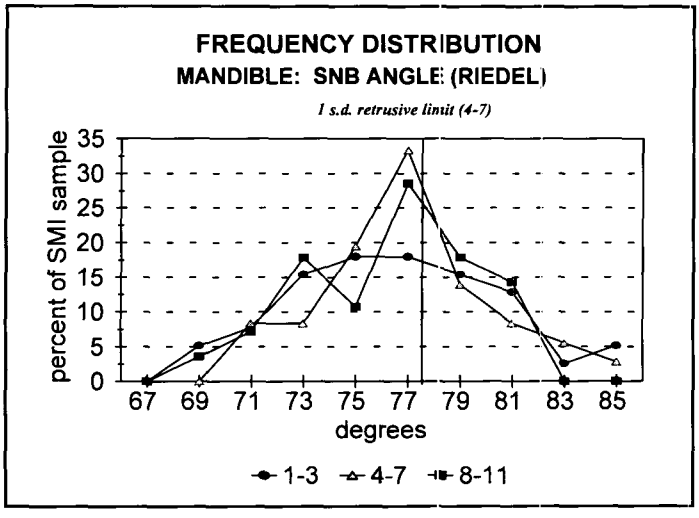

Figure 6C

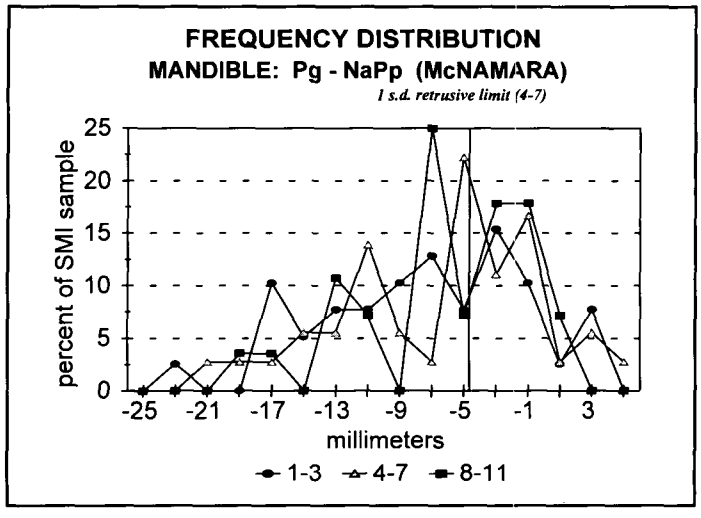

Figure 6D

Figure 6A-D Frequency distribution of the four mandibular sagittal indicators with the one standard deviation retrusive limit from the reference mean shown for the SMI 4-7 group.

whereas the SNB angle found that 72.6% were retrusive and the McNamara indicator found that 57.4% were retrusive.

Table VII shows individual mandibular measurements for 18 subjects in SMI 5, along with asterisk indication of mandibular retrusion as reported by each sagittal indicator. The Coben indicator detected only 3 patients as retrognathic, the Downs facial angle detected 6, but the McNamara indicator found 11 patients retrognathic and SNB characterized 16 patients this way. All indicators were in agreement for only three patients. Sorting based on increasing size of the angle NPg-FH shows that all indicators were in agreement for only the three most retrognathic subjects.

Correlations

Regression plots (Figures 3 and 4) were used for further evaluation of the validity of these various indicators in 104 subjects. An additional subject without a hand film was used in this portion of the study. The N-A to FH angle was used as the independent variable for the maxilla and the N-Pg to FH angle as the independent variable for the mandible. The other indicators were plotted as dependent variables.

The much greater dispersion of the SNA and SNB measurements is evident. The correlation coefficients are given in Table VIII.

Histograms

In the histograms for the maxilla (Figure 5A-D), both the Lande and the Coben results show that most values are on the protrusive side of the mean. SNA shows more distribution in the normal and retrusive range and the McNamara values show a balanced distribution.

Histograms for the mandibular indicators are shown in Figure 6A-D. The frequency distribution of the facial angle for the mandible shows that the majority of subjects did not have mandibular retrusion, in contrast to

Table IX
Other indicators of anteroposterior and vertical dysplasia and the relationship of sella-nasion and Frankfort horizontal to basion-nasion.

	APDI	ODI	AB	SN-BaN	FH-BaN
SMI 1-11n=103					
mean	73.79	75.86	-9.87	19.32	28.77
s.dev.	4.59	6.95	2.91	1.99	2.49
s.error	0.45	0.69	0.29	0.20	0.25
c.var.	6.22	9.17	*n.a.	10.32	8.66
max	85.55	91.60	-0.39	24.41	34.76
min	55.75	55.30	-21.33	12.31	21.43
limit	77.61	68.43			
%<limit	12.60	13.60			

*n.a. result not valid because of mixed positive and negative values

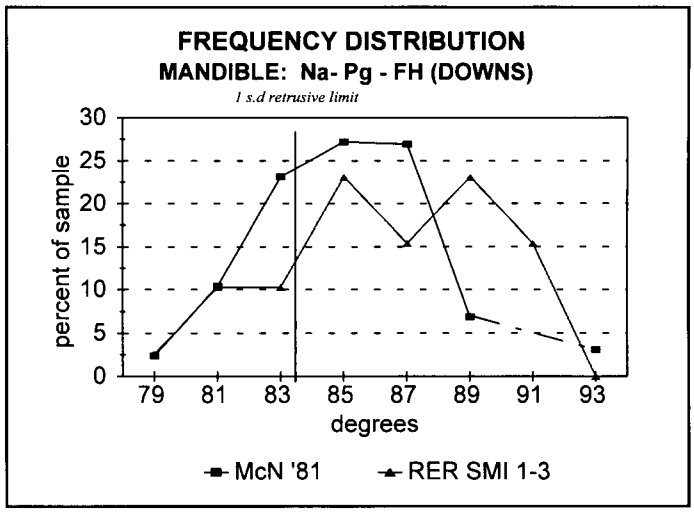

Figure 7

McNamara's results[1] but in support of Amoric,[2] Blair,[3] and Rothstein.[5,6]

Note that values for the facial angle (NPg-FH) in all three SMI groups are centered around Downs's normal mean value. The facial angle and SNB have the smoothest distributions. The SNB values are centered in the retrusive range—more retrusive than the one standard deviation limit.

Discussion

Cephalometric analyses provide indicators for characterization of the patient's craniofacial skeleton. Central to these are indicators of the anteroposterior position of the maxilla and mandible. This study has undertaken to evaluate the correlation and validity of these indicators. The Downs[10] analysis did not include an indicator of maxillary position. The angle N-A to FH from Lande's[12] work provides a measurement of maxillary protrusion or retrusion comparable to the facial angle for the mandible.

This investigation has sought something which may not yet exist—"gold standards" for evaluation of the anteroposterior positions of the maxilla and mandible. The regression plots in this study show that in the maxilla all indicators except SNA are closely correlated, as also shown by the high correlation coefficients. In the mandible all indicators except SNB are also closely correlated, but the Downs and Coben results reported much lower indications of mandibular retrusion. Downs[10] and Lundstrom and Lundstrom[15] showed examples in subjects where the use of sella-nasion-based indicators did not give as accurate an appraisal of mandibular position as did Frankfort horizontal-based indicators. Ellis and McNamara[26] also showed that Frankfort horizontal-based indicators are at least as valid as those based on sella-nasion. Ricketts, Schulhoff, and Bagha[13] showed that the facial angle is the preferred measurement of mandibular position based on five considerations.

This investigation shows that there may be biases built into McNamara's indicators. These indicators gave conflicting results in that they correlated with the facial angle and N-A to FH respectively, but the mandibular one gave much higher reporting of retrognathism than did the facial angle. This may be because of the reference standards used with them or errors inherent in the use of a linear indicator.

The reliability of using anatomic Frankfort horizontal plane instead of sella-nasion or the natural head posture horizontal has been questioned.[15,27] Downs,[10] Ricketts et al.,[13] and Ellis and McNamara[26] all supported the use of anatomic Frankfort horizontal. As Ricketts pointed out, it is essential that anatomic porion be used instead of machine porion.

Tables IV and VI show that the standard deviations and standard errors for NPg-FH and NA-FH were generally the lowest of the four indicators.

As a further indication of the reliability of the anatomic Frankfort horizontal plane compared with the sella-nasion plane, measurements of these two planes to the basion-nasion plane were done for the entire sample (Table IX). The coefficient of variation is a description of the percentage of variation for the measurement and is an indication of the reliability of measurements.[29] It is the standard deviation divided by the mean expressed as a percent and it answers the question, "What percent of the

Figure 7
Comparison of the frequency distribution of McNamara's results for Downs's facial angle with a similar age group from the present study.

mean is the standard deviation?" The c.v. was 8.62 for Frankfort horizontal and 10.3 for sella-nasion.

Table IX also shows the anteroposterior dysplasia indicator, APDI,[11] and overbite depth indicator, ODI,[28] evaluation for the total sample along with the measurement for the angle AB to the facial plane from the Downs analysis.[10] The evaluation of APDI shows that this indicator did not consider 12.5% of the sample as having as much dysplasia in the skeletal pattern as the angle of convexity had indicated. The ODI evaluation indicates that only 13.5% of the entire sample had a vertical growth tendency.

Fishman's work[7,8,9] provides a new paradigm in which subjects are stratified by level of skeletal maturation instead of by chronologic age. In these groups there will be both male and female subjects, but the chronologic age range of the females will be different from that of the males. Because these male and female subjects are at the same skeletal maturity level, this should result in a more consistent sample than a chronologically based one. The maturity level strata are more clearly delineated by the use of these skeletal maturity indicators than by skeletal ages alone.

In examining the data from this study, the related examples in the literature, and the years of their successful use at the Eastman Dental Center and in private practice, one is led to the conclusion that of the four mandibular indicators compared in this study, the Downs facial angle is the present "gold standard" for mandibular anteroposterior position. The angle N-A to FH provides a high degree of reliability for the maxilla. No single measurement may be reliable all the time and as Downs[10] pointed out, it is the manner in which all the measurements are related to one another that is important in case analysis.

Using the angle N-A to FH for the maxilla, the summary data from this study indicate that 56.6 % of subjects with Class II malocclusion and a Class II skeletal pattern had maxillary protrusion. The facial angle indicated that only 26.7% had mandibular retrusion.

Using the facial angle for the mandible as a reference showed that SNB over-reported mandibular retrusion 46% of the time (72.8% compared with 26.7%) and Pg to NPp (McNamara) over-reported this 40% of the time (67% compared to 26.7%). For the maxilla, using N-A to FH as a reference showed that SNA under-reported maxillary protrusion 39% of the time (17.57% compared to 56.6%) but A to NPp (McNamara) was close at 53.5%.

Further analysis of the pretreatment and posttreatment records of patients should help confirm the appropriateness of these indicators. The use of surgical outcomes for this evaluation, as done by Wylie, Fish, and Epker,[14] may not be appropriate. McCance et al.,[30] have shown that surgical results may not correlate with the pretreatment prediction measurements even when the esthetic result is satisfactory.

As a further test of the validity of McNamara's contention that mandibular retrognathism was the dominant characteristic of his sample, Figure 7 is a plot of the frequency distribution of McNamara's[1] data for the Downs facial angle along with the data for

the SMI 1-3 group from the present study. The one standard deviation limit for 9-year-old subjects from the Bolton study[23] is shown as a line indicating the retrusive side of the samples. This graph shows that only 35.9% of McNamara's sample was retrusive by this well-established mandibular indicator. In the SMI 1-3 group in the present study, the facial angle indicated that 28.2% were retrusive. The distribution of the two samples is similar and they overlap at the 79 and 81 degree points. The present study shows a greater percentage of the sample in the protrusive range. As previously stated, McNamara's sample was selected chronologically with an age range of 8 to 10 years. The SMI 1-3 sample of the present study was selected by skeletal maturity level with a chronologic age range for males of 11 to 12 years and for females of 10 to 11 years.

Both Blair[3] and Altemus[4] emphasized the need for Class II samples based on skeletal characteristics rather than on dental malocclusion alone in order to have a well defined sample.

The present study thus supports the conclusions of the anteroposterior evaluations of Blair,[3] Altemus,[4] Rothstein,[5,6] and Amoric[2] and not those of McNamara,[1] Hitchcock,[31] and other studies that used sella-nasion-based sagittal indicators. The results may help explain some of the reasons Harris et al.[32] found that the Steiner analysis was not useful in Class II cephalometric diagnosis.

Conclusions

This study of 103 Class II subjects with a Class II skeletal pattern at three levels of skeletal maturation found that the dominant pattern was maxillary protrusion with a normal mandible. The Class II skeletal pattern was assessed by the Downs angle of convexity and the Kim anteroposterior dysplasia indicator (APDI). The subjects were matched in groups in 11 skeletal maturity levels by the use of the Fishman skeletal maturity assessment (SMA).

In this sample, the angle NA-FH indicated that the average incidence of maxillary protrusion in the three groups was 56.3%. The NPg-FH angle (Downs facial angle) indicated that the average incidence of mandibular retrusion in the three groups was only 27.0%. There was a wide divergence in the results reported by the other indicators. Two of the other indicators under-reported maxillary protrusion 18% to 39% of the time and two over-reported mandibular retrusion 30% to 46% of the time.

These findings are in contrast to other reports in the literature using sella-nasion-based measurements indicating more mandibular retrusion or retrognathia and less maxillary protrusion in Class II subjects.

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