Cephalometric floating norms for North American adults

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An adequate description of the skeletal pattern associated with a given malocclusion is fundamental in orthodontics, especially in patients whose treatment plan involves orthognathic surgery or functional orthopedic jaw therapy. Typically, some type of cephalometric analysis is used to identify the patient's deviation from so-called normal values. These normal values are derived from an untreated sample of subjects from the same racial or ethnic group. Such norms may be determined from selected populations of subjects with so-called "ideal" occlusions and well-balanced faces,[1-3] or they may be based on norms from the same racial or ethnic group without regard for occlusion or facial balance[4-6] and thus are biased toward the prevalent skeletal and dental relationships of the sample. An example of this latter type of sample is the *University of Michigan Elementary and Secondary Growth Study*,[4] the normative values of which are prejudiced toward Class II malocclusion and increased lower anterior facial height.

Regardless of the type of comparative sample used, a major drawback of conventional cephalometric diagnosis is the use of isolated craniofacial parameters, without taking into account their possible interdependence. In fact, Solow demonstrated significant correlations among sagittal and vertical cephalometric variables, leading to the concept of "craniofacial pattern."[7] This term means that even though the cephalometric measurements of a subject lie beyond one standard deviation from the population norm, the measurements can still be considered acceptable if certain relationships are maintained.

One of the first attempts to describe combinations of acceptable values for different craniofa-

Abstract

Floating norms provide a method of analysis that uses the variability of the associations among suitable cephalometric measures, on the basis of a regression model combining both sagittal and vertical skeletal parameters. This study establishes floating norms for the description of the individual skeletal pattern in North American adults. The method is based on the correlations among the following craniofacial measurements: SNA, SNB, NL-NSL, ML-NSL, and NSBa. The results are given in a graphical box-like form. This easy, practical procedure allows for the identification of either individual harmonious craniofacial features or anomalous deviations from the individual norm. The use of cephalometric floating norms may be helpful for diagnosis and treatment planning in orthognathic surgery and dentofacial orthopedics.

Key Words

Floating norms • Cephalometry • Cephalometric analysis • Craniofacial pattern • Orthognathic surgery • Normal

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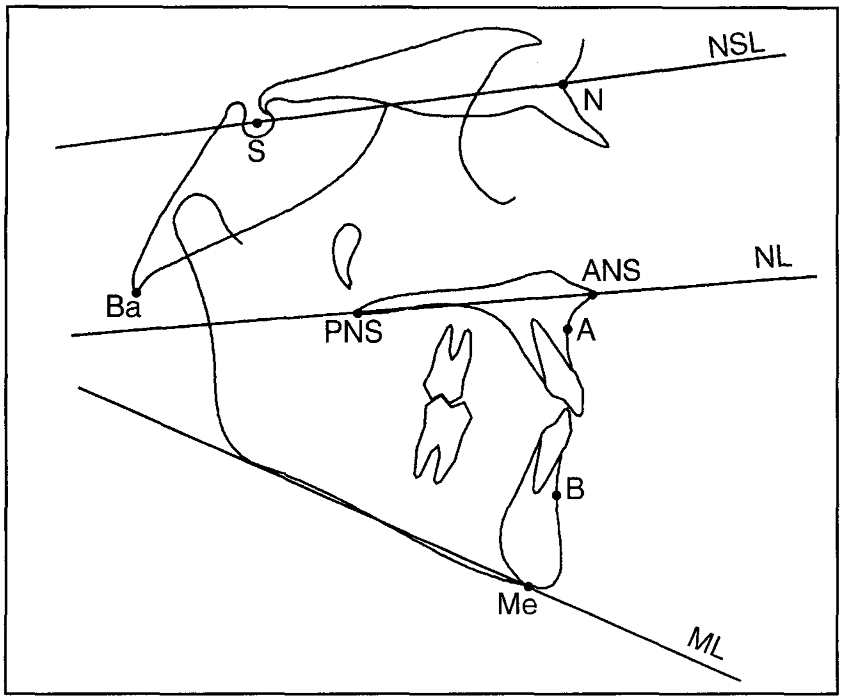

Figure 1

S-N-A	NL-NSL	N-S-Ba	ML-NSL	S-N-B
65	19	142	48	61
66	18	141	47	62
67	17	140	46	63
68	16	139	45	64
69	15	138	44	65
70	14	137	43	66
71	13	136	42	67
72	12	135	41	68
73	11	134	40	69
74	10	133	39	70
75	9	132	38	71
76	8	131	37	72
77	7	130	36	73
78	6	129	35	74
78	5	128	34	75
80	4	127	33	76
81	3	126	32	77
82	2	125	31	78
83	1	124	30	79
84	0	123	29	80
85	-1	122	28	81
86	-2	121	27	82
87	-3	120	26	83
88	-4	119	25	84
89		118	24	85
90		117	23	86
91		116	22	87
92		115	21	88
93			20	89
94			19	90
95			18	91
96			17	92
97			16	93
98			15	94
99			14	95
100			13	96
				97
				98
				99

Figure 2

Figure 1
Points and planes used in the cephalometric analysis

Figure 2
Floating norms for North American adults in a graphical box-like form

cial measurements was made by Steiner,[8] who used the ANB angle as a "guiding variable" to assess the position of the lower incisors. The ANB angle was also employed by Tweed[9] as a guiding variable to modify the norm values of his diagnostic triangle. Hasund and Böe[10] modified Steiner's analysis by means of "floating norms" for the positioning of the lower incisors, based on the guiding variables ANB, ML-NL (inclination of the mandibular plane to the palatal plane) and the N angle (the angle formed by the tangent to the bony chin passing through B-point and the mandibular plane; Figure 1). Floating norms, then, are individual norms that vary (float) in accordance with the variations of correlated measurements (guiding variables).

Järvinen[11] developed floating norms for ANB angle by using a regression analysis with SNA and ML-NSL (the inclination of the mandibular plane to the nasion-sella line) as independent variables. Finally, a more comprehensive analysis for the assessment of individual craniofacial patterns was performed by Segner[12] and by Segner and Hasund,[13] who constructed floating norms for the description of sagittal and vertical skeletal relationships in a sample of European adults. Tollaro and co-workers[14] implemented this method to establish floating norms for the cephalometric diagnosis of southern European children in the deciduous dentition phase.

The aim of the present study was to present floating norms for the description of the individual skeletal pattern in North American adults as an additional diagnostic tool for orthodontic treatment planning, especially in patients who may undergo orthognathic surgery or functional jaw orthopedics as part of their overall treatment regimen.

Material and methods

The study is based on a sample of 165 North American young adults (79 females, 86 males). All subjects were Caucasian and none had received orthodontic treatment. Subjects were included in the study if they had a well-balanced profile (assessed by three investigators) and ideal or near-ideal occlusion (Class I molar relationship, Class I canine relationship, normal overbite and overjet, no or very minimal incisal irregularity). Some of the subjects in this sample have been described previously by McNamara and coworkers.[2,3,15]

The following measurements (Figure 1) were performed by means of a digitizer (Numonics 2210, Numonics, Lansdale, Penn) and digitizing software (Viewbox, ver. 1.8, as described by Halazonetis[16]): maxillary prognathism (SNA), mandibular prognathism (SNB), maxillary inclination relative to the cranial base (NL-NSL), mandibular inclination relative to the cranial base (ML-NSL), and cranial base angle (NSBa). These angular parameters were selected to apply Segner's method[12] to the North American sample. It should be noted that the SN line is shared by all the measurements, thus enhancing the power of the mathematical correlation among the variables.[7] Although all the cephalometric measurements used in this study were angular and thus not affected by cephalometric enlargement, the enlargement for each film was standardized at 8%. The method error for these angles was assessed by means of Dahlberg's formula[17] and is reported elsewhere.[14]

Data analysis

The statistical examination (SPSS package for Windows, version 6.1.3.) of the recorded data comprised: (1) calculation of Pearson's correlation coefficients, (2) bivariate linear regression analysis, and (3) multiple linear regression analysis.

Results

Descriptive statistics for all the cephalometric measurements are given in Table 1. Table 2 shows the linear correlation coefficients (r) between the cephalometric variables. Linear regression equations with corresponding r^2 and standard error of the estimate are reported in Table 3. Table 4 shows the multiple correlation coefficients, R, the adjusted R^2, and the standard error of the estimate when predicting one of the five measured variables from the remaining four by means of a multiple regression analysis.

Figure 2 illustrates the regression results in a graphical box-like form, with SNB as the independent variable and NL-NSL, NSBa, ML-NSL, and SNA each as the dependent variable, according to the method of Segner.[12] SNB serves as an independent variable because it correlates with the highest significance with all other variables and shows the highest R^2 value in multiple regression analysis.[13]

Table 1
Descriptive statistics

Cephalometric variables	Mean	SD	SE	Min	Max
SNA	82.98	3.48	0.27	73.88	93.36
SNB	80.37	3.21	0.25	70.44	90.10
NL-NSL	7.33	3.38	0.26	-1.59	17.21
ML-NSL	30.07	4.82	0.37	18.46	44.69
NSBa	128.36	5.13	0.39	112.93	142.11

Table 2
Correlation coefficients (r) between cephalometric measurements

Cephalometric variables	NL-NSL	NSBa	ML-NSL	SNB
SNA	-0.46**	-0.39**	-0.42**	0.88**
NL-NSL		0.35**	0.35**	-0.59**
NSBa			0.25*	-0.46**
ML-NSL				-0.62**

* $p<0.01$; ** $p<0.001$

Table 3
Linear regression equations with corresponding r^2 and standard error of the estimate (SE)

Regression equations	r^2	SE
SNA = 0.956 SNB + 6.13	0.78	1.65
NL-NSL = -0.627 SNB + 57.72	0.35	2.72
ML-NSL = -0.936 SNB + 105.35	0.39	3.77
NSBa = -0.741 SNB + 187.91	0.22	4.55
SNB = -0.416 ML-NSL + 92.87	0.39	2.52

Table 4
Standard errors of the estimate when predicting one of the variables SNA, NL-NSL, NSBa, ML-NSL, and SNB from the other four by means of multiple regression analysis (n = 165)

Cephalometric variables	R	R^2	SE
SNA	0.90	0.81	1.54
NL-NSL	0.62	0.38	2.68
NSBa	0.47	0.22	4.56
ML-NSL	0.68	0.46	3.56
SNB	0.94	0.88	1.11

Discussion

The present investigation provides cephalometric floating norms that are derived from and are specific for a North American Caucasian adult sample. It always is preferable to compare the cephalometric values of a given patient with a norm extrapolated from his or her racial or ethnic group. In fact, the comparisons between the values for some of the cephalometric variables (SNA, ML-NSL, NSBa) in the present North American sample and in Segner's Middle European sample[12] were statistically significant (Student's *t*-test, $p< 0.05$). For example, SNA and ML-NSL angles were significantly greater in North Americans than in Middle Europeans.

The diagnostic diagram that is presented as a graphical box (Figure 2) is the outcome of the pattern of associations among the examined cephalometric variables. Any horizontal line con-

Figure 3
Graphical box with the harmony line and the range of accepted variability

Figure 4
Cephalometric tracing of MP, a 23-year-old female

S-N-A	NL-NSL	N-S-Ba	ML-NSL	S-N-B
65	19	142	48	61
66	18	141	47	62
67	17	140	46	63
68	16	139	45	64
69	15	138	44	65
70	14	137	43	66
71	13	136	42	67
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73	11	134	40	69
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78	6	129	35	74
78	5	128	34	75
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82	2	125	31	78
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85	-1	122	28	81
86	-2	121	27	82
87	-3	120	26	83
88	-4	119	25	84
89		118	24	85
90		117	23	86
91		116	22	87
92		115	21	88
93			20	89
94			19	90
95			18	91
96			17	92
97			16	93
98			15	94
99			14	95
100			13	96
				97
				98
				99

Figure 3

necting the values of the different variables inside the box has to be considered as a line expressing a harmonious skeletal pattern or *individual harmony line.*[12] The line may correspond to the center of the box (Figure 3). In this instance, the subject would be classified as harmonious and *orthognathic*. In fact, the central line of the box connects the mean values for the various measurements.

When the line lies in the upper part of the box, the subject, though still harmonious, is classified as *retrognathic*. In order to maintain an ideal occlusion and an acceptable craniofacial balance, both the maxilla and the mandible have to incline downward and backward in relation to cranial base. When, on the other hand, the line lies in the lower part of the box, the subject, though still harmonious, is classified as *prognathic,* and both the maxilla and the mandible will show an upward and forward inclination relative to cranial base.

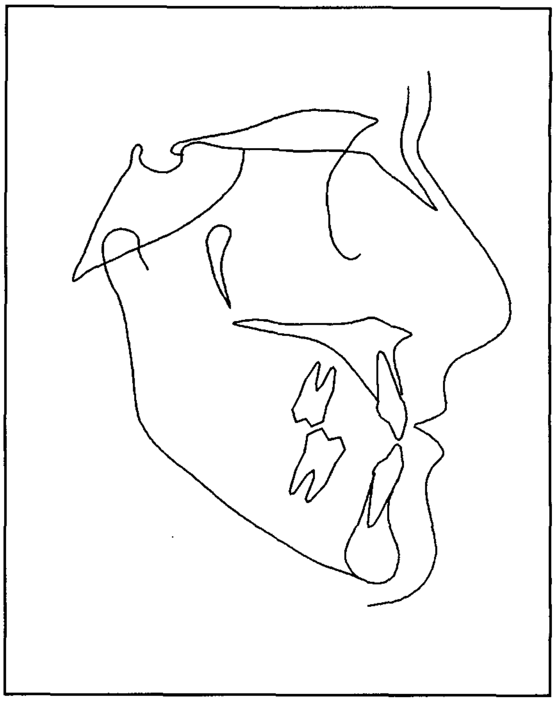

Figure 4

For any individual horizontal harmony line, a *range of accepted variability* is allowed. The range of variability is represented by the standard error of the estimate of the multiple regression analysis (Table 4). The range is narrower for SNA and SNB angles, and it is wider for the remaining three variables (Figure 3). The variability estimates of the range can be shifted to any individual "horizontal harmony line" when evaluating the craniofacial characteristics of a given patient.

A subject whose cephalometric values fall within the range can still be considered to show a harmonious skeletal relationship. The same subject will be classified further as orthognathic, retrognathic, or prognathic according to the zone of the box that includes his or her cephalometric values. The individual horizontal harmony line is traced as a best-fit line among the individual cephalometric values. If at least one individual value lies outside the range, that indicates deviations from a harmonious facial pattern. In this way, the cephalometric variables responsible for an unbalanced skeletal pattern can be easily detected.

Cephalometric floating norms are intended for initial diagnosis and for evaluation of treatment effects. Due to the correlations among the five measurements in the graphical box, every reassessment of therapeutic results will describe not only the modifications of the target variables, but

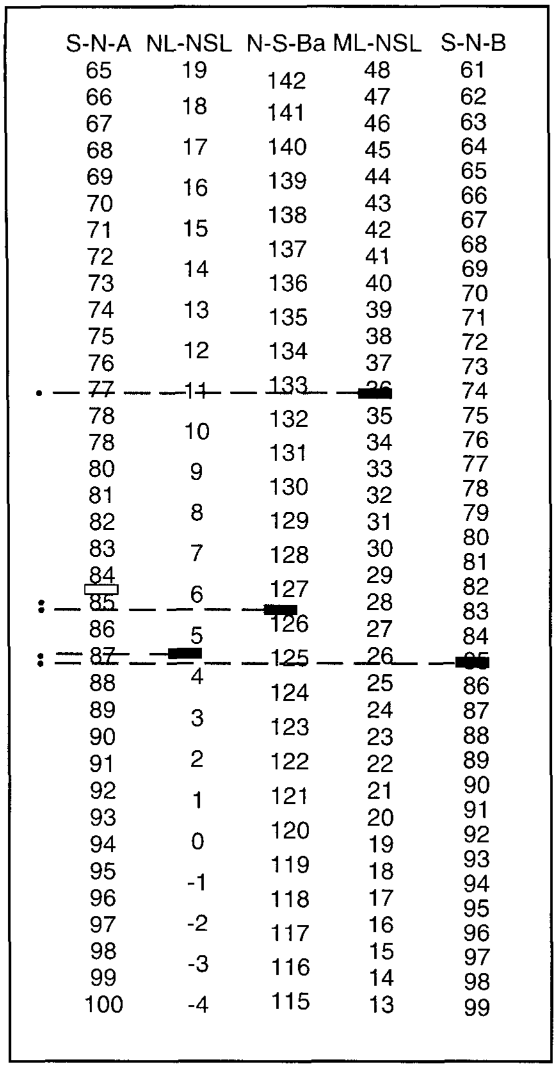

Figure 5

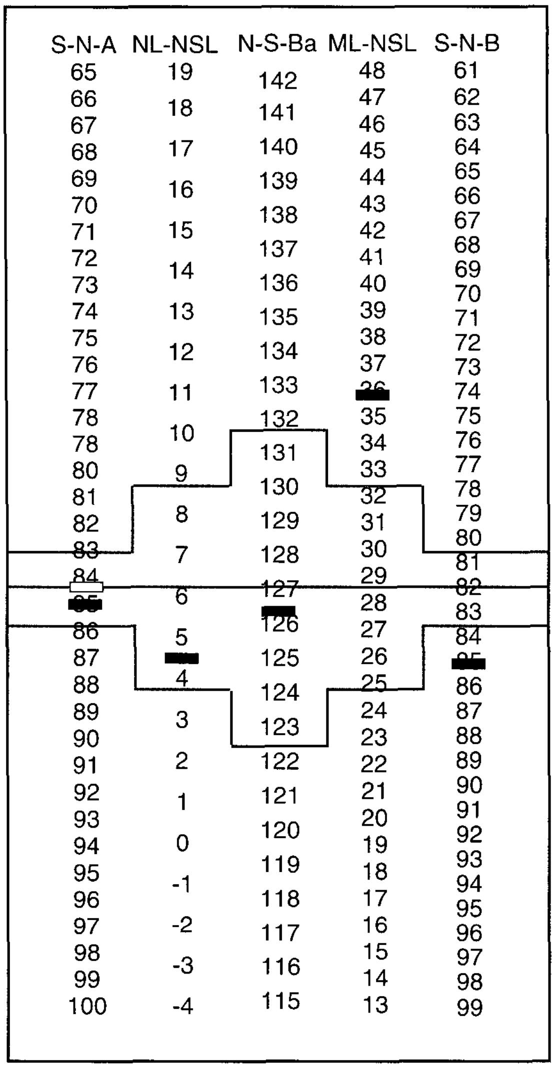

Figure 6

Figure 5
Values for MP reported inside the graphical box. See text for explanations

Figure 6
Diagnosis for MP: Excessive mandibular protrusion (SNB) and downward and backward inclination of the mandibular plane to the cranial base (ML-NSL)

also the newly established craniofacial pattern.

A step-by-step practical procedure can be performed as follows.

1. Measure the five cephalometric variables on the patient's headfilm and mark the values within the graphical box.

2. Identify on the SNA column the SNA values corresponding to the other four variables in that patient. A ruler can be used to draw horizontal lines connecting each individual value on the NL-NSL, NSBa, ML-NSL, and SNB columns to the SNA column. Calculate the average value for the five values now present on the SNA column and mark it on the SNA column (*harmony point*).

3. Photocopy the range together with the harmony line on a piece of transparent acetate.

4. Place the transparent acetate with the range and the harmony line on the graphical box so that the harmony line is positioned on the harmony point.

5. Any value that remains outside the range will indicate deviation from a harmonious craniofacial pattern.

Case example

The cephalometric tracing of MP, a 23-year-old female, is shown in Figure 4; her cephalometric values are reported in Figure 5. The black dots on the left side of the SNA column in Figure 5 identify the SNA values corresponding to the remaining four variables of the patient. The small unfilled rectangle in the SNA column (Figure 5) represents the harmony point (84.3°), i.e., the guiding point for the location of the individual harmony line together with the range.

The patient presents three out of the five individual measurements within the borders of the range (Figure 6). The individual harmony line lies in the central part of the box. This relationship classifies the patient as orthognathic. Deviations from a harmonious craniofacial pattern are located in the sagittal position of the mandible (SNB) and in the inclination of the mandibular plane in relation to the cranial base (ML-NSL). In particular, mandibular protrusion is excessive and the mandibular plane is tilted downward and backward. Consequently, a diagnosis of high-angle mandibular prognathism can be made.

Conclusions

The analysis of the individual craniofacial pattern by means of floating norms appears to provide a helpful method of determining which parameters are most responsible for the skeletal disharmony, thus representing an additional diagnostic tool in orthopedic/surgical treatment planning. However, it would be inappropriate to suggest specific surgical decisions based solely on the cephalometric data given by floating norms. The very important static and functional soft tissue relationships to the facial skeleton, the function of the occlusion and the temporomandibular joints, and the patient's chief complaint and psychosocial concerns should be taken into account in this respect.

The present norms are suitable for North American, Caucasian, young adults. Cephalometric floating norms for different racial or ethnic groups must be established on population-specific samples.

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References

1. Broadbent BH Sr, Broadbent BH Jr, Golden WHO. Bolton standards of dentofacial development growth. St. Louis: Mosby, 1975.
2. McNamara JA Jr, Ellis E. Cephalometric analysis of untreated adults with ideal facial and occlusal relationships. Int J Adult Orthod Oral Surg 1988;3:221-231.
3. Miyajima K, McNamara JA Jr, Kimura T, Murata S, Iizuka T. Craniofacial morphology of Japanese and European-American adults with normal occlusions and well-balanced faces. Am J Orthod Dentofac Orthop 1996;110:431-438.
4. Riolo ML, Moyers RE, McNamara JA Jr, Hunter WS. An atlas of craniofacial growth: Cephalometric standards from The University School Growth Study, The University of Michigan. Monograph 2, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1974.
5. Prahl-Anderson BP, Kowalski CJ, Heydendael PHJM. A mixed-longitudinal interdisciplinary study of growth and development. New York: Academic Press, 1979.
6. Richardson ER. Atlas of craniofacial growth in Americans of African descent. Monograph 26, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1991.
7. Solow B. The pattern of craniofacial associations. A morphological and methodological correlation and factor analysis study on young adults. Acta Odontol Scand 1966; suppl. 46.
8. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953;39:729-755.
9. Tweed CH. Frankfort mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning and prognosis. Angle Orthod 1954;24:121-169.
10. Hasund A, Böe OE. Floating norms as guidance for the position of the lower incisors. Angle Orthod 1980; 50:165-168.
11. Jarvinen S. Floating norms for ANB angle as guidance for clinical considerations. Am J Orthod Dentofac Orthop 1986;90:383-387.
12. Segner D. Floating norms as a means to describe individual skeletal patterns. Eur J Orthod 1989;11:214-220.
13. Segner D, Hasund A. Individualisierte Kephalometrie. 2nd edition. Hamburg: Franklin Printing and Publishing House Ltd, 1994.
14. Tollaro I, Baccetti T, Franchi L. Floating norms for the assessment of craniofacial pattern in the deciduous dentition. Eur J Orthod 1996; 18: 359-366.
15. McNamara JA Jr, Brust EW, Riolo ML. Soft tissue evaluation of individuals with an ideal occlusion and a well-balanced face. In: McNamara JA Jr, ed. Esthetics and the treatment of facial form. Monograph 28, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, University of Michigan, 1993.
16. Halazonetis DJ. Computer-assisted cephalometric analysis. Am J Orthod Dentofac Orthop 1994;105:517-521.
17. Dahlberg AG. Statistical methods for medical and biological students. New York: Interscience Publications, 1940.