Cephalometric analysis of untreated adults with ideal facial and occlusal relationships

James A. McNamara, Jr, DDS, PhD
Professor and Interim Chairman
Department of Orthodontics and Pediatric Dentistry
Research Scientist
The Center for Human Growth and Development
University of Michigan
Ann Arbor, Michigan

Edward Ellis III, DDS, MS
Associate Professor
Department of Oral and Maxillofacial Surgery
University of Texas
Southwest Medical School
Dallas, Texas
Research Investigator
The Center for Human Growth and Development
University of Michigan
Ann Arbor, Michigan

Address correspondence and reprint requests to:
James A. McNamara, DDS, PhD
Department of Orthodontics and Pediatric Dentistry
School of Dentistry
University of Michigan
Ann Arbor, Michigan 48109

Abstract

Numerous cephalometric analyses have been applied to defined samples of untreated individuals to derive cephalometric "norms" for a given population, usually grouped by age and ethnic origin. The data from such studies can be used cross sectionally for comparison during diagnosis and treatment planning. One hundred twenty-five individuals were examined in this study, and dentofacial norms for males and females with "ideal" occlusal and facial relationships were established. It should be stressed, however, that infinite combinations of dentoskeletal relationships in each patient are possible to arrive at a face that is well balanced and that has an ideal occlusal relationship. The purpose of establishing cephalometric norms is not to create "targets" for individual treatment, but rather guides for the clinical assessment of the patient. The final diagnosis and treatment plan will rely on a number of other factors that cannot be obtained from a radiograph.

Introduction

Numerous cephalometric analyses have been applied to defined samples of untreated individuals to derive cephalometric "norms" or "standards" for a given population, usually defined in terms of age and ethnic origin. The data from such studies can be used cross sectionally for comparison during the diagnosis and treatment planning of individual patients. If the cephalograms are available serially, such data on untreated individuals can be used to help determine the treatment effects of a particular therapeutic regimen.

Previously published cross-sectional cephalometric studies have varied widely in their criteria for sample selection. In fact, some studies have no documented sample, using isolated cases and opinions.[1] Others have used the occlusal relationship as the only criterion for inclusion of a subject.[2-5] The problem with this approach is obvious—an ideal occlusal relationship can exist in an individual with a severe skeletal imbalance.[5] Other studies have used facial esthetics as the sole criterion for inclusion of a subject, irrespective of the occlusal relationship.[6-8]

With the frequent use of maxillofacial surgical techniques to correct skeletal imbalances, a need has arisen for more accurate and complete cephalometric norms for the dentoskeletal complex. Using "norms" from a sample based solely upon the occlusal relationship or facial esthetics, in an era where comprehensive orthodontic and surgical therapy is possible, seems less than satisfactory.

Table 1 Cranial base relationships

Craniofacial variable	Male (n = 44)				Female (n = 81)				Sig
	Mean	SD	Min	Max	Mean	SD	Min	Max	
S-N (mm)	78.12	3.65	67.10	83.22	71.93	3.65	65.11	77.72	$P < .001$
S-Ba (mm)	49.77	3.79	39.91	57.71	45.56	3.00	32.49	54.42	$P < .001$
N-S-Ba (°)	126.19	4.92	117.54	138.73	129.30	4.84	115.32	144.53	$P < .001$
SN-FH (°)	6.99	2.06	.41	10.63	7.97	2.42	2.81	14.52	$P < .05$

Table 2 Maxillary skeletal relationships

Craniofacial variable	Male (n = 44)				Female (n = 81)				Sig
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Anteroposterior relationships									
S-N-A (°)	83.81	3.21	77.38	92.23	82.56	2.80	76.10	88.70	$P < .05$
Point A to Na ⊥ (mm)	0.96	2.67	−6.01	8.82	0.52	2.29	−5.00	7.14	NS
Vertical relationships									
PP-SN (°)	6.61	2.99	1.32	14.62	7.62	3.27	−.59	14.52	NS
PP-FH (°)	−0.38	2.89	− 6.41	5.83	−0.35	2.79	−6.50	6.62	NS
PNS-S (mm)	54.28	3.29	47.17	62.36	48.70	2.79	42.57	55.71	$P < .001$
PNS-SN ⊥ (mm)	51.08	3.23	44.81	59.91	45.91	2.64	39.92	53.61	$P < .001$
PNS-FH ⊥ (mm)	28.40	3.29	20.92	35.32	25.49	2.55	17.81	31.16	$P < .001$

Because most surgical procedures are applied to the nongrowing patient, norms for adults are most useful. Unfortunately, many norms have been derived from juvenile and adolescent samples.[1,3] Scheideman and coworkers recognized the shortcomings of previous studies and published norms on 56 white adults with untreated Class I occlusal relationships.[9] Other criteria included a ratio of upper to lower facial height within 15% of a 1:1 relationship and a point A-nasion-basion (ANB) angle between 0° and 4°. They made no attempt to select subjects with "ideal" facial esthetics. Other studies have used both occlusal and facial criteria, but without attention to ideal relationships.[10,11]

The purpose of this study is to establish dental and skeletal cephalometric norms in a large sample of adults with ideal facial and occlusal relationships.

Method and materials

The subjects used in this study were white males and females over the age of 16 who possessed ideal facial esthetics and ideal Class I occlusal relationships. The records of 57 of these individuals were part of a sample of records obtained from the normal occlusion study of the Foundation for Orthodontic Research.[12] The records of 68 additional patients were gathered by the senior author. Records included lateral posteroanterior cephalometric radiographs in all cases, and frontal and sagittal extraoral photographs and dental casts in some cases.

Table 3 Mandibular skeletal relationships

Craniofacial variable	Male (n = 44)				Female (n = 81)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Sig
Anteroposterior relationships									
S-N-B (°)	81.64	2.70	77.42	88.63	80.03	2.83	73.83	87.49	$P < .01$
Facial angle (°)	89.82	1.74	86.54	95.19	89.12	2.26	84.25	94.38	NS
Po to Na ⊥ (mm)	−0.43	3.69	−7.72	10.41	−1.72	4.42	−11.02	8.81	NS
S-N-Po (°)	82.83	2.78	78.00	89.21	81.15	2.79	74.58	87.79	$P < .01$
N-Art (mm)	103.38	4.92	91.82	113.28	94.95	3.92	88.11	104.53	$P < .001$
N-S-Art (°)	122.58	4.66	111.81	132.21	124.50	5.03	113.46	138.18	$P < .05$
Vertical relationships									
MP-SN (°)	28.54	4.76	19.23	35.82	30.68	4.87	19.60	43.01	$P < .05$
MP-FH (°)	21.55	3.95	13.21	28.23	22.71	4.40	15.33	34.00	NS
S-Art (mm)	37.71	3.76	28.89	47.27	33.51	3.22	23.64	40.30	$P < .001$
Facial axis (°)	0.51	3.41	−5.51	7.71	0.28	3.35	−6.82	6.67	NS
PBR*-SN (°)	88.97	4.65	78.00	96.77	89.53	4.20	78.05	99.16	NS
PBR*-FH (°)	81.98	4.34	73.03	90.04	81.61	4.05	74.31	91.75	NS
S-Art-Go (°)	146.39	6.52	134.60	161.32	145.01	6.58	130.70	160.83	NS
Mandibular morphology									
Co-Po (Mn Ln) (mm)	133.96	6.65	115.88	145.32	120.49	5.18	111.08	135.39	$P < .001$
Gonial angle (°)	119.57	5.70	107.82	132.63	120.95	5.49	109.55	131.57	NS
Co-Go (mm)	70.83	5.14	57.78	78.51	61.86	4.47	51.41	76.44	$P < .001$
Art-Go (mm)	57.58	3.99	47.71	67.02	50.50	4.49	40.34	67.01	$P < .001$
Go-Po (mm)	88.37	6.37	74.32	100.73	80.34	4.06	71.86	90.15	$P < .001$
Go-Gn (mm)	87.93	6.15	74.62	99.81	79.79	4.10	71.41	89.67	$P < .001$

*PBR-tangent to posterior border of mandibular ramus.

Each person was included in the study after evaluation of the untraced cephalogram, the clinical examination, and/or the extraoral photographs. The individual was included in the study after two or more investigators determined that his or her soft tissue contours were "ideal." The face was evaluated for balance and symmetry in the frontal view, and balance and sagittal relationship in the profile view. In addition, the untreated occlusal relationship had to contain a full complement of teeth, with the possible exception of the third molars, and although minor rotations of teeth were allowed, no crowding was permitted. Over a 10-year period, 81 females and 44 males who met these criteria were collected.

Radiographic enlargement was calculated as 8%.* Each cephalogram was traced by one investigator and checked by the second to verify accuracy. The cephalograms were digitized at The Center for Human Growth and Development, the University of Michigan, where the landmarks were converted to an X-Y coordinate system. Measures of craniofacial form were calculated by computer and tabulated by sex into cranial base relationships, maxillary skeletal relationships, mandibular skeletal relationships, dentoalveolar relationships, intermaxillary relationships, and vertical facial relationships. The variables used are a synthesis of those previously described by Steiner,[1] Downs,[3]

*This amount of enlargement is considered "conventional" in cephalometric radiography.

Table 4 Dentoalveolar relationship

Craniofacial variable	Male (n = 44) Mean	SD	Min	Max	Female (n = 81) Mean	SD	Min	Max	Sig
Anteroposterior relationships									
U1-SN (°)	105.68	6.56	87.68	124.01	107.10	5.62	95.04	125.32	NS
U1-FH (°)	112.67	6.30	93.82	128.32	115.07	5.11	105.07	130.42	$P < .05$
U1-Point A vertical (mm)	5.35	1.96	.45	9.75	5.44	1.70	1.62	9.20	NS
U1-PP (°)	112.29	6.45	98.10	126.42	114.73	5.54	104.93	130.49	$P < .05$
U1-NA (°)	21.81	6.32	6.00	35.64	24.55	5.10	13.93	38.20	$P < .01$
U1-NA (mm)	5.04	2.25	.26	10.63	5.26	1.69	1.28	9.51	NS
U1-APo (mm)	4.40	2.34	−.36	8.62	5.18	1.76	.38	10.14	$P < .05$
U1-NPo (mm)	5.11	3.12	−1.69	11.50	5.99	2.24	.14	11.25	NS
IMPA (°)	92.27	7.41	75.72	110.01	94.88	6.34	79.98	108.56	$P < .05$
L1-NB(°)	22.45	6.68	7.09	36.10	25.59	4.89	9.51	37.73	$P < .01$
L1-NB (mm)	4.97	2.28	.20	9.32	5.16	1.53	1.21	8.79	NS
FMIA (°)	66.18	6.56	50.28	80.40	62.41	5.45	50.92	78.29	$P < .001$
L1-OP (°)	71.74	6.94	55.21	90.00	69.32	5.54	57.57	84.45	$P < .05$
L1-Point B ⊥ (mm)	−2.06	2.20	−6.01	2.90	−1.41	1.88	−7.13	2.23	NS
L1-APo (mm)	1.32	2.29	−3.03	6.53	1.79	1.68	−2.49	5.15	NS
Vertical relationships									
SN-OP (°)	12.56	3.47	5.21	19.50	14.88	3.37	7.70	22.05	$P < .001$
FH-OP (°)	5.56	3.01	−.42	13.22	6.43	3.09	−.17	15.38	$P < .05$
U6-SN ⊥ (mm)	79.98	3.92	73.68	92.58	71.65	3.59	60.65	80.26	$P < .001$
U6-FH ⊥ (mm)	54.31	3.94	46.33	63.01	48.26	3.44	35.22	57.39	$P < .001$
U6-PP ⊥ (mm)	26.04	2.58	21.64	32.03	22.93	2.55	12.00	28.92	$P < .001$
UIE*-ANS (mm)	31.06	2.75	26.00	38.33	28.47	2.41	21.71	33.70	$P < .001$
UIE†-PP ⊥ (mm)	30.86	2.62	26.02	37.75	28.38	2.46	21.67	33.66	$P < .001$
OP-PP (°)	5.94	3.10	1.33	14.53	7.25	3.20	1.10	16.98	$P < .05$
LIE†-Me (mm)	46.58	3.52	39.44	53.43	41.70	2.40	36.40	49.00	$P < .001$
L6-MP ⊥ (mm)	37.30	2.92	28.82	44.00	33.06	2.38	27.45	38.47	$P < .001$
OP-MP (°)	15.98	4.25	7.04	27.01	15.80	4.11	6.37	27.53	NS

*UIE = upper incisal edge.
†LIE = lower incisal edge.

Table 5 Intermaxillary relationships

Craniofacial variable	Male (n = 44) Mean	SD	Min	Max	Female (n = 81) Mean	SD	Min	Max	Sig
ANB (°)	2.23	1.75	−2.71	5.38	2.52	1.41	−.69	5.46	NS
Co-Po/Co-A Point (mm)	34.37	4.12	27.27	45.32	29.27	3.47	17.93	38.55	$P < .001$
WITS (mm)	−0.72	2.84	−6.74	5.53	−0.93	2.19	−7.32	3.19	NS
Overjet (mm)	3.31	1.00	.28	6.81	3.60	0.88	0.90	5.57	NS
Overbite (mm)	2.80	1.26	−1.21	5.51	2.67	0.99	0.88	5.03	NS
PP-MP (°)	21.93	4.89	13.59	33.18	23.06	4.58	13.86	35.51	NS
U1-L1 (°)	133.51	10.83	113.90	162.91	127.34	7.40	109.09	152.32	$P < .001$

Table 6 Vertical facial components

Craniofacial variable	Male (n = 44)				Female (n = 81)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Sig
N-Me (AFH) (mm)	130.98	6.46	118.11	148.12	118.72	4.82	109.60	131.59	$p < .001$
N-ANS (UFH) (mm)	57.98	3.47	49.92	63.51	53.11	2.57	48.09	59.41	$p < .001$
ANS-Me (LFH) (mm)	74.54	5.41	65.32	87.81	66.88	4.16	58.63	78.25	$p < .001$
S-Go (PFH) (mm)	91.28	6.19	78.78	104.61	80.20	5.62	68.99	98.51	$p < .001$
UFH/AFH	0.44	0.02	.38	.48	0.45	0.02	.40	.49	NS
LFH/AFH	0.57	0.02	.52	.63	0.56	0.02	.52	.61	NS
UFH/LFH	0.78	0.07	.60	.91	0.80	0.06	.67	.94	NS
PFH/AFH	0.70	0.04	.63	.77	0.67	0.04	.57	.77	$p < .01$
N-Gn (mm)	129.44	6.49	117.63	146.92	117.26	4.85	109.11	130.81	$p < .001$
N-A (mm)	63.92	3.60	56.29	71.58	58.32	2.75	52.80	66.39	$p < .001$
A-Gn (mm)	65.71	4.40	55.51	77.39	59.11	3.52	51.92	57.92	$p < .001$
NA/AGn	0.98	0.07	.84	1.17	0.99	0.07	.83	1.18	NS

Scheideman et al,[9] McNamara,[13] and Ellis and McNamara.[14] The Student *t*-test was used to determine the significance of differences between male and female samples.

To assess patterns of dentoskeletal accommodation within this sample, Pearson's correlations were calculated for the following:

1. A measure of maxillary position (point A to nasion perpendicular)
2. A measure of mandibular position, as indicated by the angle formed between the Frankfort horizontal (FH) and a line between nasion and pogonion (Po) (facial angle)
3. The mandibular plane angle (FH to mandibular plane [MP])
4. The ANB angle
5. The Wits measure (the distance between perpendicular projected from the occlusal plane to points A and B)
6. The posterior facial height (PFH), as measured from sella (S) to gonion (Go)
7. The overbite relationship
8. A measure of maxillary incisor position relative to FH (U1-FH)
9. A measure of mandibular incisor position relative to the mandibular plane (IMPA)
10. The interincisal angle (U1-L1)

The level of acceptable statistical significance for these correlations was set at $P < .001$.

Table 7 Positive and negative correlations of variables

Positive			Negative	
Variable	r		Variable	r
		Point A-Na ⊥		
Facial angle	.60			
ANB	.52			
		Facial angle		
Point A-Na ⊥	.60		FH-MP	−.52
U1-FH	.32		ANB	−.32
		FH-MP		
ANB	.31		Facial ang	−.52
			Post fac ht	−.45
			IMPA	−.45
		ANB		
Point A-Na⊥	.52		Facial ang	−.32
FH-MP	.31			
Wits	.57			
		U1-FH		
Facial angle	.32		Overbite	−.43
IMPA	.28		U1-L1	−.75
		U1-L1		
Overbite	.47		U1-FH	−.75
			IMPA	−.70

$P < 0.001 = r > .29$

Table 8 Cephalometric standards

Measure	Downs (1948)[3] Mixed adults excellent occlusion		Reidel (1950)[4] Mixed adults excellent occlusion		Steiner (1953)[1] Personally chosen norms		Tweed (1954)[6] Mixed sample good faces		Reidel (1957)[7] Seafair princesses		Scheideman (1980)[9] Good skeletal dental balance male	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cranial base												
SN-FH (°)											8.0	3.2
S-N (mm)											77.1	3.8
N-Ba (mm)											114.5	4.2
S-Ba (mm)											49.9	2.4
Maxillary skeletal												
SNA (°)			82.01	3.89	82.0	—					82.4	3.9
Angle convex (°)		5.09	1.62	4.78					3.05	—	−0.6	4.3
SN-PP											7.3	3.4
Mandibular skeletal												
SNB (°)			79.97	3.69	80.0	—					80.9	3.4
Facial angle (°)	87.8	3.57							87.8	—	90.6	3.7
FH-MP (°)	2 1.9	3.24					24.57	—	22.5	—	21.2	5.1
SN-MP (°)			31.71	5.19							27.0	4.8
Gonial angle (°)											124.9	5.2
Facial axis (°)											90.6	3.3
Art-Go (mm)											52.6	4.0
Go-Po (mm)											84.3	3.8
Art-N (mm)											103.0	3.7
Intermaxillary												
ANB (°)			2.04	1.81	2.0	—			3.4	—	1.6	1.5
PP-MP (°)											21.9	4.7
Dental												
U1-L1 (°)	135.4	5.76	130.98	9.24	130.0	—			135.75	—	135.1	8.3
U1-SN (°)			103.97	5.75							103.4	5.9
U1-FH (°)			111.2	5.7					106.9	—		
U1-NA (°)					22.0	—			17.68	—	21.0	6.0
U1-NA (mm)					4.0	—			2.66	—	4.2	2.7
U1-APo (mm)									4.63	—	1.0	2.4
UIE*-ANS (mm)											30.1	2.2
IMPA (°)	91.4	3.78	93.09	6.78	93.0	—	86.93	—	94.2	—	94.3	6.0
L1-NB (°)					25.0	—			23.25	—	22.3	4.8
L1-NB (mm)					4.0	—					3.4	2.1
FMIA (°)							68.2	—	63.08	—		
L1-APo (°)									23.16	—		
L1-APo (mm)									3.95	—	4.0	2.1
LIE†-Me (mm)											43.9	2.9
Overjet (mm)											3.3	1.0
Overbite (mm)											3.8	1.5
OP-PP (°)											5.9	3.2
SN-OP (°)											10.7	3.1
Vertical												
AFH (N-Me;mm)											126.4	6.6
UFH (N-ANS;mm)											56.4	3.0
LFH (ANS-Me;mm)											71.3	4.7
UFH/LFH											0.79	0.05

**UIE = upper incisal edge*
†LIE = lower incisal edge

Table 8 (Cont)

Measure	Scheideman (1980)[9] (Cont) Good skeletal dental balance female		Bishara (1981)[10] Male adult acceptable occlusion		Casko (1984)[5] Mixed adults ideal occlusion		Peck and Peck (1970)[8] 52 adults (49 female, 3 male) publicly acceptable faces		Bolton sample (1975)[11] Good faces and good occlusion at age 18			
									Male (n = 16)		Female (n = 16)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cranial base												
SN-FH (°)	9.2	3.6										
S-N (mm)	73.5	3.6							75.4	2.52	70.1	2.96
N-Ba (mm)	109.0	5.2										
S-Ba (mm)	46.4	2.8							48.1	3.27	44.9	2.77
Maxillary skeletal												
SNA (°)	82.6	3.6	82	3.7			82.4	2.9	84.0	2.92	83.9	1.92
Angle convex (°)	2.0	4.7	3	6.1			3.4	3.3	175.8	2.28	176.5	2.10
SN-PP	7.0	3.5										
Mandibular skeletal												
SNB (°)	80.1	3.0	80	3.7			79.8	2.7	81.0	3.22	81.4	1.96
Facial angle (°)	90.8	3.0	86	4.5	87.9	3.6	85.7	2.8	87.6	2.47	87.9	2.79
FH-MP (°)	22.9	5.2	23	7.4	23.7	4.7	23.9	4.6	23.8	4.51	23.9	3.16
SN-MP (°)	30.3	4.7	28	7.2	29.2	5.7	29.5	4.2	28.6	4.39	28.9	2.65
Gonial angle (°)	126.5	5.0							124.9	4.34	124.8	3.87
Facial axis (°)	89.8	3.4										
Art-Go (mm)	47.1	4.8	60	6.4					52.1	2.89	47.7	2.88
Go-Po (mm)	80.6	4.0							82.7	3.55	76.9	3.62
Art-N (mm)	96.6	5.0							100.8	3.29	92.6	3.44
Intermaxillary												
ANB (°)	2.5	1.8	2.0	2.4	1.9	2.1	2.6	1.5	3.0	1.54	2.5	1.23
PP-MP (°)	25.0	4.2							20.0	5.05	21.3	2.65
Dental												
U1-L1 (°)	132.9	8.4	134	9.8	126.2	9.7	133.5	8.2	141.3	8.15	139.8	8.38
U1-SN (°)	101.7	5.4	102	6.3	107.4	5.9			99.6	6.58	100.7	4.76
U1-FH (°)												
U1-NA (°)	19.1	6.1					21.6	6.7	15.6	5.8	16.8	5.49
U1-NA (mm)	3.9	2.2					5.0	2.1	2.6	1.4	2.7	1.8
U1-APo (mm)	1.3	2.0	4.0	1.9					3.2	0.5	3.4	1.5
UIE*-ANS (mm)	29.4	1.5										
IMPA (°)	95.6	6.7	96.0	9.2	96.8	6.0	94.9	4.2	90.7	6.32	90.5	5.36
L1-NB (°)	25.5	5.3					23.7	5.4	20.3	5.26	20.8	4.76
L1-NB (mm)	4.0	1.8	4	2.5			5.1	1.6	3.4	1.7	3.3	1.4
FMIA (°)			62.0	10.1	59.8	6.6						
L1-APo (°)												
L1-APo (mm)	4.7	1.8			2.2	2.1						
LIEt-Me (mm)	40.3	2.4										
Overjet (mm)	3.7	0.9										
Overbite (mm)	3.8	1.6										
OP-PP (°)	8.4	4.3										
SN-OP (°)	13.2	4.5					13.5	3.5	12.2	3.92	13.5	2.52
Vertical												
AFH (N-Me:mm)	119.8	4.5	122	6.0					124.7	5.05	114.8	4.83
UFH (N-ANS;mm)	54.1	2.9	54	2.9					57.0	2.55	51.6	2.1
LFH (ANS-Me;mm)	67.2	3.4							67.7	4.63	63.2	4.31
UFH/LFH	0.81	0.05										

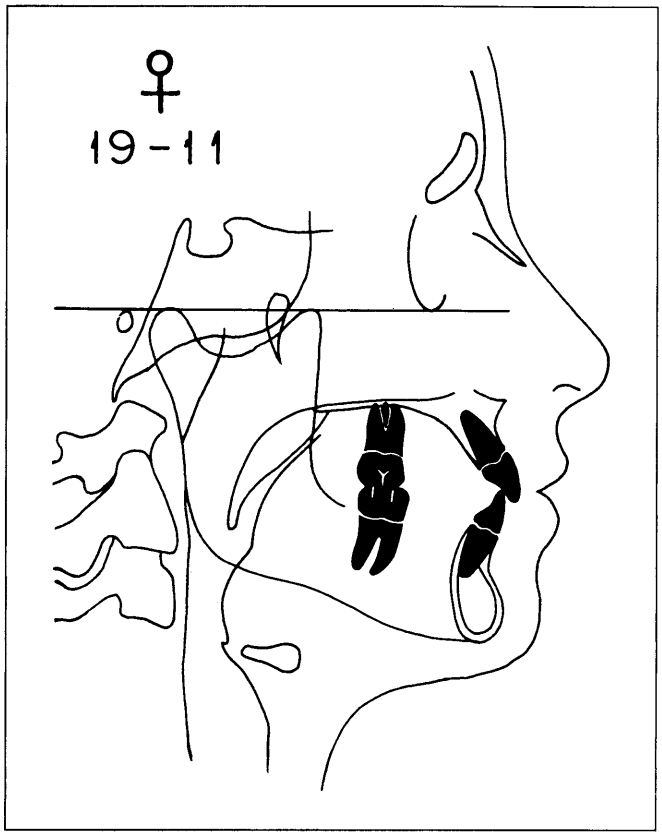

Fig 1 Tracing of a female with mandibular protrusion and a decrease in lower facial height (point A to Na ⊥ = 3.8 mm; facial angle = 93.6°; MP-FH = 18.4°; ANB = 2.2°; UFH/LFH = .87; U1-FH = 118°; IMPA = 95.7°).

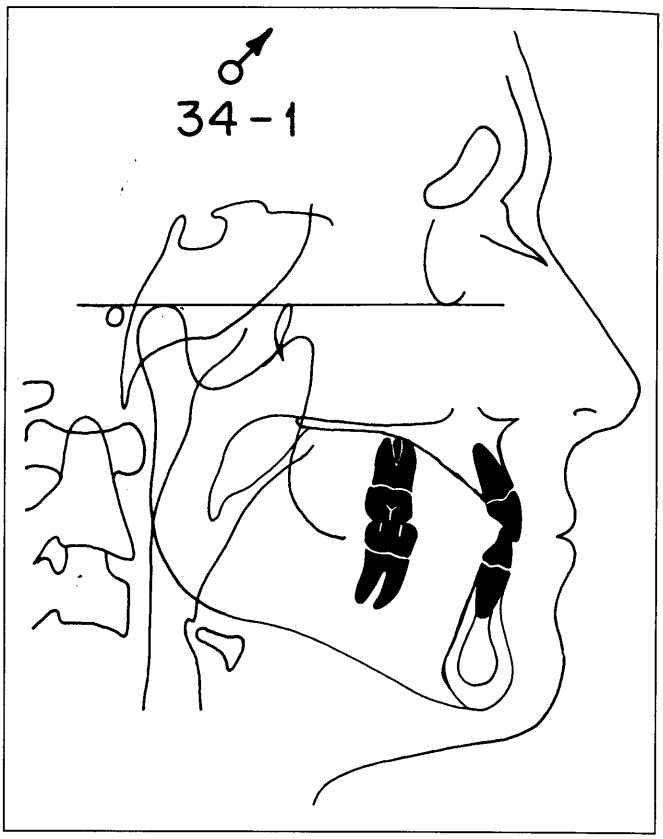

Fig 2 Tracing of a male with mandibular protrusion and retroclined mandibular incisors (point A to Na ⊥ = −.95 mm; facial angle = 91.5°; MP-FH = 20.7°; ANB = −.85°; UFH/LFH = .75; U1-FH = 110.2°; IMPA = 81.1°).

Results

Mean values, standard deviations, and significance of difference between males and females are listed in Tables 1 to 6. Significant positive and negative correlations with six specific measurements are shown in Table 7. Because it is beyond the scope of this paper to discuss each variable, the discussion will be limited to a comparison of a few frequently used measures between this sample and samples published previously (Table 8), and to a discussion of the results of the correlations.

Discussion

An overview of the results shows that most of the significant differences between male and female variables are those using linear measurements. When angles or ratios are used, many variables do not significantly differ between male and female samples. This indicates that in individuals with ideal occlusal and facial relationships, the dentoskeletal variables between males and females are similar except in size, where males tend to be larger.

The results of the mandibular skeletal, intermaxillary, dentoalveolar, and vertical relationships in this study do not differ greatly from previously published norms. This is of particular interest because the criteria for inclusion of a subject has varied in most studies. Even though our inclusion criteria were more restrictive than previous studies, only minor differences were noted in the results. These few differences are probably based on the nature of the individuals included in the samples.

A glance at published norms finds that

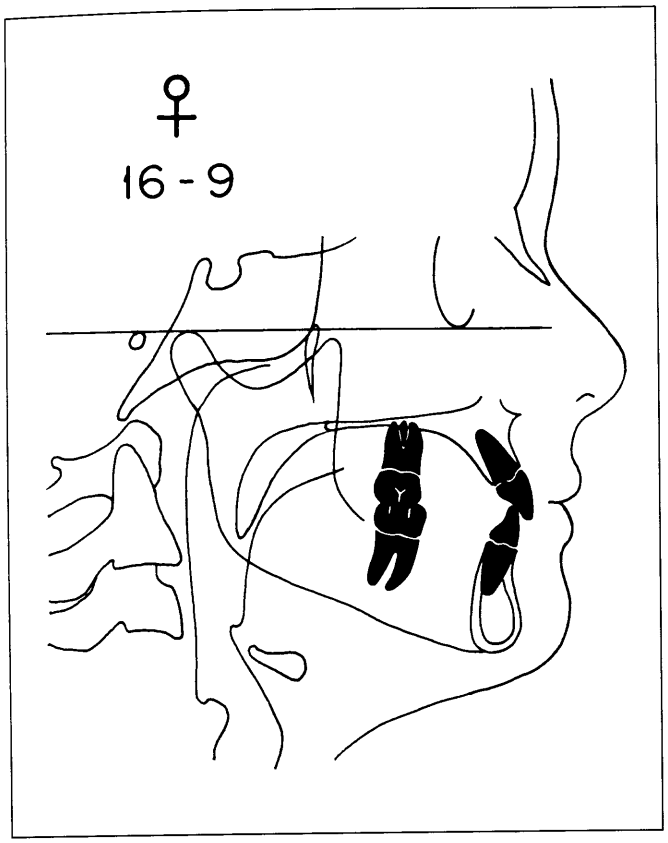

Fig 3 Tracing of a female with maxillary retrusion (point A to Na ⊥ = −3.6 mm; facial angle = 90.2°; MP-FH = 20.4°; ANB = −1.56°; UFH/LFH = .88; U1-FH = 120.2°; IMPA = 87.8°).

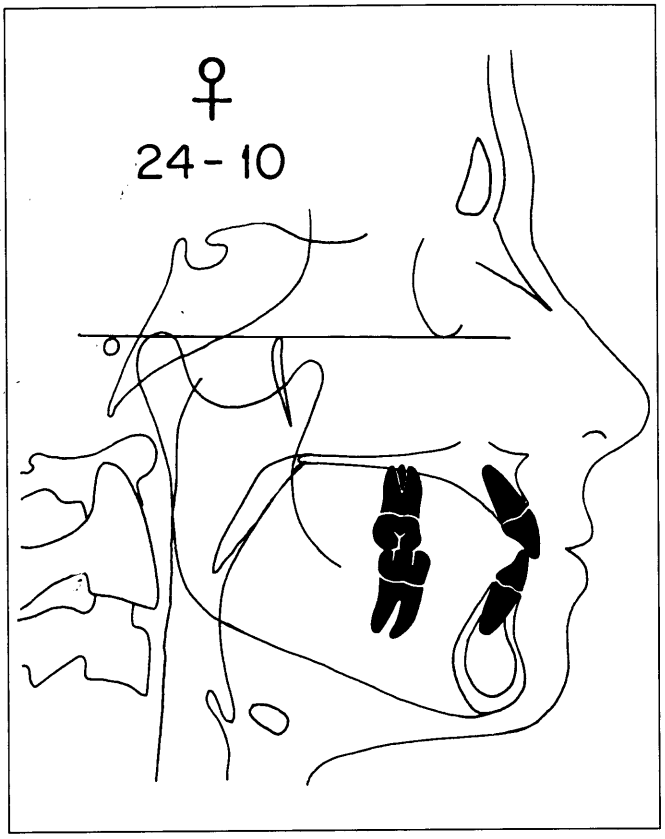

Fig 4 Tracing of a female with bimaxillary protrusion (point A to Na ⊥ = 5.9 mm; facial angle = 94.4°; MP-FH = 19.3°; ANB = 2.4°; UFH/LFH = .89; U1-FH = 117.4°; IMPA = 94.1°).

the most frequently employed variable for measuring maxillary position is the sella-nasion-point A (SNA) angle (see Table 8). Most studies have found the SNA angle to be approximately 82° in both males and females. However, the Bolton sample[11] and the sample reported in this study showed larger SNA angles, especially in males, averaging almost 2° larger than the 82° usually reported. Our study showed the SNA angle to be approximately 1.5° larger in males than females ($P < .05$). Taken in concert, the Bolton study,[11] the study by Scheideman et al (females),[9] and the present study indicate that SNA angles of 82° may be low for individuals with good to ideal faces. Whether one chooses to use larger SNA angles or not, it is clear that SNA angles of 83° to 84° should not be considered evidence of maxillary protrusion, especially in males.

Correlations of dentoskeletal variables

Data from this study show a large range in normal variation for many dental and skeletal variables in individuals with ideal occlusal and facial relationships. An evaluation of the correlations in Table 7 highlights some interesting patterns of accommodation within this sample. For instance, when the mandibular plane angle is high, pogonion is positioned more posteriorly, and there is a decrease in posterior facial height. To maintain Class I occlusal relationship, the mandibular incisor is more retroclined in relation to the mandible (IMPA). Similarly, when the ANB angle is low, the maxilla is more retrusive and the mandibular plane angle is lower. When the mandible is protrusive (as shown by the facial angle), the maxilla and the maxillary incisor are more protrusive.

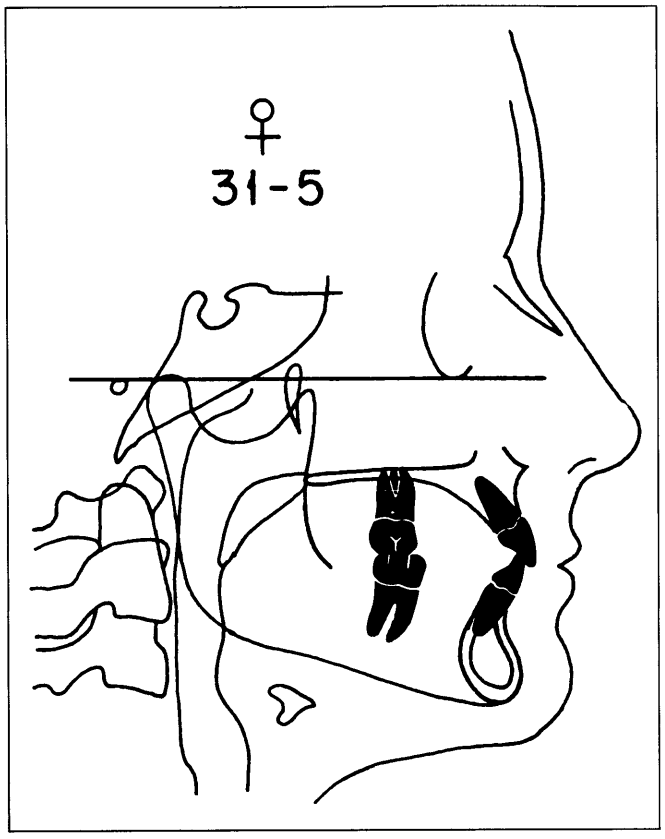

Fig 5 Tracing of a female with a low mandibular plane angle, mandibular protrusion, and decreased lower anterior facial height (point A to Na ⊥ = 1.7 mm; facial angle = 91.8°; ANB = 2.4°; UFH/LFH = .92; U1-FH = 119.3°; IMPA = 101.8°).

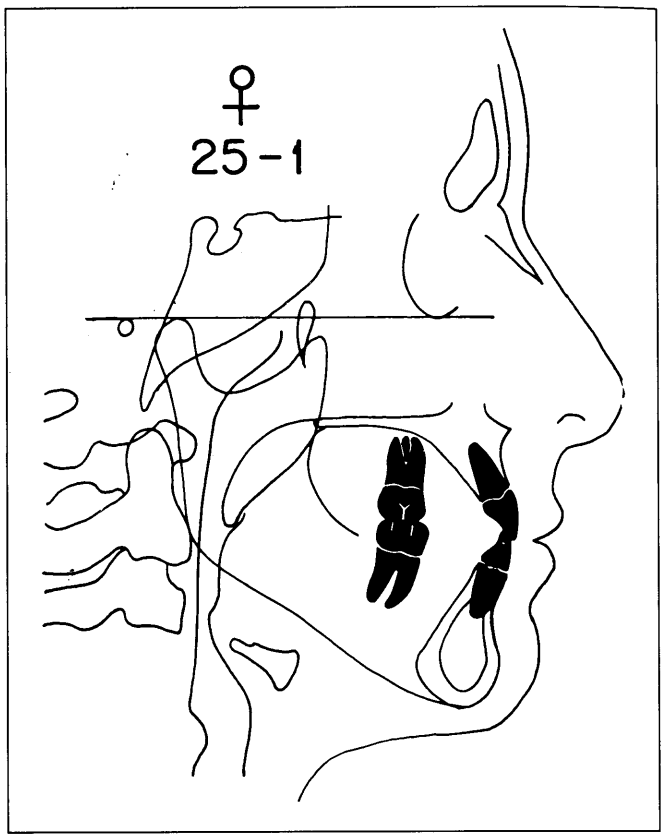

Fig 6 Tracing of a female with a high mandibular plane angle (point A to Na ⊥ = −.1 mm; facial angle = 89.9°; MP-FH = 30.0°; ANB = 1.29°; UFH/LFH = .79; U1-FH = 113°; IMPA = 82.8°).

From these findings, it is clear that a wide range of dental and skeletal relationships exists, which, in the appropriate combination, results in an ideal Class I occlusal relationship in a well-balanced face. To highlight this point, several individuals who had at least one dental or skeletal variable far removed from the mean were selected from the sample. Figure 1 is the tracing of a female who demonstrates bimaxillary protrusion and a decrease in lower anterior facial height with normal dental position. Figure 2 is the tracing of a male who demonstrates mandibular protrusion and a low ANB angle. In order to maintain a Class I dental relationship, the mandibular incisors are retroclined. Figure 3 is the tracing of a female who demonstrates maxillary retrusion and a low ANB angle. Dental compensations to this skeletal pattern include maxillary incisor protrusion and mandibular incisor retrusion. Figure 4 is the tracing of a female who demonstrates bimaxillary protrusion and a decrease in lower facial height with normal dental relationships. Figure 5 is the tracing of a female who has an extremely low mandibular plane angle and a low facial height with bialveolar protrusion. Figure 6 is the tracing of a female who has a very high mandibular plane angle. To compensate, the mandibular incisors are retroclined.

Conclusions

This study presents dentofacial norms for males and females with "ideal" occlusal and facial relationships. It should be stressed that in each individual, infinite combinations of dentoskeletal relationships are possible to arrive at a face that is well balanced with an

occlusal relationship that is ideal. The purpose of establishing cephalometric norms, therefore, should not be to create "targets" for individual treatment but to have guides for the clinical assessment of the patient. The final diagnosis and treatment plan must rely on a number of other factors that are beyond the information obtained from a radiograph.

Acknowledgments

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