Morphology and growth in convex profile facial patterns: A longitudinal study

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Abstract: Two groups of females, one with normal anteroposterior jaw-base relationships and the other with distal jaw-base relationships, were selected at age 6 and compared longitudinally up to age 18. The purposes of this study were, first, to reveal morphological factors that caused or contributed to a distal jaw-base relationship, and second, to compare growth in the two groups. A distal jaw-base relationship is not a morphological entity caused by some specific aberration in the cranial base or jaws. Rather, it is the result of a combination of predisposing deviations with varying degrees of gravity. A short mandibular corpus and a large MP-SN angle were the only deviations with significant group differences. Distal jaw-base relationships generally worsened with age as compared with normal anteroposterior jaw-base relationships. Inadequate increase in mandibular corpus length in the 6- to 12-year period contributed to the worsening, as did the mandible growing more vertically than normal after age 12.

Key Words: Cephalometrics, Longitudinal, Convex profile, Distal jaw-base relationship, Females

Björk[1] stated that the shape of the facial profile depends upon the relationship between the prognathism of the jaws. He found that prognathism increased during the growth period due to the greater percentage increase in jaw length compared with cranial base. Because prognathism increased more in the mandible than in the maxilla, the facial profile straightened.

Lande[2] studied growth change of the bony facial profile longitudinally. He reported that the mandible tended to become more prognathic in relation to the brain case, whereas maxillary prognathism changed very little over time.

McNamara[3] presented composite norms of growth determined by arbitrarily combining average values of the Burlington, Bolton, and Ann Arbor samples. The anteroposterior growth movements of A-point and pogonion were evaluated in relation to a perpendicular to the Frankfort horizontal plane, extended inferiorly from nasion. Between ages 6 and 18, A-point moved forward relative to the nasion perpendicular by only 1 mm. In contrast, pogonion moved forward an average of 0.5 mm every year during that same period.

McNamara's standards were based on normal samples. Do those standards also hold true for distal jaw-base relationships, or will such aberrations change with age compared with normal jaw-base relationships? Lande[2] suggested that normal and so-called "unesthetic" facial patterns grow alike, i.e., the retrognathic juvenile face does not tend to become more retrognathic with age. That observation, however, was based on a rather moderate range of facial types.

Some researchers have reported that a distal jaw-base relationship at a juvenile age quite often improves with time. Kerr and Hirst[4] thus performed longitudinal comparisons between subjects with Class I and Class II occlusal relationships. A considerable number (17%) who exhibited Class II occlusal and skeletal characteristics at age 5 developed normal occlusal and skeletal characteristics by age 15. A smaller number (9%) moved in the opposite direction.

Pancherz, Zieber, and Hoyer[5] studied Class II malocclusion cross-sectionally. In subjects with Class II Division 1 (Class II-1), mandibular skeletal retrusion was less frequent in 11- to 13-year-olds than in 8- to 10-year-olds. In Class II Division 2 subjects, no such age-related difference was noted. Improvement of the mandibular skeletal retrusion in Class II-1 subjects was

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attributed to normal mandibular growth. In Class II-2 subjects, the retroclined maxillary incisors in combination with a deepbite possibly restricted the mandible to extend anteriorly.

In the present study, two groups of females were compared longitudinally from 6 to 18 years of age. Subjects in one group had normal anteroposterior jaw-base relationships, whereas those in the other group had distal jaw-base relationships. Both groups had acceptable occlusions during the observation period. The purposes of the study were, first, to define morphological characteristics that caused or contributed to a distal jaw-base relationship, and, second, to discover whether faces of the two groups grew differently.

Materials and methods

The material consisted of lateral cephalograms selected from the Oslo Growth Material, University of Oslo Department of Orthodontics. This material (n=2167) is based on six age classes from the county of Nittedal, near Oslo, Norway. In collecting the Oslo Growth Material, lateral cephalograms were taken, with the teeth in occlusion, every third year from early childhood to adulthood. Subjects in need of orthodontic treatment at 12 years of age were excluded from further registration. Therefore, subjects with cephalograms available after that age generally had acceptable occlusal conditions.

None of the subjects selected in the present study received orthodontic treatment. Selection criteria were based on the anteroposterior jaw-base relationship at 6 years of age. The anteroposterior jaw-base relationship was defined as the distance between the perpendicular projections from pogonion and A-point along the Frankfort horizontal plane. The distance was required to be 6-8 mm in the normal group and 11 mm or more in the distal jaw-base relationship group. Figure 1 illustrates mean group anteroposterior distances between pogonion and A-point in 6-year-olds of the two groups.

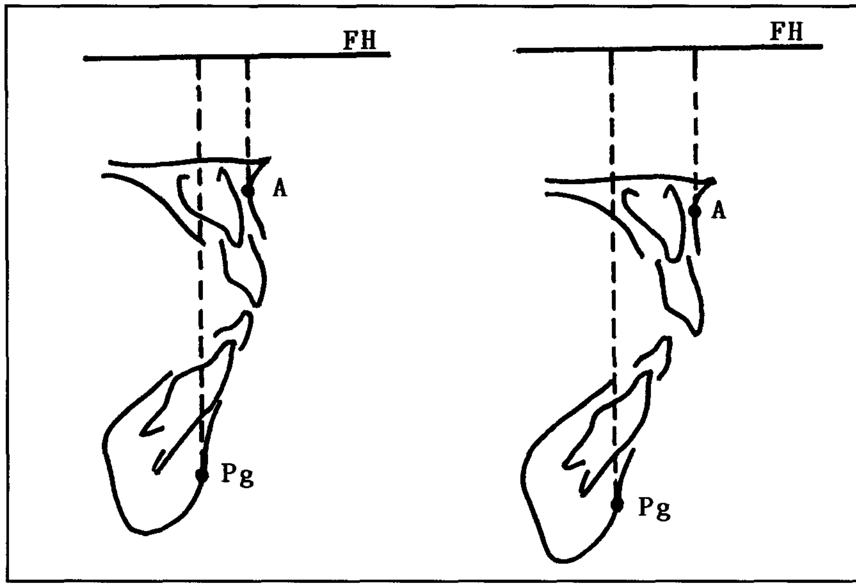

Figure 1
Selection criteria based on the anteroposterior jaw-base relationship at age 6. The distance between perpendicular lines from pogonion and A-point onto the Frankfort horizontal plane (distance PgA a-p) was required to be 6 to 8 mm in the normal group and >11 mm in the distal jaw-base relationship group. Means and standard deviations for PgA a-p were (in millimeters) 6.8 ± 0.8 in the normal group and 12.1 ± 1.2 in the distal jaw-base relationship group

It was stipulated that the data collected should be purely longitudinal. Thus, all subjects selected had a full set of lateral cephalograms taken at 6, 9, 12, 15, and 18 years of age. This criterion limited the number of cases available in the files. Just a few males were at hand, therefore, only females were included in the study. Eventually, the normal group comprised 18 individuals and the distal jaw-base relationship group 14 individuals. The sample thus included all the females in the files who met the requirements for inclusion. The two groups seemed satisfactory in size and comparable with previous longitudinal studies.[6] The advantage of purely longitudinal data over mixed and/or cross-sectional data for measuring average incremental growth has been pointed out by earlier writers.[7,8]

Analysis of craniofacial morphology and growth

Each cephalogram was traced and measured once. The set of cephalograms belonging to an individual were traced at the same sitting. Linear and angular dimensions were measured to the nearest 0.5 mm or 0.5°. The following points and lines were identified: sella (S), nasion (N), condylion (Cd), porion (Po), orbitale (Or), pterygomaxillare (Pm), spinal-point (Sp), gonion (Go), A-point, infradentale (Id), B-point, pogonion (Pg), prognathion (Pgn), gnathion (Gn), incision superius (Is), incision inferius (Ii), SN line (SN), Frankfort horizontal plane (FH), nasal plane (NP), mandibular plane (MP), ramus line (RL), chin line (CL), and A-Pg line. The points and lines have been defined before.[9,10]

It was desirable to measure anteroposterior growth along the Frankfort horizontal plane. On some cephalograms, however, accurate registration of FH was difficult. Bhatia and Leighton[11] showed that the angle between FH and the SN line changed little with growth. In 6-year-olds of the present study, group means and standard deviations for FH-SN were (in degrees) 6.9 ± 2.0 in the normal group and 7.2 ± 2.9 in the distal jaw-base relationship group. At 18 years, corresponding values were 7.0 ± 2.0 and 7.0 ± 2.7. Thus, the following procedure was established: On the cephalogram taken at age 6, FH and SN were drawn and the angle FH-SN measured and designated angle alpha (α). On subsequent cephalograms, a line was constructed through sella at an angle to SN equivalent to α. That line, designated FH estimated (FHe), was used as a substitute for FH. FHe was easily reproducible and its course was probably very near the real FH.

Figure 2 illustrates the construction of FHe. Points in the cranial base and jaws were projected perpendicularly on a line parallel to FHe. Anteroposterior distances were measured along the FHe parallel. Distances were read from left to right and marked "a-p." For example, the anteroposterior distance from pogonion to A-point was denoted PgA a-p. Other linear variables in the cranial base and jaws are shown in Figure 3, as are points and lines used in measurement of angular variables. Variables used in measurement of incisal relations are illustrated in Figure 4. Definitions of linear and angular variables appear in Table 1.

Reliability

In order to determine the extent of measurement error, the sets of cephalograms belonging to three subjects were traced and measured a second time. Using Dahlberg's formula,[12] the measurement error for a single measurement of linear and angular variables ranged between 0.2 and 0.6 mm/degrees.

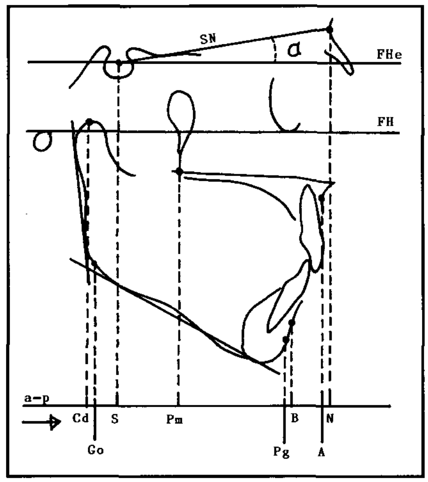

Figure 2
On the cephalogram taken at age 6, the angle FH-SN was measured and designated angle alpha (α). On subsequent cephalograms, a line was constructed through sella at an angle to SN equivalent to angle α. That line, designated FH estimated (FHe), was used as an anteroposterior reference line instead of FH. Points in the cranial base and jaws were projected onto a line parallel to FHe. Anteroposterior distances were read from left to right and marked "a-p" (variables 1-8)

Statistical analysis

Absolute and incremental group differences were tested with Student's t-test for independent samples. Differences in skeletal morphology were tested at ages 6, 9, 12, 15, and 18 years. Differences in incisal relations were tested at 9 and 18 years. Incremental differences were tested for the 6- to 12-year, 12- to 18-year, and 6- to 18-year periods. Significance level was set at $p < 0.05$. With the intention of finding whether the initial grouping variable PgA a-p would prevail as a group identifier, it was tested alone at ages 9, 12, 15, and 18 in linear discriminant analysis. Statisitical analyses were done with programs in the statistics package BMDP.[13]

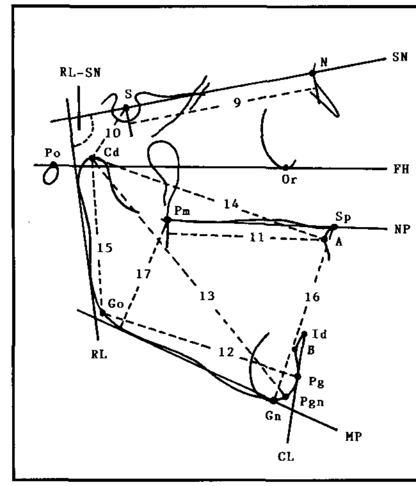

Figure 3
Linear variables in the cranial base and jaws (variables 9-17). Distance Pm-A (v. 11) was measured along the nasal plane (NP). Points and lines used in measurement of angular variables are also shown (variables 19-23)

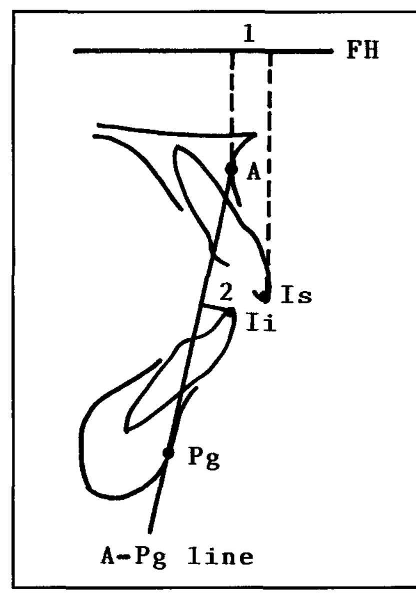

Figure 4
Incisal relationships (variables 26 and 27). The anteroposterior position of the maxillary incisors relative to maxilla was defined as the distance (measured along FH) from the incisal edge of the most prominent maxillary central incisor (Is) to A-point (1). The anteroposterior position of the mandibular incisors relative to basal structures was determined by measuring the distance from the incisal edge of the most prominent mandibular incisor (Ii) to the A-Pg line (2)

Results

Differences in morphology (Table 2)

Initial group differences in anteroposterior jaw-base relationship remained significant throughout the 6- to 18-year period (v. 1). Nearly all subjects investigated (97%) were categorized identically at 6 and 18 years of age by using distance PgA a-p as the group predictor.

Distal jaw-base relationships were characterized by a retrusive position of pogonion relative to the anterior cranial base throughout the 6- to 18-year period. Mandibular retrognathism with distal jaw-base relationships was highly significant when evaluated relative to nasion (v. 4), and also significant, but slightly less marked, when evaluated relative to sella (v. 5).

Subjects in the distal jaw-base relationship group had a significantly shorter mandibular corpus than those of the normal group. The group difference in corpus length, however, was significant only at 12 years of age and later (v. 12). The index that presents the size relationship between the corpora of the two jaws showed a significantly higher value with distal jaw-base relationships than with normals (v. 18).

Subjects with distal jaw-base relationships further distinguished themselves by an excessive lower anterior facial height, both initially at age 6 and later (v. 16). They also had a significantly larger MP-SN angle than normal (v. 21).

At 9 years of age, overjet was significantly larger in the distal jaw-base relationship group than in the normal group; at 18 years, however, overjet was pretty much the same in the two groups (v. 24). With distal jaw-base relationships, the mandibular incisors became more protruded with age. At age 18, they had a more protrusive position than normal relative to basal structures (v. 27).

Table 1
Definition of variables

Anteroposterior distances measured along FHe (Figure 2)	
1. PgA a-p	Anteroposterior jaw-base relationship. If pogonion lay anterior to A-point, the distance was given a negative value
2. AN a-p	Maxillary prognathism. If A-point lay anterior to nasion, the distance was given a negative value
3. SA a-p	Another measurement of maxillary prognathism
4. PgN a-p	Mandibular prognathism. If pogonion lay anterior to nasion, the distance was given a negative value
5. SPg a-p	Another measurement of mandibular prognathism
6. SPm a-p	Anteroposterior position of the rearmost section of the maxillary corpus relative to the anterior cranial base
7. CdS a-p	Anteroposterior position of the mandibular condyles relative to the anterior cranial base
8. GoS a-p	Anteroposterior position of the gonial area relative to the anterior cranial base. If gonion lay anterior to sella, the distance was given a negative value
Linear distances within the cranial base and jaws (Figure 3)	
9. S-N	Length of the anterior cranial base
10. Cd-S	Length of the lateral cranial base, posterior portion
11. Pm-A	Length of the maxillary corpus
12. Go-Pg	Length of the mandibular corpus
13. Cd-Pgn	Effective length of the mandible
14. Cd-A	Midfacial length
15. Cd-Go	Height of the mandibular ramus
16. Sp-Gn	Lower anterior facial height
17. Pm-MP	Lower posterior facial height
18. Pm-A/Go-Pg·100	Size relationship between the corpora of the two jaws
Angles (Figure 3)	
19. Cd-S-N	Lateral cranial base angle (saddle angle)
20. NP-SN	Inclination of the nasal plane
21. MP-SN	Inclination of the mandibular plane
22. MP-RL	Gonial angle
23. RL-SN	Inclination of the mandibular ramus
Incisal relations (Figure 4)	
24. Overjet	
25. Overbite	
26. is-A	Anteroposterior position of the maxillary incisors relative to the maxillary corpus
27. ii-A/Pg	Anteroposterior position of the mandibular incisors relative to basal structures

Differences in incremental growth (Table 3)

The anteroposterior distances between pogonion and A-point (PgA a-p) and between pogonion and nasion (PgN a-p) decreased with age in both groups, but to a lesser degree with distal jaw-base relationships than with normals. Group differences in decrease of PgA a-p and PgN a-p were significant for the 12- to 18- year period and for the 6- to 18- year period as a whole (v. 1, 4).

The anteroposterior distance between sella and pogonion increased in both groups, but less so in the distal jaw-base relationship group. The group difference was significant only for the 6- to 18-year period as a whole (v. 5).

In the 6- to 12-year period, the anteroposterior distance between condylion and sella (CdS a-p) increased significantly most in the normal group. In the following period up to age 18, quite the reverse happened when CdS a-p increased significantly most in the distal jaw-base relationship group (v. 7).

The anterior cranial base length (distance S-N) increased more in

Table 2
Morphological differences between the two groups tested using Student's *t*-test. Skeletal differences tested at ages 6, 9, 12, 15, and 18 years, differences in incisal relations tested at ages 9 and 18. Standardized enlargement 5.6%

	6 yrs		9 yrs		12 yrs		15 yrs		18 yrs	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1. PgA a-p (mm)										
Normal	6.8	0.8	4.8	1.1	2.9	1.8	0.8	2.1	-0.4	2.3
Distal	12.1	1.2	9.9	1.5	9.1	1.4	8.3	2.2	7.5	2.4
p-value	0.000xxx		0.000xxx		0.000xxx		0.000xxx		0.000xxx	
2. AN a-p (mm)										
Normal	0.6	1.9	0.6	2.1	0.3	2.1	0.0	2.0	-0.1	2.0
Distal	-0.7	2.0	-0.3	2.0	-0.6	1.9	-0.9	2.1	-1.0	2.2
p-value	0.08		0.21		0.20		0.22		0.24	
3. SA a-p (mm)										
Normal	62.2	2.2	64.6	2.5	67.3	2.8	68.9	2.8	69.3	2.8
Distal	63.8	2.8	66.0	3.1	68.6	3.2	70.4	3.3	70.9	3.4
p-value	0.09		0.18		0.24		0.18		0.17	
4. PgN a-p (mm)										
Normal	7.1	2.1	5.3	2.6	3.0	3.0	0.6	3.1	-0.5	3.0
Distal	11.4	2.5	9.9	2.4	8.5	2.3	7.4	3.5	6.4	3.7
p-value	0.000xxx		0.000xxx		0.000xxx		0.000xxx		0.000xxx	
5. SPg a-p (mm)										
Normal	55.5	2.6	60.0	3.2	64.3	4.2	68.1	4.1	69.6	4.2
Distal	51.9	3.6	56.3	3.6	59.2	4.0	62.0	5.1	63.4	4.9
p-value	0.004xx		0.005xx		0.001xxx		0.001xxx		0.000xxx	
6. SPm a-p (mm)										
Normal	20.3	1.6	21.1	1.8	21.1	2.1	21.3	2.4	21.0	2.5
Distal	20.6	2.7	21.1	2.5	20.8	2.6	21.2	2.7	21.2	3.0
p-value	0.77		0.98		0.70		0.94		0.85	
7. CdS a-p (mm)										
Normal	10.4	2.0	11.6	2.7	12.8	3.1	13.3	3.1	13.5	3.2
Distal	11.0	1.8	12.0	2.0	12.5	2.1	13.6	2.0	13.9	2.1
p-value	0.37		0.67		0.79		0.70		0.71	
8. GoS a-p (mm)										
Normal	2.4	1.5	3.9	2.0	4.2	2.9	4.8	3.4	5.0	3.9
Distal	4.3	4.1	4.5	4.3	5.5	4.5	6.4	4.9	6.6	5.1
p-value	0.13		0.59		0.37		0.31		0.34	
9. S-N (mm)										
Normal	63.4	2.0	65.8	2.2	68.0	2.2	69.3	2.5	69.4	2.4
Distal	63.3	2.1	66.1	2.4	68.4	2.6	70.1	2.4	70.4	2.3
p-value	0.88		0.75		0.66		0.32		0.23	
10. Cd-S (mm)										
Normal	20.3	1.8	21.9	2.3	23.9	2.9	24.8	2.9	25.1	3.0
Distal	19.5	2.7	21.4	3.2	22.1	3.5	23.7	3.1	24.0	3.2
p-value	0.37		0.62		0.14		0.33		0.35	
11. Pm-A (mm)										
Normal	42.2	1.8	43.8	2.0	46.4	1.8	48.0	2.7	48.4	2.5
Distal	43.1	2.5	44.8	2.5	47.8	3.4	49.4	3.0	49.8	3.0
p-value	0.23		0.24		0.20		0.18		0.19	
12. Go-Pg (mm)										
Normal	61.4	2.9	67.2	3.0	72.3	3.8	76.2	3.2	77.2	3.5
Distal	60.3	4.1	65.0	4.3	69.2	4.5	72.8	4.8	74.0	4.9
p-value	0.40		0.12		0.04x		0.03x		0.05x	
13. Cd-Pgn (mm)										
Normal	93.2	3.3	100.9	3.1	108.2	4.1	113.6	3.6	115.1	3.8
Distal	92.9	3.8	100.0	4.5	106.6	5.3	111.8	5.2	114.1	5.1
p-value	0.83		0.52		0.37		0.28		0.54	
14. Cd-A (mm)										
Normal	76.1	2.7	80.0	2.7	84.1	3.0	86.4	2.8	86.9	2.9
Distal	78.0	3.0	81.8	3.3	85.5	3.6	88.4	3.3	88.9	2.9
p-value	0.08		0.12		0.26		0.08		0.06	
15. Cd-Go (mm)										
Normal	43.4	2.2	47.5	2.3	51.3	2.5	55.3	3.3	56.8	3.3
Distal	43.3	2.2	47.5	2.9	51.2	3.0	55.0	3.4	56.7	3.7
p-value	0.93		0.97		0.93		0.76		0.96	

Table 2, cont.

Variables	6 yrs Mean	SD	9 yrs Mean	SD	12 yrs Mean	SD	15 yrs Mean	SD	18 yrs Mean	SD
16.Sp-Gn (mm)										
Normal	54.4	2.5	56.9	2.6	59.4	3.4	61.3	3.5	61.9	3.5
Distal	57.7	3.5	60.3	3.7	62.9	4.5	65.9	4.5	66.9	4.7
p-value	0.007xx		0.008xx		0.02x		0.004xx		0.003xx	
17.Pm-MP (mm)										
Normal	35.1	2.1	37.7	2.2	40.0	2.3	43.4	3.0	44.7	3.2
Distal	35.6	2.7	38.4	3.4	40.0	3.9	43.7	4.2	45.3	4.6
p-value	0.61		0.49		0.96		0.84		0.72	
18.Pm-A/Go-Pg · 100										
Normal	68.8	3.6	65.2	3.1	64.3	3.5	63.1	3.7	62.8	3.5
Distal	71.8	4.2	69.0	3.6	69.1	4.1	68.0	4.3	67.4	4.5
p-value	0.04x		0.004xx		0.001xxx		0.001xxx		0.004xx	
19.Cd-S-N (°)										
Normal	128.0	6.7	128.4	7.1	128.7	6.8	128.9	6.6	129.1	6.8
Distal	131.9	6.4	131.9	6.5	132.1	6.5	132.0	5.9	132.4	5.9
p-value	0.10		0.16		0.16		0.18		0.15	
20.NP-SN (°)										
Normal	8.0	2.1	7.6	2.3	7.6	2.5	7.6	2.6	7.6	2.8
Distal	7.8	2.7	7.9	2.9	7.7	3.0	8.1	3.3	7.9	3.5
p-value	0.86		0.80		0.90		0.67		0.80	
21. MP-SN (°)										
Normal	32.3	2.1	30.4	2.4	28.9	2.3	26.6	2.8	25.7	3.2
Distal	35.9	5.7	34.3	5.6	33.3	5.8	32.1	6.1	30.7	6.3
p-value	0.03x		0.02x		0.01xx		0.006xx		0.01xx	
22.MP-RL (°)										
Normal	128.1	3.7	125.1	4.6	123.3	4.4	120.0	5.1	118.9	5.5
Distal	130.3	6.5	127.9	7.0	126.1	7.7	124.2	8.0	122.3	8.2
p-value	0.26		0.22		0.25		0.10		0.20	
23.RL-SN (°)										
Normal	84.0	3.0	85.2	3.3	85.8	4.0	86.6	4.1	86.8	4.6
Distal	85.6	5.2	86.8	5.2	88.0	5.3	88.5	5.7	89.1	5.7
p-value	0.29		0.32		0.21		0.29		0.23	
24.Overjet (mm)										
Normal			3.0	0.6					3.3	0.8
Distal			3.9	1.1					3.5	1.1
p-value			0.01xx						0.61	
25.Overbite (mm)										
Normal			3.5	1.2					3.7	0.9
Distal			3.2	2.5					3.9	1.4
p-value			0.69						0.60	
26.is-A (mm)										
Normal			2.6	1.4					4.3	1.4
Distal			2.3	1.5					3.4	1.9
p-value			0.52						0.19	
27.ii-A/Pg line (mm)										
Normal			1.7	0.8					1.4	1.4
Distal			2.4	1.4					3.0	1.5
p-value			0.11						0.003xx	

xxx $p \leq 0.001$ xx $p \leq 0.01$ x $p \leq 0.05$

the distal jaw-base relationship group than in the normal group. The difference was significant only for the 6- to 18-year period as a whole (v. 9).

In the 6- to 12-year period, the length of the mandibular corpus increased significantly less in the distal jaw-base relationship group than in the normal group. The group difference in corpus growth was also significant for the 6- to 18-year period as a whole (v. 12). As for vertical skeletal relations, lower anterior facial height increased significantly most with distal jaw-base relationships after the age of 12 (v. 16).

Overjet generally decreased with age in distal jaw-base relationships but remained fairly unchanged in normals. The group difference in growth change of overjet was significant for the 12- to 18-year period and for the 6- to 18-year period as a whole (v. 24).

Discussion

Stipulation of selection criterion

Previous reports on the craniofacial pattern associated with a distal jaw-base relationship are usually confined to studies of Class II malocclusion. In the present study, however, selection criteria were based on skeletal, not dental, characteristics. According to standards of normal growth worked out by McNamara,[3] A-point in mixed dentition subjects lies on a perpendicular to FH extended inferiorly from nasion. Pogonion, on the other hand, lies 6 to 8 mm posterior to the nasion perpendicular. When stipulating the criterion for inclusion in the normal group, the mentioned norms were guidelines. Admittedly, most 6-year-olds of the normal group had not yet reached the mixed dentition stage, but they were about to do so.

Comparison of skeletal morphology (Table 2)

Theoretically, a distal jaw-base relationship may be due to maxillary skeletal protrusion, mandibular skeletal retrusion, or both. In the present study, there was no significant group difference in maxillary prognathism (v. 2, 3), but a highly significant difference in mandibular prognathism (v. 4, 5). Obviously, distal jaw-base relationships for the most part were accompanied by mandibular skeletal retrusion. The present study thus supports previous writers who have found mandibular skeletal retrusion to be a characteristic feature of Class II-1 malocclusion,[14-24] and not those who have reported maxillary skeletal protrusion to be typical of Class II-1.[25-27]

According to Table 2, significant group differences mainly involved the skeletal profile. Significant differences were sparse in the more posterior parts of the craniofacial complex, indicating that the craniofacial patterns associated with a distal jaw-base relationship varied widely. Apparently, distal jaw-base relationships were not a single and homogeneous entity caused by some major and specific aberration in the cranial base or jaws. Rather, distal jaw-base relationships seemed to be the result of a number of deviations that acted together and significantly affected the anteroposterior relationship between the jaw bases. Previous writers have suggested that slight changes in more than one variable can have an additive effect that influences the overall result of growth.[8,28,29]

Some writers have found that Class II-1 malocclusions are generally accompanied by a short mandibular corpus.[15,18,24,30] In distal jaw-base relationships of the present study, the mandibular corpus was significantly shorter than normal only at 12 years and later (v. 12). The findings thus accord with Nelson and Higley,[15] who reported that the mandibular corpus in Class II-1 females was significantly shorter than normal in age group 11 to 14 years, not in age group 7 to 10 years. A deficiency in mandibular size with the present distal jaw-base relationships solely involved the corpus, not the ramus, which was about the same in the two groups (v. 15).

The index that presents the size

Table 3
Group differences in incremental growth tested with Student's *t*-test. Only variables with significant group difference are listed. Standardized enlargement 5.6%

Variables	6 -12 yrs Mean	SD	12 - 18 yrs Mean	SD	6 - 18 yrs Mean	SD
1. PgA a-p (mm)						
Normal	-3.9	1.9	-3.2	1.8	-7.2	2.6
Distal	-3.0	1.7	-1.6	1.6	-4.6	2.8
p-value	0.16		0.01xx		0.01xx	
4. PgN a-p (mm)						
Normal	-4.1	2.2	-3.6	2.0	-7.6	3.0
Distal	-2.9	1.8	-2.1	1.8	-5.0	3.1
p-value	0.10		0.04x		0.02x	
5. SPg a-p (mm)						
Normal	8.8	3.4	5.3	2.8	14.1	3.8
Distal	7.3	2.4	4.2	1.9	11.5	2.7
p-value	0.15		0.20		0.03x	
7. CdS a-p (mm)						
Normal	2.4	1.4	0.8	0.5	3.1	1.5
Distal	1.5	0.8	1.4	0.8	2.9	0.7
p-value	0.03x		0.02x		0.54	
9. S-N (mm)						
Normal	4.6	1.0	1.4	0.9	6.0	0.9
Distal	5.1	1.5	2.1	1.3	7.2	1.1
p-value	0.30		0.12		0.004xx	
12. Go-Pg (mm)						
Normal	10.9	2.1	4.9	1.9	15.8	2.2
Distal	8.9	1.4	4.8	2.2	13.8	2.1
p-value	0.002xx		0.96		0.01xx	
16. Sp-Gn (mm)						
Normal	4.9	1.7	2.6	1.3	7.5	1.9
Distal	5.2	1.7	4.0	1.6	9.2	2.3
p-value	0.70		0.01xx		0.03x	
24. Overjet (mm)						
Normal	0.5	1.2	0.0	0.7	0.5	1.4
Distal	-0.1	1.1	-0.5	0.7	-0.6	1.3
p-value	0.14		0.04x		0.02x	

xx $p \leq 0.01$ x $p \leq 0.05$

relationship between the corpora of the two jaws indicates how moderate deviations in two variables can have a synergistic effect on growth. At ages 6 and 9, a slightly longer maxillary corpus and a slightly shorter mandibular corpus than normal (v. 11, 12) acted synergistically on the index value so that a significant variation from normal occurred (v. 18). The deviations in length of the maxillary and mandibular corpora probably acted synergistically on the anteroposterior jaw-base relationship as well.

Aside from a short mandibular corpus (v. 12) and a slightly longer maxillary corpus than normal (v. 11), subjects with distal jaw-base relationship generally exhibited a number of nonsignificant deviations or trends predisposing to a distal relationship between the jaws. They had a relatively large midfacial length (v. 14), which predisposed to maxillary skeletal protrusion. Further, they had a relatively obtuse cranial base angle (v. 19), a somewhat vertical course of the mandibular ramus (v. 23), and a slightly retrusive position of gonion (v. 8), which were all deviations predisposing to mandibular skeletal retrusion. Finally, distal jaw-base relationships were attended by an excessive MP-SN angle, causing mandibular growth to be directed less horizontally than normal (v. 21).

The aforementioned deviations represent average values. Individually, the value of variables predisposing to a distal jaw-base relationship (v. 8, 11, 12, 14, 19, 21, 23) showed broad variation. To get some idea of the frequency of appearance of variable values beyond the average normal range (average normal value ± 1 standard deviation[31]), each member of the distal jaw-base relationship group was examined separately at age 12. Every member of the group had at least one extreme variable value predisposing to a distal jaw-base relationship, the most common ones being a deficiency in mandibular corpus length, an excessive maxillary corpus length, and a very large MP-SN angle. Only one subject, however, had all three in combination.

With distal jaw-base relationships, the vertical direction of mandibular corpus growth contributed not only to mandibular skeletal retrusion, it also gave rise to an excessive development of the lower anterior facial height (v. 16). In an earlier study,[24] a distinction was drawn between the craniofacial patterns associated with Class II-1 with deepbite and Class II-1 without deepbite. Class II-1 deepbites were accompanied by a normal or slightly deficient lower anterior facial height. Class II-1 nondeepbites, on the other hand, were attended by excessive lower anterior facial height and a steep mandibular plane. Those features of Class II-1 nondeepbites also characterized the distal jaw-base relationships of the present study. Possibly, some distal jaw-base relationships with deepbites were excluded from the Oslo Growth Material at age 12 because they needed orthodontic treatment. In theory, such an early exclusion of Class II-1 deepbites could explain why so few distal jaw-base relationships of the present study were associated with a normal or deficient lower anterior facial height.

Some writers, however, have reported long anterior facial height to be a common feature of Class II malocclusion.[14,23] McNamara[23] thus concluded that Class II was not a single clinical entity, but the result of numerous combinations of components. Broad variation was found in his sample, the most common findings being mandibular skeletal retrusion and excessive lower anterior facial height. Those conclusions for Class II also are appropriate for the present sample of distal jaw-base relationships.

Incisal relations (Table 2)

In the distal jaw-base relationship group, both overjet and overbite were normal at 18 years of age (v. 24, 25). Normal incisal relations occurred partly because the mandibular incisors became more protruded with age (v. 27). Protrusion of the mandibular incisors thus compensated for the distal relationship between the jaw bases.

Class II-1 malocclusions are usually reported to be associated with protruded maxillary incisors.[14,16,19] With distal jaw-base relationships, however, the maxillary incisors were in a normal position anteroposteriorly relative to A-point (v. 26). The position of the maxillary incisors was probably influenced by the lower lip. Nearly all subjects in the distal jaw-base relationship group (13 subjects out of 14) had competent lip morphology, with the lower lip covering between 3 mm and 6 mm of the labial surfaces of the maxillary incisors. Most likely, the lower lip thereby stabilized the position of the maxillary incisors and prevented them from proclining (Figure 5). Perhaps the distal jaw-base relationship also enabled the lower lip to have a certain retroversive effect on the maxillary incisors. Such an idea would be along the lines of Hovell,[32] who maintained that the influence of soft tissue morphology on the dental structures should always be evaluated in light of the underlying skeletal relationships. That the lower lip, by virtue of its morphology, can exert retroversive forces on the maxillary incisors previously has been asserted by Nicol.[33]

Comparison of incremental growth (Table 3)

The length of the anterior cranial base increased more in the distal jaw-base relationship group than in the normal group. The incremental group difference was significant only for the 6- to 18-year period as a whole. Seemingly, minor group differences in increase of anterior cranial base length in the 6- to 12-year and 12- to 18-year periods had an additive effect on the incremental difference for the entire observation period (v. 9).

According to Björk,[34] the progressive increase in length of the anterior cranial fossa during childhood is the result of sutural growth displacing the frontal bone as a whole in an anterior direction. The extension of the anterior cranial fossa, however, gradually ceases around the age of 10. Thereafter, the continued growth of the upper facial structures is compensated by appositional growth of the bone in the glabella region.

The present findings indicate that extension of the anterior cranial fossa in childhood and the subsequent bone apposition in the glabella region were somewhat greater in the distal jaw-base relationship group than in the normal group, causing distance S-N to increase an average of 1.2 mm more with the distal jaw-base relationships in the 6- to 18-year period. With reference to this, Rothstein[26] compared the skeletal morphology between children with Class II-1 malocclusion and normal occlusion. Children with Class II-1 had a larger anterior cranial base length attended by increased thickness of the frontal bone at the level of the sinus. Most of the children investigated by Rothstein were between 10 and 14 years old, indicating that the difference in frontal bone thickness had to do with a difference in bone apposition at the glabella after age 10.

In the present study, the group difference in growth of nasion relative to sella brought into question the appropriateness of nasion as a basis for evaluating group differences in prognathism. Thus, prognathism of the jaws was evaluated not only relative to nasion but also relative to sella. The two methods, however, yielded similar results. With distal jaw-base relationships, pogonion had a significantly more retrusive position than normal relative to both nasion and sella (Table 2, v. 4-5).

Mandibular prognathism increased distinctly with growth, whereas maxillary prognathism remained fairly unchanged. The facial profile thereby straightened in both groups, but less so with distal jaw-base relationships. In the 6- to 18-year period, average decreases in distance PgA a-p were 7.2 mm in the normal group and 4.6 mm in the distal jaw-base relationship group, the average group difference of 2.6 mm being significant with $p = 0.01$ (v. 1). Compared with normal anteroposterior jaw-base relationships, distal jaw-base relationships did not generally improve, instead they slightly worsened (Figure 6). In all subjects investigated, however, distance PgA a-p decreased with age. Increase in the distance, causing the skeletal profile to become more convex, was not noted. The findings thus agree with Lande,[2] who concluded that the convexity of the bony facial profile nearly always decreases with growth.

Almost all subjects investigated (97%) were categorized identically at 6 and 18 years of age using distance PgA a-p as a group predictor. Within the respective groups, however, change in distance PgA a-p varied considerably. In about 35% of subjects with distal jaw-base relationships, distance PgA a-p decreased by only 3.5 mm or less from 6 to 18 years of age. The smallest decrease was 0.5 mm. In contrast, one subject with distal jaw-base relationship was utterly atypical of her group: distance PgA a-p decreased by 12 mm, i.e., from 15 mm at the age of 6 to 3 mm by the age of 18.

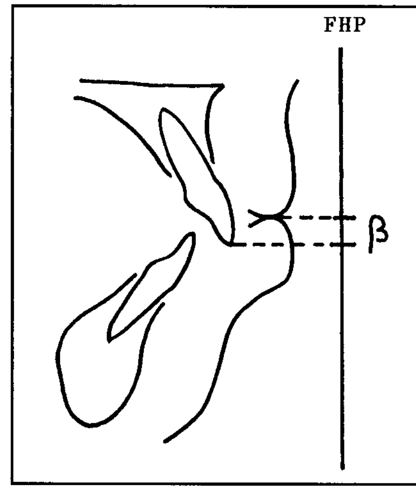

Figure 5
Labio-incisal relations in 13 subjects with distal jaw-base relationship and competent lip morphology, evaluated at age 15. Measured along a perpendicular to FH (FHP), the distance from the uppermost point of the lower lip to the incisal edge of the most prominent maxillary central incisor averaged 4.3 mm and ranged from 3 mm to 6 mm (distance β)

The fact that distal jaw-base relationships generally worsened as compared with normal anteroposterior jaw-base relationships had to do with dimensional and positional growth aberrations of the mandible. In the 6-to 12-year period, inadequate increase in mandibular corpus length (v. 12) was probably the primary contributor to an unfavorable development of distal jaw-base relationships. In the 12- to 18-year period, lower anterior facial height increased significantly most in subjects with distal jaw-base relationships, suggesting that the mandible grew more vertically (and less horizontally) than normal. A change in the growth direction of the mandible may have been influenced by an incremental group difference in the cranial base, where the condyles of distal jaw-base relationships moved slightly, but significantly, more distally than normal relative to sella in the 12- to 18-year period (v. 7).

Conclusions

1. The anteroposterior distance between pogonion and A-point (PgA a-p) prevailed as an effective group identifier throughout the 6- to 18-year period, correctly categorizing 97% of subjects investigated at 18 years of age.

2. In general, distal jaw-base relationships were attended by a distal position of pogonion relative to the anterior cranial base. However, distal jaw-base relationships were not a homogeneous morphological entity caused by some major and specific aberration in the cranial base or jaws. Rather, they were the result of a number of predisposing deviations with varying degrees of gravity. Seemingly, predisposing deviations had an additive effect on the anteroposterior jaw-base relationship. Among such deviations, a short mandibular corpus and a large MP-SN angle were the only ones exhibiting significant group difference.

3. In all subjects investigated, mandibular prognathism increased more than maxillary prognathism. The skeletal profile therefore straightened with growth in both groups, but less so in the distal jaw-base relationship group. Thus, distal jaw-base relationships did not usually improve with age, rather they were aggravated as compared with normal anteroposterior jaw-base relationships. The aggravation was brought about partly by inadequate growth in length of the mandibular corpus in the 6- to 12-year period, and partly by the mandible growing more vertically than normal after age 12.

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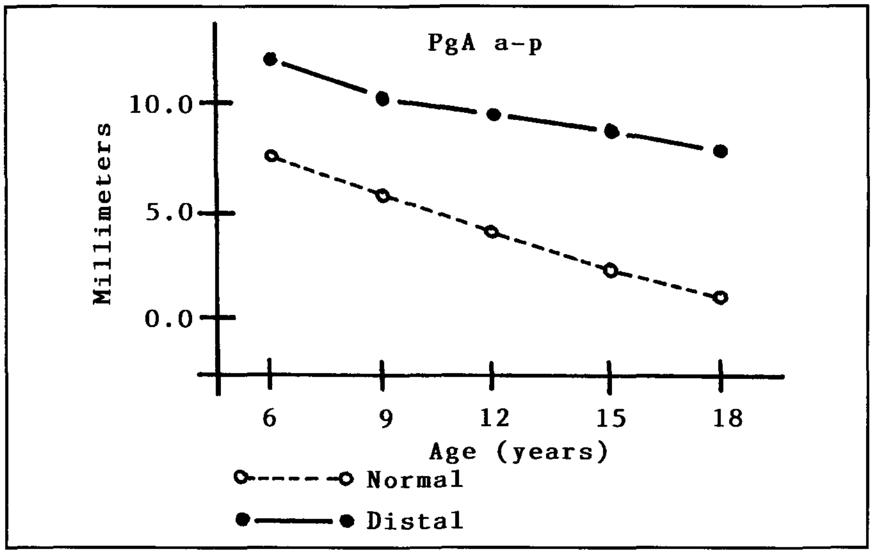

Figure 6
Change in group mean anteroposterior distance between pogonion and A-point (PgA a-p). In both groups the distance gradually decreased, but less so in the distal jaw-base relationship group, especially from 9 to 15 years of age

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