Original Article

New Posteroanterior Cephalometric Norms: A Comparison with Craniofacial Measures of Children Treated with Palatal Expansion

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Abstract: The aim of the study was to evaluate posteroanterior (PA) cephalometric characteristics in a normal longitudinal database and compare these measurements with corresponding measures in a group of patients treated with rapid maxillary expansion. Posteroanterior cephalographs of 16 girls and 14 boys from the Bolton-Brush growth study, taken at ages 10 and 18 years, were used to track growth in children with normal occlusion. Pretreatment PA cephalograms of 24 patients who had palatal distraction around age 10 were compared with the 10-year-old normal patients. Digitized landmarks included right and left jugale (J, at intersection of maxillary tuberosity and zygomatic buttress) and antegonion (AG, at notch of antegonial protuberance). Mandibular width (AG-AG) was similar in boys and girls at age 10 but not 18, when the difference between gender groups was statistically significant ($P < .05$). Maxillary width (J-J) was greater in boys than girls at both ages. The increase in AG-AG (5.5 mm, boys; 3.9 mm, girls) was more than twice that of J-J (2.4 mm, boys; 1.2 mm, girls). Arch width (at first molar) was nearly stable with age, indicating compensatory occlusal adaptation to differential changes between maxillary and mandibular widths. At age 18, the distance between the centers of the orbits, a surrogate measure of cranial width, was almost equal to J-J in girls and significantly correlated with AG-AG in boys ($r = .71$, $P < .002$) and girls ($r = .77$, $P < .0001$). The majority of treated children had both skeletal and dentoalveolar widths narrower than control values. Linear regressions between J-J and AG-AG revealed almost parallel slopes for control and treated groups in both genders, but the treated group was at a lower level, which is consistent with smaller maxillary widths. (*Angle Orthod* 2001;71:285–292.)

Key Words: Posteroanterior; Cephalometric; Normal; Bolton; Palatal expansion

INTRODUCTION

Early cephalometry recognized the importance of a 3-dimensional approach to study the face and dentition. This consideration gained momentum when interest in nonextraction treatment resurfaced in orthodontics, along with movement away from the "extraction look."[1] This development emphasized the need for the orthodontic diagnostic records to include these radiographs. A number of analyses for PA cephalgraphs have emerged, based mostly on linear measurements.[2–7]

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The aims and corresponding rationale of this investigation were to:

1. Evaluate transverse craniofacial relationships and longitudinal changes on PA cephalographs based on new and available linear measurements, but also through the introduction of angular measurements that are presumed to be less variable than linear measurements. Since previous work exists regarding the longitudinal cephalometric evaluation on an annual basis,[2] these measurements were performed in only 2 age groups representing pre- and postpubertal ages in both girls and boys.
2. Compare the generated normative data with the transverse skeletal pattern of patients whose treatment included rapid maxillary expansion. In addition to testing the practical use of the new norms in a group of patients whose pretreatment cephalometric measurements are expected to deviate from the average, a clinical significance is attached to this assessment. Indeed, underlying the need for this evaluation is the premise that deviations from normal PA relationships must be corrected to a

level comparable with normal relationships and eventually normal adult size.

MATERIALS AND METHODS

The control material included the PA cephalographs of 30 subjects, at ages 10 and 18 years, from the Bolton-Brush Growth Center. They were selected by the Center from a longitudinal database collected earlier in the 20th century. The data include serial cephalometric records of some 5000 persons registered from childhood to young adulthood. Posteroanterior cephalograms were taken at a distance between the x-ray tube and the porionic axis fixed at 5 feet (1.524 m), and the film placed close to the nose.[8] Consequently, the enlargement factor was different for each headfilm, but the film-porionic plane distances were recorded to compute and correct for the enlargement.[2]

Subgroups in this study were formed according to gender, and included 16 females and 14 males. They were selected based on availability of longitudinal records, ''excellent static occlusion'' on study casts, good health, and esthetically favorable faces that conformed to the statistically derived means of craniofacial measurements.[8]

The age groups were selected on assumptions made regarding growth. The first group included subjects at age 10 years, a prepubertal age in boys (more than 2 standard deviations less than the average age of peak height velocity [PHV][9]) and in most girls (more than 1.5 standard deviations from the average age of PHV). Age 18 was selected for the young adult group as an age when most growth has been achieved in girls and the majority of boys.

The normative values were developed through a computer program written by Gallop Advanced Technologies Compuceph Software, LLC (Bethesda, MD). The program allowed for several operations to be conducted, including digitization of individual tracings, generation of the average location of landmarks, and mean linear and angular measurements. Editable measurement templates for linear (2-point and point-to-line distance) and angular (3-point and 2-line angles) measurements are incorporated in the computerized program.

The treatment group included the pretreatment PA cephalographs of 24 patients (16 girls and 8 boys) treated with rapid maxillary expansion in the orthodontic graduate clinic of the University of Pennsylvania School of Dental Medicine. Their average ages were: 10.5 $\pm$ 0.89 years for girls and 10.01 $\pm$ 0.79 years for boys. Patients were restricted to around age 10 years for 2 reasons: (1) The pretreatment records can be compared with the 10 year old norms, and (2) palatal expansion can be achieved without recourse to surgical osteotomy as might be needed for orthopedic palatal expansion at postpubertal ages. The fixed maxillary expander used had acrylic palatal coverage (Haas type) and was activated twice a day (approximately 0.5 mm).

The following landmarks were identified on the right and left sides of the tracings (Figure 1):

- Center of the orbit (CO), the geometric center of the area defined by tangents to the most superior (S), lateral (L), inferior (I), and medial (M) points on the outline of the orbital margin;
- Jugale (J), at the jugal process, the intersection of the outline of the maxillary tuberosity and the zygomatic buttress;
- Points on each of the maxillary and mandibular first molars: 6C, the most lateral point of the crown convexity, and 6A, the most apical point on the buccal root surface. Considering the difficulty of tracing the maxillary molars on a PA cephalograph, these buccal landmarks were deemed adequate to provide a proxy measure of molar axial inclination.
- 1A, the tip of the root apex of the maxillary and mandibular central incisors;
- 1C, the incisal edge of the maxillary and mandibular central incisor, centered mediolaterally;
- Gonion (Go), at the gonial angle of the mandible;
- Antegonion (AG), at the antegonial notch, the lateral inferior margin of the antegonial protuberance; and
- Articulare (Ar), at the intersection of the ramus and temporal bone.

The following landmarks were identified in the midline (Figure 1):

- The most superior point of the crista galli (Cr) at its intersection with the sphenoid;
- The tip of the anterior nasal spine (ANS); and
- Menton (Me), the most inferior point on the border of the mandible, at the symphysis.

The computer program generated the following measurements, simply by clicking on the appropriate landmarks on the monitor screen:

Angular measurements

- J-CO-AG (R): angle formed by jugale, geometric center of the orbit, and antegonion on the right side.
- J-CO-AG (L): the same angle on the left side.
- J-Cr-AG (R): angle formed by jugale, crista galli, and antegonion on the right side.
- J-Cr-AG (L): the same angle on the left side.
- UR6: angle between the tangent to the buccal surface of the maxillary right first molar and the line J-J.
- UL6: the corresponding angle for the left maxillary first molar.
- LR6: angle between the tangent to the buccal surface of the mandibular right first molar and the line AG-AG.
- LL6: the corresponding angle for the left mandibular first molar.
- IM (R): angle between the tangent to the buccal surface

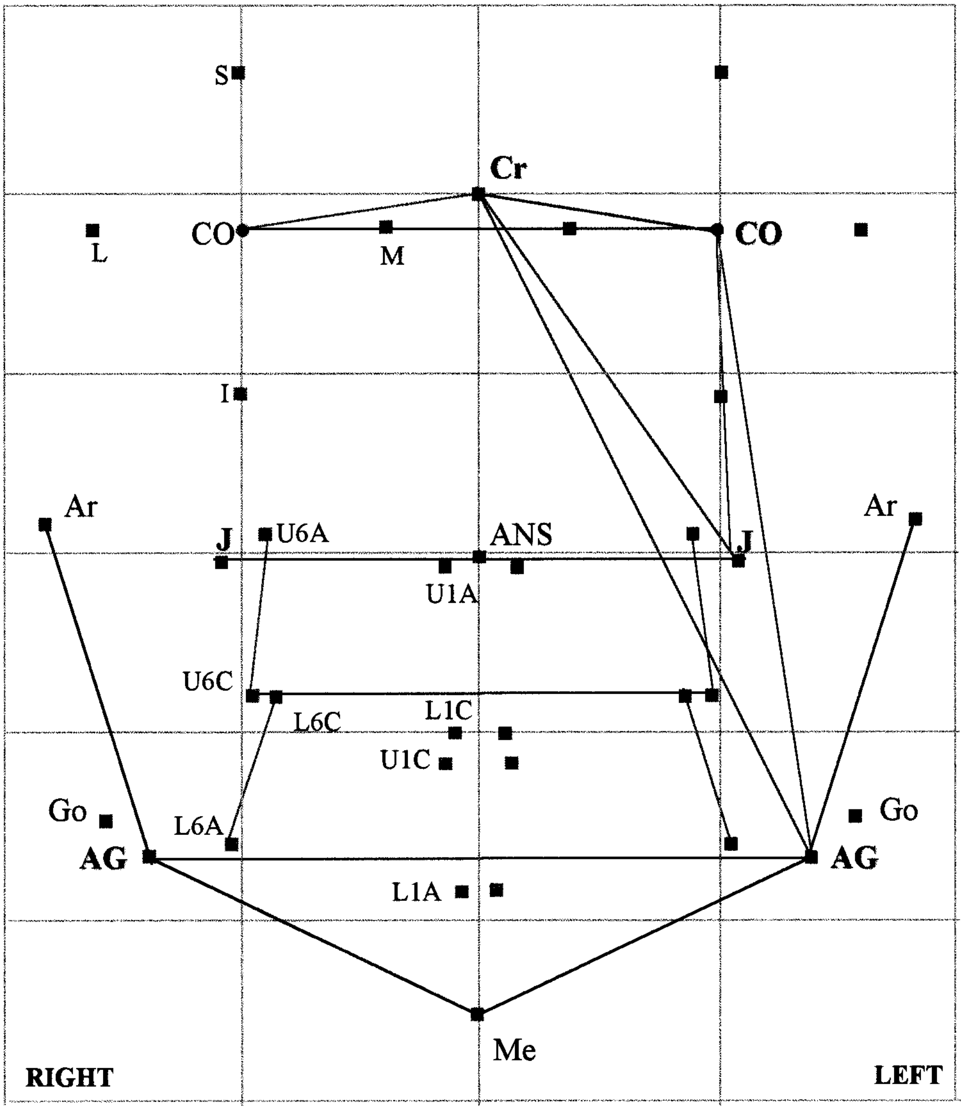

FIGURE 1. Posteroanterior cephalometric tracing with evaluated landmarks: CO, center of orbit (see text for construction); J, jugale; 6C and 6A, most lateral point of crown and most apical point of buccal root of first molars; 1A and 1C, tip of root apex and incisal edge of central incisors; Go, gonion; AG, antegonion; Ar, articulare; Cr, superior point of cristagalli; ANS, anterior nasal spine; Me, menton.

of the maxillary right first molar and the tangent to the buccal surface of the mandibular right first molar.
- IM (L): the corresponding angle on the left side.

Linear measurements

- CO-CO: distance between the geometric centers of the orbits.
- J-J: distance between right and left jugale.
- AG-AG: distance between right and left antegonion.
- L6–6A: distance between the apices of the distobuccal roots of mandibular first molars.
- L6–6C: distance between the most buccal points of the crowns of mandibular first molars.
- U6–6A: distance between the apices of the distobuccal roots of maxillary first molars.
- U6–6C: distance between the most buccal points of the crowns of maxillary first molars.

Distances were recorded 3 times after the landmarks were redigitized each time and the averages of the repeated recordings were used in the statistical analysis. All cephalometric distances were adjusted for radiographic distortion by subtracting the percentage of enlargement, which was computed on the basis of the distance between porionic axis and film for both the Bolton-Brush group and the treated group.[2,10] Distances presented in this paper are the corrected measures.

All cephalograms were traced and digitized by the same operator (DH). To assess intraexaminer reliability, the operator traced 20 randomly selected cephalograms (10 in males and 10 in females) at 2 different times. Examiner

TABLE 1. Means and Standard Deviations (SD) of Selected Craniofacial Distances in Untreated and Treated Groups

	CO-CO (mm)	J-J (mm)	AG-AG (mm)	[AG-AG] − [J-J] (mm)
Untreated males (n = 14)				
Age 10	53.16 (2.39)	58.64 (2.55)	73.43 (3.32)	14.19 (3.00)
Age 18	57.05 (3.10)	61.50 (2.49)	79.10 (4.04)	17.60 (3.41)
P	.001	.002	.0001	.001
Treated males (n = 8)[a]	52.78 (2.11)	54.79 (3.81)	75.73 (5.04)	20.94 (2.65)
P	NS	.02	NS	.0001
Untreated females (n = 16)				
Age 10	54.71 (3.20)	57.57 (2.89)	73.08 (3.14)	15.52 (2.62)
Age 18	57.70 (3.39)	59.05 (2.65)	76.75 (2.82)	17.70 (3.15)
P	.0001	.007	.0001	.001
Treated females (n = 16)[a]	53.12 (3.01)	54.31 (2.81)	73.67 (3.63)	19.36 (3.46)
P	NS	.003	NS	.001

[a] Treated group was compared with untreated 10-year-old age group.

variability of repeated measurements was evaluated by calculating the intraclass correlation coefficient and error of measurement for several linear distances.

Differences between genders were evaluated with *t*-tests for different parameters. Linear correlation and regression techniques were used to evaluate relationships among and between transverse skeletal and dentoalveolar measures, whether measured through angles or distances. Where appropriate, ANOVA was employed to evaluate differences among gender, treatment, and control groups.

RESULTS

The intra-examiner errors of measurement for several distances were less than 0.5 mm, and the corresponding intraclass correlation coefficients were greater than $r = .95$.

Normative data

In both gender groups, the only differences that were statistically significant were between ages 10 and 18 years for the following distances: CO-CO, J-J, AG-AG, and for the difference between AG-AG and J-J (Table 1). Most statistically significant differences between gender groups occurred at age 18 years and involved the following distances: J-J ($P = .009$), maxillary interapical ($P = .004$), mandibular interapical ($P = .005$), and maxillary intermolar distance U6–6C ($P = .005$). Certain measures were statistically significantly different only on 1 side of the face, reflecting asymmetry more than a general trend regarding the affected measures.

The distance between CO-CO, a surrogate measure of cranial width, was almost equal to J-J in 18-year-old girls, but highly correlated with AG-AG at age 18 years in both gender groups: ($r = .71$, $P = .002$ in males; $r = .77$, $P = .0001$ in females). Correlations between CO-CO and J-J, between J-J and AG-AG, or between these and their difference were low to moderate (highest, $r = .63$, $P = .005$, between 10- to 18-year increments of J-J and the difference [AG-AG]-[J-J]).

In both sex groups, the increase in AG-AG (+5.5 mm in boys, +3.9 mm in girls) was more than twice that of J-J (+2.4 mm in boys, +1.2 mm in girls). The ratios J-J/AG-AG were higher in boys (80.3%) than girls (78.8%) at age 10 years, but the difference narrowed at age 18 years (77.7% in males; 76.9% in females).

Dentoalveolar measurements, represented by the distances between right and left first molars at the level of the crowns and apices, were practically similar at both age groups in both boys and girls (Table 2). Distances between the crowns of maxillary and mandibular first molars exhibited levels of correlation greater than $r = .7$ in all age and gender groups ($.86 < r < .90$, $P = .0001$) except 10-year-old girls ($r = .63$, $P = .003$).

New measures of relationship between the jaws included the right and left angles between jugale, antegonion, and either crista galli in the midline, or the center of the orbit on the corresponding lateral side (Tables 3 and 4). In boys, J-Cr-AG and J-CO-AG were highly correlated with the linear difference between J-J and AG-AG at both age groups ($.64 < r < .85$, $.01 < P < .0001$). In girls, only J-CO-AG exhibited a high correlation with the linear difference at age 10 years ($r = .66$, $P = .003$; $r = .72$, $P = .001$ on right and left sides, respectively) and age 18 years ($r = .73$, $P = .001$; $r = .84$, $P = .0001$ on right and left sides, respectively).

Palatal expansion group

In the treated group, maxillary skeletal and dentoalveolar widths were narrower ($.003 < P < .02$) than in the corresponding Bolton-Brush normative group (Tables 1 through 3). The difference between maxillary and mandibular widths was greater in the treated group. Linear regressions of the relations between J-J and AG-AG show almost

TABLE 2. Means and Standard Deviations (SD) of Distances Between Right and Left First Molars in Untreated and Treated Groups

	Maxillary Distances (mm)		Mandibular Distances (mm)	
	Crowns	Apices	Crowns	Apices
Untreated males (n = 14)				
Age 10	51.22 (3.14)	47.22 (3.31)	46.91 (2.73)	54.94 (3.15)
Age 18	50.57 (2.71)	47.84 (3.70)	47.22 (2.58)	56.09 (2.97)
P	NS	NS	NS	NS
Treated males (n = 8)[a]	48.08 (2.95)	42.93 (2.72)	46.01 (3.51)	53.97 (3.13)
P	NS	NS	NS	NS
Untreated females (n = 16)				
Age 10	50.80 (3.00)	44.00 (3.67)	45.74 (3.20)	53.95 (3.49)
Age 18	49.52 (2.14)	44.13 (3.27)	44.65 (2.33)	52.96 (3.02)
P	.05	NS	NS	NS
Treated females (n = 16)[a]	47.95 (2.31)	39.68 (3.70)	44.03 (2.06)	53.58 (2.76)
P	.005	.002	NS	NS

[a] Treated group was compared with untreated 10-year-old age group.

TABLE 3. Means and Standard Deviations (SD) of Selected Angular Measurements in Untreated and Treated Groups

	J-Cr-AG (degrees)			J-CO-AG (degrees)		
	Right	Left	Average	Right	Left	Average
Untreated males (n = 14)						
Age 10	9.19 (1.88)	8.37 (2.77)	8.77 (2.32)	3.25 (1.67)	4.48 (2.78)	3.86 (2.22)
Age 18	8.00 (2.90)	9.53 (3.21)	8.76 (3.05)	5.23 (2.10)	4.12 (2.39)	4.68 (2.24)
P	NS	NS	NS	.005	NS	NS
Treated males (n = 8)[a]	3.64 (2.29)	4.22 (1.10)		8.86 (1.63)	7.66 (1.66)	
P	.0001	.0001		.0001	.003	
Untreated females (n = 16)						
Age 10	7.72 (2.09)	8.47 (2.13)	8.09 (2.51)	5.09 (1.97)	5.32 (2.63)	5.20 (2.30)
Age 18	8.47 (2.02)	8.63 (1.73)	8.55 (1.86)	5.55 (2.00)	5.96 (2.58)	5.75 (2.28)
P	NS	NS	NS	NS	NS	NS
Treated females (n = 16)[a]	4.94 (3.23)	4.43 (3.40)		7.01 (3.08)	8.42 (2.82)	
P	.007	.0001		.05	.003	

[a] Treated group was compared with untreated 10-year-old age group.

parallel slopes for control and treated groups in both boys and girls, with the treated group at a lower level, consistent with smaller J-J distances in this group (Figures 2 and 3). The differences between the slopes were not statistically significant (P = .118 in boys; P = .51 in girls), and the variances of control and treated groups were similar in both gender groups.

TABLE 4. Means and Standard Deviations (SD) of Selected Angular Measurements in Untreated Group at Ages 10 and 18 Years

	J-Cr-midline (degrees)	AG-Cr-midline (degrees)	Difference (degrees)
Age 10	26.02 (1.91)	35.03 (2.69)	9.01 (2.35)
Age 18	23.43 (1.73)	32.42 (2.39)	9.02 (2.88)
P	NS	NS	NS

DISCUSSION

Craniofacial Transverse Relations

The results support previous conclusions that different normative data should be used for males and females when linear measurements are considered.[2–7,11,12] However, the newly introduced angular measurements, like angular measurements in the sagittal plane, are similar in both sexes and can be used for either (Table 2). The new measurements relate the maxilla and mandible on the right and left sides to either crista galli (Cr) in the midline or the center of the orbit (CO).

Interestingly, the angles J-CO-AG exhibited higher correlations than J-Cr-AG with the linear difference ([AG-AG]-[J-J]) between the jaws. In addition to determining any discrepancy between the jaws, the angles J-Cr-midline and AG-Cr-midline, or the corresponding measures relating J and AG to the vertical through CO parallel to the midline, help determine which of the jaws deviates from the norm.

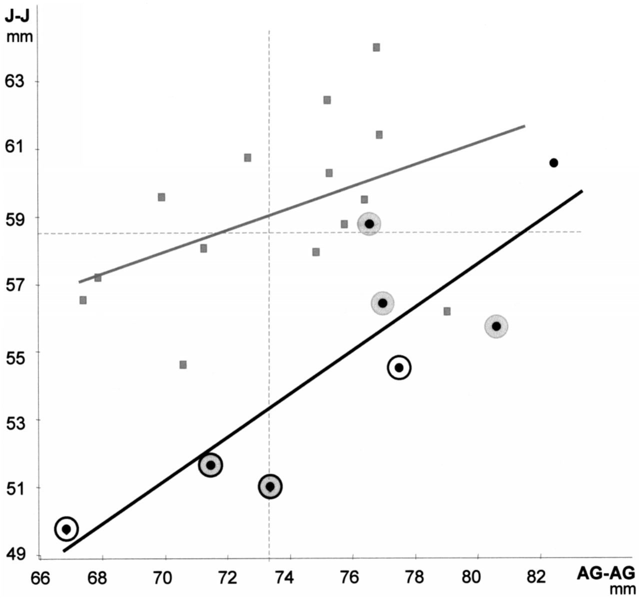

FIGURE 2. Relation between maxillary width (J-J) and mandibular width (AG-AG) in 10-year-old control males (gray line and corresponding gray squares, $R^2 = .194$; $r = .44$) and corresponding treated group (black line and corresponding black dots, $R^2 = .733$; $r = .86$). Differences between the slopes were not statistically significant. Unfilled black circle: posterior crossbite; gray circle: ANB $> 4.5°$; gray circle with black border: both posterior crossbite and ANB $> 4.5°$. The horizontal dashed line indicates the normative value for J-J at age 10 years. The vertical dashed line indicates the corresponding value for AG-AG. Note that the majority of treated boys (7/8) had a maxillary width smaller than the average, and (6/8) a mandibular width at or greater than the average.

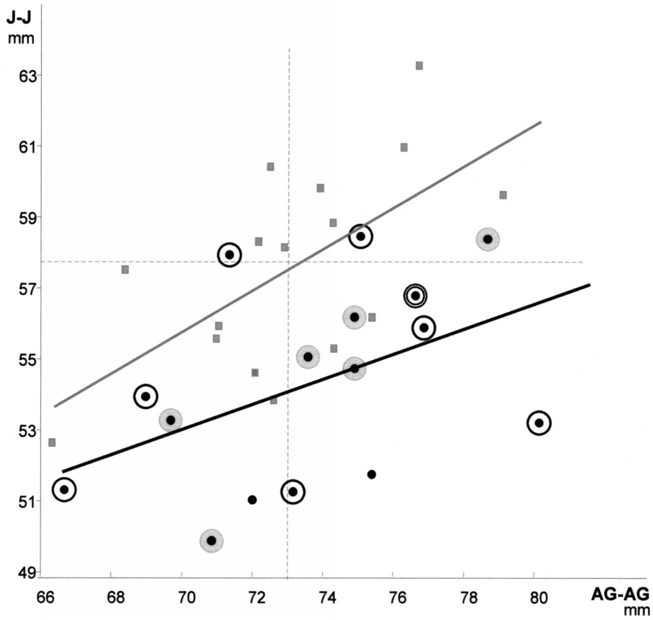

FIGURE 3. Relation between maxillary width (J-J) and mandibular width (AG-AG) in 10-year-old control females (gray line and corresponding gray squares $R^2 = .392$; $r = .63$) and corresponding treated group (black line and corresponding black dots $R^2 = .201$; $r = .45$). Differences between the slopes were not statistically significant. Unfilled black circle, posterior crossbite; gray circle, ANB $> 4.5°$; unfilled double black circle, class III malocclusion. The horizontal gray line indicates the normative value for J-J at age 10 years. The vertical gray line indicates the corresponding value for AG-AG. The horizontal dashed line indicates the normative value for J-J at age 10 years. The vertical dashed line indicates the corresponding value for AG-AG. Note that the majority of treated girls (13/16) had a maxillary width smaller than the average and 10 out of 16 had a mandibular width at or greater than the average.

These angles also help to determine asymmetry of jaw position between right and left sides.

High correlations were noted between CO-CO and AG-AG and, in 18-year-old girls, the middle interorbital width was almost equal to the maxillary width. Of potential clinical significance, the relationship between interocular width and commissural width at rest and during smile might emerge as a useful guide when evaluating facial proportions and esthetics. Research of these proportions is warranted.

Transverse Growth

This study and our previous work[2] indicate that transverse development of the jaws is characterized by differential growth between maxilla and mandible. Mandibular width proceeds, on average, at a ratio of 2:1 relative to maxillary width between ages 10 and 18 years. In the same interval, a differential ratio has been described in the vertical and sagittal planes.[13–17] Correlations between the differential interjaw changes in all planes of space are not known, nor how their timely interaction contributes to the development of malocclusion. Consequently, early intervention to correct a developing malocclusion would depend not only on intercepting unfavorable discrepancies in differential ratios between the jaws, but as importantly on when this treatment is rendered.

Changes observed in the posterior width of the maxilla (J-J) and mandible (AG-AG) are consistent with observations by Björk and Skieller[18] who measured growth in maxillary width between posterior implants in 9 boys (10 to 11 years to adult age). The changes are also in agreement with Baumrind and Korn[19] who evaluated the lateral displacement of metallic implants in the mandibles of 31 subjects (ages of 8.5 to 15.5 years). In addition, the authors of both studies report that posterior width grows more than the anterior breadth of the jaws.

While the ratio of transverse mandibular to maxillary growth is 2:1 between ages 10 and 18 years, posterior teeth and associated alveolar bone compensate for this discrepancy. In this time interval, normal transverse occlusion is maintained (as per inclusion criteria), dentoalveolar width at the level of first molars (between right and left buccal surfaces of crowns and apices) seems to be stable (Table 2) and maxillary and mandibular intermolar (crown) distances exhibit high levels of correlation at both ages. This finding might conceptually support the functional matrix

TABLE 5. Incidence of Malocclusion in Treated Group

	Posterior Crossbite	Class II	Class III	Other
Male (n = 8)	4[a] (50%)	5[a] (62.5%)	0	1 (12.5%)
Female (n = 16)	7 (44%)	6 (37.5%)	1 (6%)	2 (12.5%)
Total (n = 24)	11 (46%)	11 (46%)[a]	1 (4%)	3 (12.5%)

[a] Combined Class II and posterior crossbite, n = 2 (25%).

premise of functional requirements influencing optimal form.[20]

A potential therapeutic corollary may be attached to these dentoalveolar compensations. If the clinician does not widen the maxillary arch (usually through palatal expansion) to limit the extent of the compensations (ie, excessive lingual inclination of the mandibular posterior teeth or buccal inclination of the maxillary teeth), posterior crossbite or mandibular crowding may occur, particularly in the presence of severe skeletal discrepancies. Excessive compensations also may affect periodontal health, including gingival recession and buccal bone loss. Therefore, early treatment to correct transverse problems may be needed in order to forego extreme compensation.

Palatal expansion

The group of patients treated with maxillary expansion predominantly had both maxillary basal and dentoalveolar constrictions (Tables 1 and 2). The slopes of maxillary/mandibular regressions of control and treated children were not statistically significant (Figures 2, 3), a finding illustrated by the nearly parallel regression lines. This result suggests that an increase of maxillary width (J-J) would normalize the interjaw relationship in the treated group to approach control values.

The rationale for planning maxillary distraction by the treating orthodontists was discounted as an inclusion criterion. The results revealed that a majority of the children had posterior crossbites (46%) or Class II skeletal relations (46%), or both (Figures 2 and 3; Table 5). Maxillary arch form is known to be narrower in distoclusions.[21,22] Several female patients who had a relation between J-J and AG-AG close to normal had posterior crossbites (Figure 2), suggesting that these malocclusions were of dentoalveolar, not skeletal nature. Expansion apparently was planned in some children to create space or enhance facial appearance during smile. A narrow maxillary arch impacts the width and configuration of the space between the maxillary lateral teeth and the corner of the lips during smile.[23] An enlargement of this space has been referred to as the ''black'' space or corridor.

Issues of stability of occlusion also are related to width of the dental arches and, by extension, the underlying jaws. Further research should be conducted at different ages and follow-up studies should investigate short- and long-term effects of palatal expansion. Such studies could determine not only the stability of the results, but also whether the widened maxillae are closer to adult norms, and whether the maxilla should be overexpanded to adult proportions in anticipation of the expected increase in mandibular width with growth. In this context, it would be important to investigate gender differences in treatment needs, because the ultimate difference in maxillary width (and in maxillary/mandibular discrepancy) between pretreatment and normal values is greater in males (Table 1; Figures 2 and 3). In contrast, the corresponding differences at the level of the intermolar (crown) distances are rather similar in both genders (Table 2).

It may be argued that whether the decision to treat is related to the posterior crossbite, space management (creation), or esthetic consideration, clinical impression anticipates or foregoes cephalometric findings. Moreover, the target of correction tends to be the maxilla through palatal distraction, even if the mandible is the discrepant jaw, because maxillary expansion is feasible but restraining transverse growth of the mandible is difficult. The fact that the majority of the treated children in this study had narrow maxillary width seemingly supports discarding the PA record, given the prevalent approach of maxillary correction. However, the PA cephalogram, like sagittal cephalography, is only a guide to assist proper diagnosis. Both records complete the 3-dimensional evaluation of the patient and support the rationale for treatment, notwithstanding their undeniable value in research. Unfortunately, the overlap of structures on the PA film renders the identification of molars difficult, and consequently the diagnosis of posterior alveolar inclination. For this reason, and to lessen error, we introduced identification of the molar teeth as the line connecting the most buccal points on crowns and roots at the level of apices.

CONCLUSIONS

The newly introduced linear and angular measurements reveal additional characteristics to the PA craniofacial cephalometric record. Angular norms can be used for both males and females.

Nearly half of the children treated with rapid palatal expansion had a posterior crossbite, a condition that may have warranted expansion regardless of the outcome of PA cephalometric analysis. However, the PA record revealed that most of these patients had a narrow maxilla. Those patients who underwent maxillary distraction and had no posterior crossbite also had a decreased maxillary width. Similar to the evaluation of sagittal problems, clinical impressions apparently anticipate cephalometric findings.

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REFERENCES

1. Moorrees CF. Orthodontics and dentofacial orthopedics: past, present and future. Part 1. *Kieferorthop.* 1998;12:17–26.
2. Cortella S, Shofer FS, Ghafari J. Transverse development of the jaws: norms for the posteroanterior cephalometric analysis. *Am J Orthod Dentofacial Orthop.* 1997;112;519–522.
3. Grummons DC, Kappeyne van de Coppelo MA. A frontal asymmetry analysis, *J Clin Orthod.* 1987;21:448–465.
4. Ricketts R. Perspectives in the clinical application of cephalometrics: the first fifty years. *Angle Orthod.* 1981;51:115–150.
5. Ricketts RM, Roth RH, Chaconas SJ, Schulhof RJ, Engel GA. *Orthodontic Diagnosis and Planning.* Denver, Col: Rocky Mountain Data Systems; 1982.
6. Sassouni V. *The Face in Five Dimensions.* Philadelphia, Penn: Growth Center Publication; 1955.
7. Bergman R. Practical application of the PA cephalometric headfilm. *Orthod Rev.* 1988;2:20–26.
8. Broadbent BH Sr, Broadbent BH Jr, Golden WH. *Bolton Standards of Dentofacial Developmental Growth.* St Louis, Mo: CV Mosby; 1975.
9. Tanner JM, Davies P. Clinical longitudinal standards for height and height velocity for North American children. *J Pediatr.* 1985; 107:317–329.
10. Ghafari J, Carter PE, Shofer FS. The effect on film object distance on posteroanterior cephalometric measurements: suggestions for standardized cephalometric methods. *Am J Orthod Dentofacial Orthop.* 1995;108:30–37.
11. Christie TE. Cephalometric patterns of adults with normal occlusions. *Angle Orthod.* 1977;47:128–133
12. Farkas LG. *Anthropometry of the Head and Face in Medicine.* New York, NY: Elsevier Science; 1981.
13. Bambha JK. Longitudinal cephalometric roentgenographic study of face and cranium in relation to body height. *J Am Dent Assoc.* 1961;63:776–799.
14. Baughan B, Demirjian A, Lesveque GY, Lapalme-Chaput L. The pattern of facial growth before and during puberty as shown by French-Canadian girls. *Ann Human Biol.* 1979;6:59–76.
15. Hunter CJ. The correlation of facial growth with body height and skeletal maturation at adolescence. *Angle Orthod.* 1966;36:44–54.
16. Nanda RS. The rates of growth of several facial components measured from serial cephalometric roentgenograms. *Am J Orthod.* 1955;41:658–673.
17. Enlow DH. *Facial Growth.* 3rd ed. Philadelphia, Penn: WB Saunders Company; 1990:240–242.
18. Björk A, Skieller V. Growth of the maxilla in 3 dimensions as revealed radiographically by the implant method. *Br J Orthod.* 1977;4:53–64.
19. Baumrind S, Korn EL. Postnatal width changes in the internal structures of the human mandible: a longitudinal three-dimensional cephalometric study using implants. *Eur J Orthod.* 1992; 14:417–426.
20. Moss ML. The primary role of functional matrices in facial growth. *Am J Orthod.* 1969;55:566–577.
21. Moorrees CF, Grøn AM, Lebret LM, Yen PK, Frohlich FJ. Growth studies of the dentition: a review. *Am J Orthod.* 1969;55: 600–616.
22. Varrela J. Early developmental traits in class II malocclusion. *Acta Odontol Scand.* 1998;56:375–377.
23. Ghafari JG. Emerging paradigms in orthodontics—an essay. *Am J Orthod Dentofacial Orthop.* 1997;111:573–580.