Posteroanterior cephalometric norms for an adolescent Kuwaiti population

Rashed Al-Azemi* and Jon Årtun**

*Department of Developmental and Preventive Sciences, Faculty of Dentistry, Kuwait University, Kuwait City, Kuwait, **Department of Orthodontics, Nicolas & Asp University College, Dubai Healthcare City, Dubai, United Arab Emirates

Correspondence to: Dr Rashed Al-Azemi, Department of Developmental and Preventive Sciences, Faculty of Dentistry, Kuwait University, PO Box 24923, Safat, Kuwait City 13110, Kuwait. E-mail: rashed@hsc.edu.kw

SUMMARY The aim of the study was to establish posteroanterior (PA) cephalometric norms for adolescent Kuwaitis of an age comparable with the start of comprehensive orthodontic treatment, and to compare these with similar normative data, considering a difference of 2.0 mm or degrees as clinically significant. Digital PA cephalograms of 159 13- to 14-year-old Kuwaitis (81 boys and 78 girls) with untreated ideal occlusions were evaluated. Anatomic landmarks were identified directly on digital computer images and linear and angular measurements were calculated electronically. Mean values (norms), standard deviations, and ranges were calculated for the parameters. Student's *t*-tests were employed to test for gender differences.

The dental norms were clinically similar to those of Ricketts' analysis, but the ranges of the skeletal dental width and relationship measurements were clinically larger. Only the ranges of skeletal symmetry measurements were larger. Regarding the four dental to skeletal relationships, the norms were larger only for the molar to jaw relationship, while the ranges were larger for all. No gender differences were detected after Bonferroni adjustments. The findings suggest clinically significant racial differences in PA cephalometric norms with minimal gender differences at adolescence. The ranges of the various parameters in adolescent subjects with natural development of an ideal occlusion are considerably larger than those suggested in Ricketts' analysis system.

Introduction

Comprehensive cephalometric analysis systems have been developed to determine the lateral skeletal and dentoalveolar components of a malocclusion (Steiner, 1959; Ricketts, 1960). Approximately 90 per cent of orthodontic practitioners in the USA make routine use of lateral cephalograms for every comprehensive case (Keim *et al.*, 2002), illustrating the accepted value of lateral cephalometric analysis as an aid in orthodontic diagnosis and treatment planning. However, accurate diagnosis of discrepancies in width dimensions as well as of occlusal cants and asymmetries may also require a posteroanterior (PA) cephalometric evaluation.

Increases in transverse dental arch dimensions are associated with arch perimeter gain (Adkins *et al.*, 1990). Bimaxillary expansion has therefore been recommended as a suitable alternative to premolar extraction, particularly in patients presenting with narrow dental arches (Cetlin and Ten Hoeve, 1983; Vanarsdall, 1999; McNamara *et al.*, 2003; Ferris *et al.*, 2005). However, that treatment decision should be based not only on dental arch measurements but also on suitable PA cephalometric analysis. The high prevalence of arch length deficiency and transverse malocclusions in different populations (Hill, 1992; Behbehani *et al.*, 2005) may indicate that a considerable proportion of orthodontic patients may benefit from PA cephalometric evaluation.

Several PA cephalometric analysis systems have been proposed (Sassouni, 1958; Letzer and Kronman, 1967; Ricketts *et al.*, 1972; Hewitt, 1975; Svanholt and Solow, 1977; Grayson *et al.*, 1983; Grummons and Kappeyne Van De Coppello, 1987). Of the two that are commercially available through the Dolphin® software (Ricketts *et al.*, 1972; Grummons and Kappeyne Van De Coppello, 1987), only Ricketts' analysis (Ricketts *et al.*, 1972) is accompanied by a comprehensive set of norms, proposing age specific adjustments from adolescence to adulthood (Ricketts, 1981; Ricketts *et al.*, 1982). However, the specific materials and methods used for calculating the norms have not been published. Grummons and Kappeyne Van De Coppello (1987) have presented a comprehensive analysis system for comparison of right and left triangular shapes, linear dimensions, and facial proportions. Since their purpose is to identify individual areas of asymmetry rather than determining actual discrepancies, the analysis is not accompanied by normative data. The focus of the remaining analyses is to evaluate the skeletal and dental components of asymmetry through comparison of right and left triangular measurements (Letzer and Kronman, 1967; Hewitt, 1975), variables suitable for assessment of midline discrepancies

(Svanholt and Solow, 1977; Grayson *et al.*, 1983), or to determine the individual harmony of various proportions (Sassouni, 1958). Only a few of these analyses are supported by a limited set of normative data (Letzer and Kronman, 1967; Hewitt, 1975; Svanholt and Solow, 1977).

Several well-known craniofacial growth studies include records suitable for transverse analyses. However, with the exception of select measurements of relatively small samples (Woods, 1950; Snodell *et al.*, 1993; Cortella *et al.*, 1997; Huertas and Ghafari, 2001; Hesby *et al.*, 2006), normative data have been published only for 60 subjects without an ideal occlusion (Basyouni and Nanda, 2000).

Athanasiou *et al.* (1992) provided norms for selected PA cephalometric measurements of 588 Austrian schoolchildren aged 6–15 years. Although the sample of adolescents was large, the inclusion of subjects without an ideal occlusion limits the validity of the findings. In addition, while Uysal and Sari (2005) provided PA cephalometric norms for adult Turks, analysing a large sample with a Class I occlusion and pleasing facial morphology, no adolescents were included in their sample.

Ethnic differences of clinical significance have been established in selected width measurements of Chinese relative to published data for Japanese and American Whites (Wei, 1970). Although the sample of Chinese was relatively large, only adults were included without occlusal selection criteria. In addition, similar differences have been established between Egyptians and other ethnic groups (Aboul-Azm and Korayem, 1987). The Egyptian sample was also limited to adults.

Cephalometric norms should represent the means and ranges or clinically useful parameters from large samples of subjects of a similar age and ethnicity with untreated almost ideal occlusions to be valid as standards for comparison. According to these criteria, few of the existing data allow valid interpretations of skeletal versus dental components of malocclusions in the frontal plane, particularly for adolescent subjects. The aim of this study was to establish PA cephalometric norms for adolescent Kuwaitis of an age comparable with the normal start of comprehensive orthodontic treatment, and to compare these norms with those suggested in the available analysis systems as well as to other published information.

Subjects and methods

Sample

Stratified cluster sampling methods (Cochran, 1977) were applied when determining the school classes from which students should be screened, defining the students in the public schools of each of the six administrative areas in Kuwait as six different strata and the students in the different private schools as the seventh stratum.

Following approval by the ethical committee at Kuwait University, Faculty of Dentistry, and authorization by the Research Department of the Kuwaiti Ministry of Education, eighth-grade students were screened in a well lit room provided by the respective school principals. Kuwaiti nationals aged 13–14 years with no history of orthodontic treatment and an almost ideal occlusion, defined as Class I intercuspation and posterior tooth alignment with no transverse discrepancies, no detectable lateral shift, an anterior shift less than 2 mm, no midline deviation, a positive overjet of less than 3.5 mm, a positive overbite with less than two-third overlap of the maxillary to mandibular incisors, an arch length excess less than 2 mm in either arch, and anterior tooth irregularity less than 3.5 mm in either arch, were invited to participate in a PA cephalometric examination. Following written parental consent, 82 boys with a mean age 13.27 years [standard deviation (SD) 0.42] and 80 girls mean age 13.21 years (SD 0.43) were examined. The PA cephalogram of one girl was missing, and two boys had to be excluded due to incorrect head positioning.

The digital PA cephalograms were obtained at Division of Radiology, Faculty of Dentistry, with the teeth in centric occlusion at a focus/object distance of 150 cm and an object/receptor distance of 20 cm using a Planmeca cephalostat (Planmeca OY, Helsinki, Finland). The subjects were placed in the headholder and asked to look straight forward.

Anatomic landmarks and end points of the 10-mm metal bar on the left arm of the headholder were identified directly on the digital computer images (Figure 1). Linear and angular measurements were calculated electronically using the Dolphin version 9 (Dolphin Imaging and Management Solutions, Chatsworth, California, USA) software package, adjusting linear readings to the actual subject dimensions according to the enlargement of the metal bar.

Error of the method

The reproducibility of the measurements was assessed by statistically analysing the difference between double measurements taken at least 1-week apart on 20 randomly selected cephalograms. The error was calculated as

$$S_x = \sqrt{\frac{\sum D^2}{2N}},$$

where *D* is the difference between duplicated measurements and *N* is the number of double measurements (Dahlberg, 1940). The errors ranged from 0.33 (molar relationship left) to 1.00 (maximum width). Pearson's *R* between the respective first and second measurements were all >0.90 except for molar relationship left and right, which were 0.73 and 0.72, respectively ($P < 0.001$).

Data analyses

Descriptive statistics were performed, and Student's *t*-tests were employed to test for gender differences following
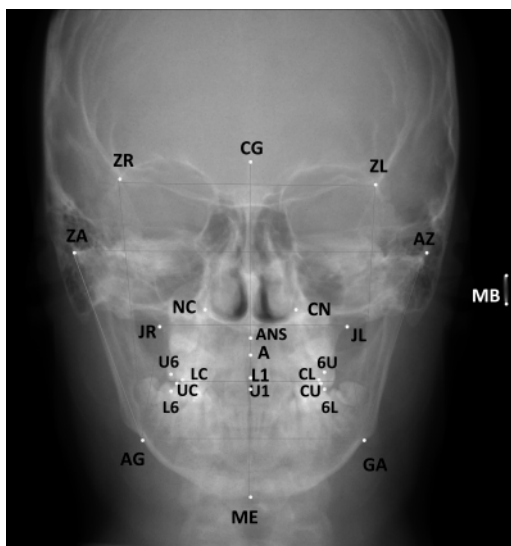
Figure 1 Cephalometric radiograph of an average subject in the sample, indicating identification of landmarks and measurements. Landmarks— MB: metal bar; ZR: intersection between right zygomatico-frontal suture and orbit; ZL: intersection between left zygomatico-frontal suture and orbit; ZA: most lateral aspect of the centre of the right zygomatic arch; AZ: most lateral aspect of the centre of the left zygomatic arch; NC: most lateral aspect of the right piriform aperture; CN: most lateral aspect of the left piriform aperture; ME: most inferior aspect of the mandibular (mand) symphysis; CG: crista galli; JR: intersection between the lateral contour of the maxillary alveolar process and the lower contour of the right maxillozygomatic process of the maxilla; JL: intersection between the lateral contour of the maxillary alveolar process and the lower contour of the left maxillozygomatic process of the maxilla; AG: lateral and inferior border of the right antegonial notch; GA: lateral and inferior border of the left antegonial notch; A: point A; U6: most prominent lateral point on the buccal surface of the right maxillary first molar; UC: buccal cusp tip of the right maxillary first molar; 6U: most prominent lateral point on the buccal surface of the left maxillary first molar; CU: buccal cusp tip of the left maxillary first molar; U1: midpoint between the maxillary central incisors at the level of the incisal edges; L6: most prominent lateral point on the buccal surface of the right mand first molar; LC: buccal cusp tip of the right mand first molar; 6L: most prominent lateral point on the buccal surface of the left mand first molar; CL: buccal cusp tip of the left mand first molar; L1: midpoint between the mand central incisors at the level of the incisal edges; ANS: anterior nasal spine. Measurements—occlusal plane: line bisecting UC and LC as well as CU and CL; molar relationship right: distance U6 to L6 along the occlusal plane; molar relationship left: distance 6U to 6L along the occlusal plane; max intermolar width: distance U6 to 6U along the occlusal plane; mand intermolar width: distance L6 to 6L along the occlusal plane; denture midline: distance U1 to L1 along the occlusal plane; nasal width: distance NC to CN; max width: distance JR to JL; mand width: distance AG to GA; Max–mand difference: the difference between the distances AG to GA and JR to JL; facial width: distance ZA to AZ; frontal convexity right: distance JR to the line connecting AG and ZR; frontal convexity left: distance JL to the line connecting GA and ZL; max–mand midline: angle between ANS–ME and the perpendicular to ZL–ZR; postural symmetry: the difference between angle ZL–GA–AZ and angle ZR–AG–ZA; occlusal plane tilt: the difference between distances UC to ZL–ZR and CU to ZL–ZR; molar to jaws right: distance L6 to JR–AG; molar to jaws left: distance 6L to JL–GA; denture to jaw midline: distance L1 to ANS–ME.

Bonferroni corrections (Woodward, 2004). Sample means, SDs, and ranges of each respective linear and angular measurement (Table 1) were interpreted as PA cephalometric norms for adolescent Kuwaitis. Pairwise comparisons were made between the Kuwaiti norms and the respective

available norms. Prior to comparison, available linear norms were multiplied by 0.92 to adjust for a likely 8 per cent magnification (Ricketts, 1982; Athanasiou *et al.*, 1992; Uysal and Sari, 2005), with the exception of the norms for molar relation left and right, dental and skeletal midline discrepancies, occlusal plane tilt, and denture to jaw midline (Table 1). A difference of 2.0 degrees or 2.0 mm was considered clinically significant.

Results

Dental norms

The dental arch widths were clinically similar to the normative data of Ricketts and to those for adolescent Austrians, but narrower than the norms for adult Turks (Table 1). The ranges were clinically larger than those proposed by Ricketts, but smaller than those of adult Turks. Compared with adolescent Austrians, the range for mandibular arch width was larger while that for maxillary arch width was smaller. The norms and ranges for molar relationships were clinically similar to those proposed by Ricketts and to those for adult Turks, and the values for midline discrepancy were similar to Ricketts' norms (Table 1).

Skeletal norms

All skeletal width dimensions were clinically larger than those proposed by Ricketts, but similar to those for adolescent Austrians and adult Turks, with the exception that the adult Turks demonstrated a clinically wider mandible and face (Table 1). The ranges of all measurements were clinically larger than those proposed by Ricketts. While the ranges for maxillary and facial width were clinically larger than the ranges for adolescent Austrians and adult Turks, the differences in range varied regarding nasal and mandibular width (Table 1). The norms for frontal convexity were clinically larger than those of Rickets, with clinically larger ranges. While only the norm for right frontal convexity was clinically smaller than that for adult Turks, the ranges of both right and left frontal convexity were clinically smaller (Table 1). The norms for midline discrepancy and postural symmetry were clinically similar to those of Ricketts, but the ranges were clinically larger (Table 1).

Dental to skeletal norms

With the exception of the two measurements for molar to jaw relationship, the norms for dental to skeletal relationships were clinically similar to those of Ricketts, and all were clinically similar to those available for adult Turks (Table 1). All ranges except for those for denture to jaw midline were clinically larger than the values proposed by Ricketts. While the range for occlusal plane tilt was clinically larger than the value for adult Turks, the ranges for molar to jaw relationship were clinically smaller.

Table 1 Means, standard deviations (SDs), and ranges [minimum (min) and maximum (max)] of posteroanterior cephalometric parameters of 13- to 14-year-old Kuwaiti boys and girls with almost ideal occlusion (Kuwaiti norms) and similar published data from other populations mand, mandibular.

Measurements	Kuwaiti norms (N = 159)				Ricketts norms [N = not applicable (NA)]				Turkish norms (N = 100)				Austrian norms (N = 58)			
	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Dental																
Width																
Mand intermolar width (mm)	52.0	58.9	46.9	2.66	50.1	52.1	48.1	NA	54.7	62.6	46.9	3.68	53.6	58.9	50.9	4.63
Max intermolar width (mm)	54.1	61.5	48.7	2.74	52.9	54.9	50.9	NA	56.8	63.0	48.8	3.45	55.2	61.9	45.5	3.44
Relationship																
Molar relationship left (mm)	1.9	3.3	−1.0	0.69	1.5	3	0	NA	1.7	5	0	1.62				
Molar relationship right (mm)	2.1	4.3	−1.3	0.82	1.5	3	0	NA	1.4	5	0	1.28				
Symmetry																
Midline discrepancy (mm)	−0.2	1.1	−1.5	0.48	0	1.5	0	NA								
Skeletal																
Width																
Nasal width (mm)	29.0	38.4	22.4	2.85	26.2	28.2	24.2	NA	29.8	39.6	22.1	3.85	27.8	41.3	20.2	3.7
Max width (mm)	62.7	80.3	49.9	4.88	59.4	62.4	56.4	NA	61.3	77.3	54.3	4.85	61.8	71.1	56.1	3.49
Mand width (mm)	82.4	96.9	70.9	5.39	75.7	78.7	72.7	NA	90.2	113.2	79.1	7.36	82.8	92.8	72.7	5.1
Mand–max difference (mm)	19.7	33.0	8.4	4.72	16.3	19.3	13.3	NA								
Facial width (mm)	125.8	145.0	108.0	7.43	116.4	119.4	113.4	NA	128.4	143.5	116.8	7.25				
Relationship																
Frontal convexity, left (mm)	11.7	18.9	6.9	2.16	9.2*	10.7	7.7	NA	13.6	22.1	4.6	3.35				
Frontal convexity, right (mm)	11.2	17.3	6.2	2.27	9.2*	10.7	7.7	NA	14.1	23	4.1	3.23				
Symmetry																
Midline discrepancy (mm)	0.3	6.5	−6.3	1.9	0	2	0	NA								
Postural symmetry ()	0.5	8.8	−4.2	2.31	0	2	0	NA								
Dental to skeletal																
Occlusal plane tilt (mm)	0.5	4.4	−3.8	1.61	0	2	0	NA	1.4	5	0	1.28				
Molar to jaw, left (mm)	10.5	16.4	5.2	2.18	5.8*	7.5	4.1	NA	9.4	22.1	4.6	3.31				
Molar to jaw, right (mm)	10.6	15.4	5.0	2.22	5.8*	7.5	4.1	NA	9.6	18.4	3.7	3.3				
Denture to jaw midline (mm)	−0.4	1.2	−2.0	0.62	0	1.5	0	NA								

*Skeletal age 8.5.

Gender differences

Following Bonferroni correction, no gender differences were found.

Discussion

Despite efforts to achieve population proportions among subjects with untreated almost ideal occlusions, those from the administrative areas of Ahmadi and Jahra and the private school stratum were underrepresented in the sample due to non-participation. However, no differences were observed in skeletal and dentoalveolar parameters among the subjects from the seven strata ($P > 0.05$). The data from this study may therefore allow inferences to the background population and hence serve as valid PA cephalometric norms for adolescent Kuwaitis of an age comparable with the start of comprehensive orthodontic treatment.

PA cephalometric information from different ethnic groups of similar age and representativity is limited. For that reason, statistical analyses were not performed to compare this data to the norms proposed by Ricketts or to the available data for adolescent Austrians (Athanasiou *et al.*, 1992) and adult Turks (Uysal and Sari, 2005). However, pairwise comparisons were still considered meaningful, since they might serve as an indication regarding whether currently published norms are likely to be valid, and whether there is a need for different norms for different ages and ethnic groups. For that purpose, mean values and ranges that differed by at least 2 mm or 2 degrees were considered to be clinically significant.

The adolescent Kuwaiti norms for dental arch width are similar to the norms of Ricketts as well as to the available data for adolescent Austrians. In keeping with the Austrian sample, the ranges were considerably larger than those proposed by Ricketts. The fact that the adult Turkish sample demonstrated a slightly wider dental arch may reflect changes during the developmental period from adolescence to adulthood. Assuming an average bucco-lingual maxillary first molar width of 10.7 mm (Howe *et al.*, 1983), the minimum maxillary intermolar width in the Kuwaiti sample of 48.7 mm (Table 1) corresponds to a lingual intermolar width of 48.7 mm – (10.7 mm × 2) = 27.3 mm. Moreover, 15.7 per cent of the adolescent Kuwaitis with untreated ideal occlusions demonstrated a maxillary intermolar width of 51.4 mm or less, which may be comparable with a distance between the lingual surfaces of 30 mm. These figures suggest that the decision to perform bimaxillary expansion for arch length gain in adolescent patients with a lingual intermolar width of 30 mm or less (McNamara, 2002) should also be based on other considerations.

The present study used the buccal prominence of the maxillary molars as a reference for dental arch width and the buccal prominence of the maxillary and mandibular first molars as references for molar relationships. The fact that some subjects demonstrated a negative value for molar relationship may reflect compensation for transverse skeletal discrepancies expressed as buccal inclination of the maxillary and lingual inclination of the mandibular molars. The measurement error of approximately 0.4 mm in this study can also contribute to occasional negative readings. The high degree of dental symmetry in this sample is a reflection of the selection criteria.

All skeletal width dimensions were clinically larger than Ricketts' norms, and similar to those for adolescent Austrians. The clinically wider mandible and face of adult Turks may reflect growth changes from adolescence to adulthood. In keeping with the data for adolescent Austrians and adult Turks, all ranges were clinically larger than those proposed by Ricketts. The fact that some ranges were clinically larger in the Austrian adolescents and adult Turks than in the sample of adolescent Kuwaitis may reflect post-adolescent growth and the inclusion of some cases with malocclusions in the two samples.

Vanarsdall (1999) cautioned that orthodontic compensation for maxillo-mandibular discrepancies larger than 5 mm relative to Ricketts' norms is likely to be associated with adverse periodontal responses, unstable dental camouflage, and less than optimal dentofacial aesthetics. The critical figure following adjustment for magnification should therefore be 21.3 mm in young adolescents (Table 1). However, a total of 47 subjects in this sample, or almost 30 per cent of 13- to 14-year-old Kuwaitis with an untreated ideal occlusion, presented with a maxillo-mandibular difference larger than 21.3 mm. A periodontal, functional, and aesthetic follow-up examination of those subjects might therefore be of clinical interest.

The average subject in this sample had a larger frontal convexity than that proposed by Ricketts. In keeping with the findings in adult Turks (Uysal and Sari, 2005), the ranges were also clinically larger. The findings may therefore challenge the statement that a convexity outside the range from 7.7 to 10.7 mm indicates a transverse skeletal discrepancy (Ricketts *et al.*, 1982).

The range in mandibular midline deviation relative to the maxilla was clinically larger than the normative data proposed by Ricketts (Table 1), suggesting a potential for development of an ideal occlusion with coinciding midlines within patterns of skeletal asymmetry that are larger than previously suggested by Ricketts *et al.* (1982). The present Kuwaiti norms also demonstrate a clinically larger range in occlusal tilt relative to the norms of Ricketts (Table 1). The fact that this range was clinically similar to Ricketts' norms (Table 1) might indicate that part of the dental compensation for transverse skeletal discrepancy is associated with a change in tilt of the occlusal plane.

Ricketts *et al.* (1982) suggested that a distance from the buccal surface of the mandibular molars to the respective lines from JR to AG and from JL to GA (Figure 1) larger than 7.5 mm allows room for buccal expansion of the

mandibular arch. The finding that the average adolescent Kuwaiti with natural development of an ideal occlusion has a distance of 10.5 mm may clearly be used to challenge that interpretation.

The average subject in this sample had a postural asymmetry similar to Ricketts' recommendation for acceptable positioning in the cephalostat, but the range was clinically larger (Table 1). However, the fact that the maximum deviation in one direction was less than the acceptable deviation of 10 degrees (Ishiguro *et al.*, 1974) (Table 1) suggests clinically acceptable positioning in the cephalostat.

Conclusions

The present data demonstrate means and ranges of commonly used PA cephalometric parameters for a large, representative sample of adolescent Kuwaitis with natural development of almost ideal occlusion, and are therefore valid as norms for that population. Comparable information from different ethnic groups of similar age and representativity is very limited. However, the findings suggest minimal gender differences at adolescence, with considerably larger ranges of the various parameters than those proposed in Rickets' analysis.

Funding

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