Title	Comprehensive cephalometric analyses of 10 to 14-year old southern Chinese
Author(s)	Wu, JYC; Hagg, U; Wong, RWK; McGrath, C
Citation	The Open Anthropology Journal, 2010, v. 3, p. 85-95
Issued Date	2010
URL	http://hdl.handle.net/10722/66756
Rights	Creative Commons: Attribution 3.0 Hong Kong License

Open Access

Comprehensive Cephalometric Analyses of 10 to 14-Year Old Southern Chinese

John Y.C. Wu[a], Urban Hägg*[,b], Ricky W.K. Wong[c] and Colman McGrath[d]

[a]*Doctorate Degree Candidate;* [b]*Chair Professor in Orthodontics;* [c]*Associate Professor in Orthodontics;* [d]*Professor in Dental Public Health, Faculty of Dentistry, the University of Hong Kong, Hong Kong SAR, China*

Abstract: *Aims:* (Part 1) To review the orthodontic literature and assess which cephalometric methods were the most frequently used, and (Part 2) provide comprehensive cephalometric reference values for 10 to 14-year old southern Chinese.

Materials and Methods: (Part 1) The cephalometric methods used in the orthodontic literature over a ten-year period (1999-2008) were investigated. (Part 2) The material comprised lateral cephalometric radiographs of a random sample of 200 males and 205 females 12-year old southern Chinese in Hong Kong. The radiographs were digitized twice with the Computer Assisted Simulation System for Orthognathic Surgery (CASSOS) program. Referenced values for 10-, 11-, 13- and 14-year old were obtained by extrapolation of data from measurements of templates of longitudinal sample of Swedish.

Results: (Part 1) The four most frequently used cephalometric methods were those devised by Björk, Jacobson, Pancherz and McNamara. (Part 2) Reference population values for those four methods of 12-year old southern Chinese children were collected from three of our previous publications, and for the McNamara analysis expanded to include 10 to 14-year old children. At the age of 12-year there were statistically-significant gender differences for the majority of the cephalometric variables based on linear measurements, varying from -0.4 to +0.8 standard deviation (SD)-scores, and about half of the angular measurements, varying from -0.4 to +0.4 SD-scores.

Conclusion: Four cephalometric methods presented over a 10-year period were more commonly used than the other cephalometric methods. The use of specific cephalometric standards of those four methods for southern Chinese, separate for gender, seem to be justified.

Keywords: Cephalometrics, Diagnosis, Chinese.

INTRODUCTION

Cephalometric analysis is the most commonly used method to assess the dentofacial morphology, which it is important in orthodontic treatment planning and evaluation of treatment changes [1]. A large number of cephalometric methods and analyses have been suggested in the orthodontic literature [1] since the introduction of cephalometry in 1931 [2,3]. Cephalometrics is also important in the field of anthropology for understanding of the ethnic dentofacial characteristics of various populations [4,5]. Because of the variation in craniofacial features in different populations, for appropriate application of any cephalometric analysis, it should preferably be used with norms derived from a population similar to that of the actual orthodontic patients with regard to ethnic group, gender and age. Cephalometric reference values for the various methods have been obtained from various sources, such as population and selected samples. Population norms are obtained from a random sample of a defined population, and selected norms are based on e. g. samples with 'beautiful faces', 'balanced faces', subjects with Class I occlusion [1,6-9] including those with minor malocclusions. Since orthodontic patients nowadays range from juveniles to senior citizens and come from various ethnic groups, a wide range of representative norms would be ideal. Nevertheless, most patients undergo orthodontic treatment at 10 to 14-years of age, subsequently priority should be given to obtain norms for this age group. The aims of this paper were to define the most frequently used cephalometric methods, and provide comprehensive cephalometric reference values for southern Chinese.

MATERIAL AND METHODS

Part I

A PubMed search of the use of cephalometric analysis within orthodontics was undertaken using the keyword 'cephalometric analysis' and 'orthodontics' and the search limited to within the past 10 years (1999-2008) which indicated the current usage by researchers and clinicians. Any cephalometric method used for orthodontic diagnosis, treatment planning and evaluation, and for establishing cephalometric norms were included. Animal studies, studies on syndromes, cleft, sleep apnea, case reports and literature reviews were excluded.

Part II

Lateral cephalograms had been obtained from 409 12-year old southern Chinese school children who were a part of a partially stratified random sample from ten schools in

*Address correspondence to this author at the Orthodontics, Faculty of Dentistry, the University of Hong Kong, Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong SAR, China; E-mail: euohagg@hkusua.hku.hk

1874-9127/10 2010 Bentham Open

Table 1. Demographic Data on the Samples

		Age			Range	
	n	Mean	SD	Median	Minimum	Maximum
Male	200	12.4	0.60	12.5	11.0	13.0
Female	205	12.5	0.38	12.6	11.9	13.0
Difference[a]		-0.1		-0.1	-0.9	0.0

[a]Sex difference was not statistically significant.
Publishing with the approval of by AJODO and Angle Orthod.

Hong Kong [10]. Therefore the sample included subjects with a range of different of occlusions. Two females with previous or current orthodontic treatment were excluded, and the final sample consisted of 200 males and 205 females (Table **1**). The study had been approved by the Ethics Committee of Faculty of Dentistry, The University of Hong Kong.

RADIOGRAPHIC TECHNIQUE

The method of obtaining the lateral cephalograms in natural head posture has been described in detail elsewhere [10-13].

CEPHALOMETRIC METHODS

The landmarks and reference lines for four included cephalometric analysis: modified Björk analysis [14] and Wits appraisal [6], Sagittal and Vertical Occlusal (SO and VO) analysis [15,16], and McNamara analysis [7], are summarized in Tables **2-4**, and Fig. (**1**). Initially, the radiographs were traced manually and then rechecked by digitization and application of the program CASSOS (CASSOS Clinical Evaluation Version 2004, Soft Enable Technology Limited, China). All radiographs were traced and digitized twice by the same investigator, taking the average of each of the investigated cephalometric variables

Table 2. Landmarks (Fig. 1) Devised by four Cephalometric Methods (Björk [3], Jacobson [4], SO [5]/ VO [6] and McNamara [7])

Variable	**Variable**	**Definitions**	**Björk**	**Wits**	**SO/VO**	**McNamara**
Abbreviation	**Landmark**					
S	Sella	The center of sella turcica	X		X	X
N	Nasion	The most anterior limit of suture nasofrontalis	X		X	X
Ba	Basion	The posterior interior point on the occipital bone at the anterior margin of the foramen magnum	X			
Po	Porion	The most superior point of the external auditory canal				X
Or	Orbitale	The most inferior point on the infraorbital rim				X
ANS	Anterior Nasal Spine	The apex of the anterior nasal spine	X		X	X
PNS	Posterior Nasal Spine	The apex of the posterior nasal spine	X		X	X
A	A-point	The most posterior point on the concave anterior border of the maxillary alveolar process	X	X	X	X
B	B-point	Innermost point on the anterior contour of the mandible	X	X		
Pg	Pogonion	The most anterior point on the mandibular symphysis	X		X	X
Me	Menton	The most inferior point on the mandibular symphysis	X		X	X
Go	Gonion	The lowest posterior and most outward point of the angle of the mandible	X			
Co	Condylion	The most superoposterior point on the curvature of the condylar head			X	X
Is	Incisor superior	Incisal tip of the most prominent maxillary central incisor	X		X	X
Ii	Incisor inferior	Incisal tip of the most prominent mandibular central incisor	X		X	X
Mi	Molar inferior	Mesial contact point of mandibular permanent first molar			X	
Mic	Molar inferior cusp	Molar inferius mesial cusp, mesio-buccal cusp tip of mandibular permanent first molar			X	
Ms	Molar superior	Mesial contact point of maxillary permanent first molar			X	
Msc	Molar superior cusp	Molar superior mesial cusp, mesio-buccal cusp tip of maxillary permanent first molar			X	

Table 3. Angular Measurements Devised by three Cephalometric Methods (Björk [3], SO [5]/ VO [6] and McNamara [7])

Variable	Definitions	Björk	SO/VO	McNamara
NSBa	The angle formed by the anterior (NS) and posterior skull base (SBa)	X		
SNA	The angle formed by the SN and NA lines	X		X
SNB	The angle formed by the SN and NB lines	X		
ANB	The angle formed by the AN and NB lines	X		
SNPg	The angle formed by the SN and NPg lines	X		
SN/MnPl (ML/NSL)	The angle formed by the SN line and the mandibular plane	X	X	
FH/MdPl	The angle formed by the FH line and the mandibular plane			X
SN/MxPl (NL/NSL)	The angle formed by the SN line and the maxillary plane	X	X	
Mx/MnPl	The angle formed by the maxillary and mandibular planes	X		X
UI/MxPl	The angle formed by the upper incisor and the maxillary plane	X	X	
LI/MnPl	The angle formed by the lower incisor and the mandibular plane	X	X	
UI/LI	The interincisal angle formed by the upper incisor and the lower incisor	X		
Facial Axis Angle	A line is constructed from the basion to nasion (NBa). A second line (the facial axis) is constructed from the most posterosuperior aspect of the pterygomaxillary fissure(PTM) to constructed gnathion (the intersection of the facial plane and the mandibular plane). Measure the facial axis angle (basion-PTM-gnathion) and substract this value from 90^{o}. Zero degree (90^{o}) is the reference used for this measure [7].			X
OLs/NSL	The angle formed the upper occlusal line and the SN line		X	
OLi/NSL	The angle formed the lower occlusal line and the SN line		X	

Table 4. Linear Measurements Devised by four Cephalometric Methods (Björk [3], Jacobson [4], SO [5]/ VO [6] and McNamara [7])

Variable	Definitions	Björk	Wits	SO/VO	McNamara
LI to A-Pg	The distance from the tip of the lower incisor to the A-Pg line	X			X
A,B on OP	The distance between the projections from A and B points to the functional occlusal plane		X		
UFH	Upper facial height: the distance from Nasion to MxPl	X			
LFH	Lower facial height: the distance from MxPl to Menton	X		X	X
UL to E-line	The distance from the upper lip to the esthetic line	X			
LL to E-line	The distance from the lower lip to the esthetic line	X			
N-A perpendicular	A vertical line is constructed perpendicular to the Frankfort horizontal and extended inferiorly from nasion. The perpendicular distance is measured from point A to the nasion perpendicular				X
Co-Gn	A line is measured from the condylion to the anatomic gnathion				X
Co-A	A line is measured from the condylion to the point A				X
MxMd –diff	Maxillomandibular differential, effective mandibular length minus the effective midface length				X
Pg-N	The perpendicular distance is measured from the pogonion to the nasion perpendicular				X
UI-A	A point A perpendicular is constructed parallel to the nasion perpendicular throught point A. The perpendicular distance is measured from the most anterior surface of the upper incisor to the point A perpendicular				X
A-OLp	Sagittal linear position of maxillary base			X	
Pg-OLp	Sagittal linear position of mandibular base			X	

(Table 4). Contd…..

Variable	Definitions	Björk	Wits	SO/VO	McNamara
Is-OLp	Sagittal linear position of maxillary incisor			X	
Ii-OLp	Sagittal linear position of mandibular incisor			X	
Ms-OLp	Sagittal linear position of maxillary 1st molar			X	
Mi-OLp	Sagittal linear position of mandibular 1st molar			X	
Ii-OLs	Overbite			X	
Msc-NL	Vertical linear position of maxillary 1st molar			X	
Mic-ML	Vertical linear position of mandibular 1st molar			X	
A-Pg	Sagittal jaw base relationship			X	
Is-Ii	Overjet			X	
Ms-Mi	Molar relationshiop			X	

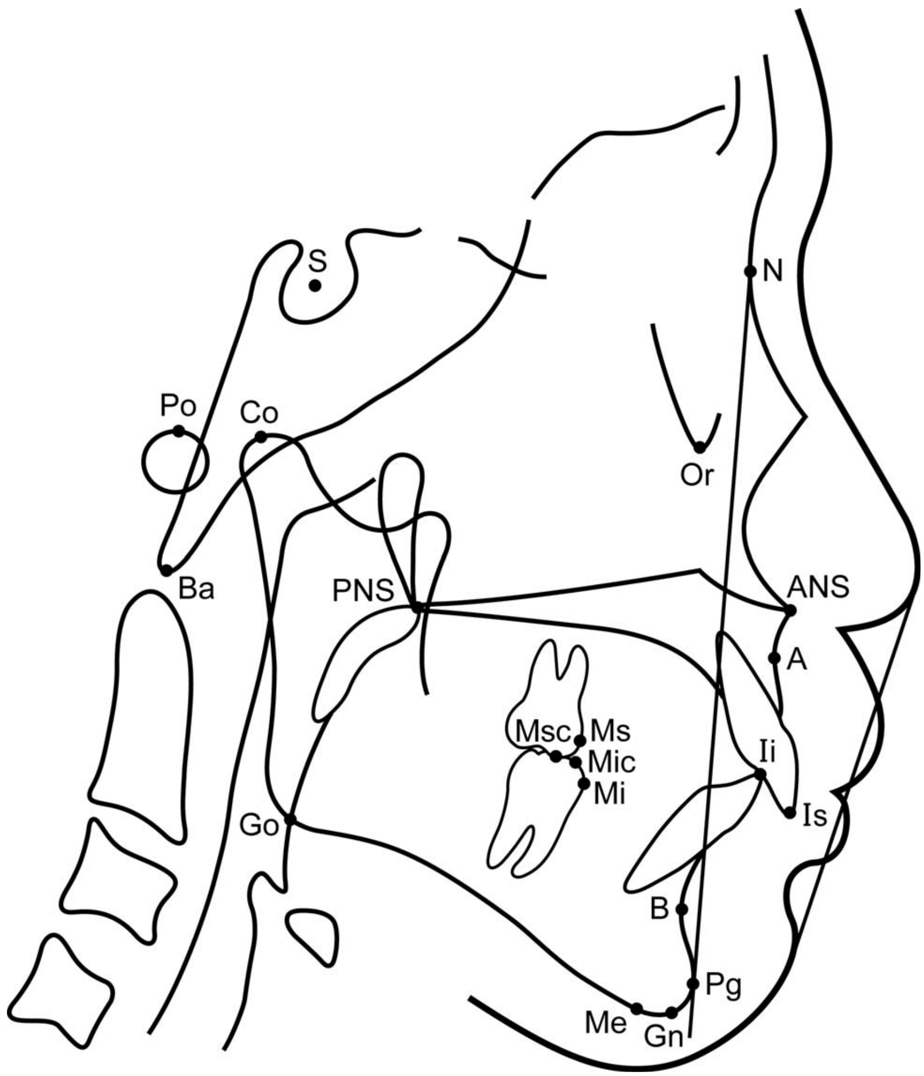

Fig. (1). Cephalometric landmarks, for definition, see Table **2**.

in order to reduce the error in landmark identification [17]. Besides the actual population reference values for 12-year old children, additional 'reference values' for the ages 10-, 11-, 13- and 14-year, and increments for the age period 10 to 14 years, were extrapolated from increments obtained from the analysis of templates obtained from Scandinavian standards [18,19]. It is assumed that the growth increments between the two populations are similar.

STATISTICAL ANALYSIS

T-test for independent samples was used, and the levels of statistical significance were p<.05, p<.01 and p<.001. The gender differences at the age of 12-year were also presented in standard deviation-score [20]; i. e. for a certain variable A:

SD-score of gender difference of variable A:

$$= \frac{\text{Mean of gender difference}}{(\text{SD of A for males} + \text{SD of A for females})/2}$$

METHOD ERROR

There was no statistically-significant difference between the method error of the tracing by manual and digitizer. Finally, all the radiographs were digitized twice with the program CASSOS. The data were averaged and analyzed by SPSS.

Method errors (M.E.) were calculated by Dahlberg's formula [21], $M.E. = \sqrt{\frac{\sum d^2}{2n}}$. Where $\sum d^2$ is the sum of the squared differences between the two mean values, and n is the number of double measurements. The method errors for linear and angular measurement were not statistically significant, and did not exceed 0.5mm and 0.7 ^{o} respectively for any variables.

RESULTS

Part I

The results of the literature search on the utilization of various lateral cephalometric methods are presented in Table **5**. There was 10 cephalometric methods used in 120 publications during 1999-2008, of which five were used more frequently (96/120 papers), being Wits appraisal [6], Ricketts analysis [22], McNamara analysis [7], Björk/Downs modified analysis [14,23] and Sagittal and Vertical Occlusal (SO and VO) analysis [15,16]. Since Ricketts analysis [22] is a superimposition method used for analysis of individual patients rather than a numerical description of dento-facial morphology and changes, it was not included in the second part of this paper.

Part II

There was no statistically-significant difference between the ages of females and males (Table **1**). At the age of 12-year the gender difference of the linear measurements reached statistically significant level for 21 out of 29 variables of which 4 out of 5 were included in Björk modified analysis (Table **6**), 1 out of 1 in Wits appraisal (Table **6**), 12 out of 15 in SO/VO analysis (Table **7**) and 4 out 8 in McNamara analysis (Table **8**). Angular measurements were not a part of the Wits appraisal, and the gender differences reached statistically significant level for 9 out of 15 variables of which 5 were included in Björk modified analysis (Table **6**), 2 in SO/VO analysis (Table **7**) and 2 in McNamara analysis (Table **8**). Expressed in SD-scores, the gender differences for linear measurements varied from -0.4 to +0.8 SD-scores, and for angular measurements from -0.4 to +0.4 SD-scores.

In modified Björk analysis [14] 7 variables were significantly larger in males and 2 variables were significantly larger in females (Table **6**), showing larger mandibular prognathism in 12-year old females. There was statistically significant gender difference for Wits appraisal (Table **6**). For SO/VO analyses [15,16], all variables were larger in males and all sagittal variables except Ms-Mi (SO-analysis) and 4 out of the 6 vertical variables (VO-analysis) showed statistically significant gender differences (Table **7**). For McNamara analysis [7], there was statistically-significant gender difference for 6 variables (Table **8**). Three variables were significantly larger in males: effective midfacial length, lower face height, and mandibular plane angle, whereas three variables were significantly smaller in males, maxillomandibular difference, facial axis angle, and pogonion to nasion perpendicular.

Reference Values and Changes for Age 10 to 14-Years

The mean values and changes for the cephalometric variables for 10 to 14-years, separate for sex, are given in Tables **6**, **7** and **8**. With increase in age, the maxillary and mandibular prognathism increased assessed with linear and angular measurements (Tables **6-8**), but the jaw-base did not change for females with A-Pg (Table **7**). The lower face height increased in both sexes expressed with LFH (Table **6**), Sp-Me (Table **7**) and ANS-Me (Table **8**). The distance of both lips to the E-line was reduced with a similar amount in both sexes (Table **6**).

DISCUSSION

Only 10 cephalometric methods were used in the orthodontic literature over the last decade, and 5 of those were used in 3 out of 4 papers (Table **5**). Two of those cephalometric methods, the SO/VO analysis [15,16] and the Pitchfork analysis [24] were not among the 23 cephalometric methods included in the cephalometric textbook by Athanasiou [1]. Of the 4 most frequently used cephalometric methods which make use of reference values only one original method published reference vales obtained from a population, but limited to males only, and two age groups [14]. For two of the other methods Wits appraisal [6] and McNamara analysis [7] the reference values have been obtained from 'selected' samples, such as 'pleasant faces', 'balanced face'

Table 5. Distribution of Cephalometric Methods Used in the Orthodontic Literature 1999 – 2008 [8]

Cephalometric analysis	Bjork (Downs)	Harvold	Holdaway	Wits	Jarabak	McNamara	Pancherz	Pitchfork	Ricketts	Riolo	Steiner	Tweed
Cephalometric norms studies	4	1	5	8	1	7	0	0	4	2	2	1
Treatment change studies	12	1	4	22	0	11	12	4	10	1	8	0
Total	16	2	9	30	1	19	12	4	16	3	10	1

Table 6. Reference Values and Increments for Modified Björk [3] and Wits [4] Analyses for 10-14 Year Old Males and Females

	Reference Values										Increments					
	Males					Females					Sex diff. at 12 year old			Males	Fe-males	Sex diff.
Variables	10[b]	11[b]	12[a]	13[b]	14[b]	10[b]	11[b]	12[a]	13[b]	14[b]	Mean		SD-Score	10-14[c)]	10-14[c)]	10-14[c)]
Björk Analysis																
Angular measurements																
NSBa	129.6	129.0	128.5	128.0	127.7	129.4	129.1	128.8	128.6	128.8	-0.3		-0.1	-1.9	-0.6	-1.3
SNA	81.3	81.5	81.8	82.0	82.1	81.2	81.6	82.0	82.4	82.3	-0.2		-0.1	0.8	1.1	-0.3
SNB	77.8	78.2	78.6	78.9	79.2	78.2	78.9	79.6	80.3	80.7	-1.0	**	-0.3	1.4	2.5	-1.1
ANB	3.5	3.3	3.2	3.1	2.9	3.0	2.7	2.4	2.1	1.7	0.9	***	0.4	-0.6	-1.3	0.7
SNPg	77.7	78.2	78.7	79.2	79.6	78.5	79.2	80.0	80.7	80.9	-1.3	***	-0.4	1.9	2.4	-0.5
SN/MnPl	36.3	35.8	35.3	34.8	34.3	35.0	34.3	33.6	33.0	32.6	1.7	**	0.3	-2.0	-2.4	0.4
SN/MxPl	9.4	9.3	9.1	8.9	8.9	9.5	9.3	9.0	8.7	8.5	0.1		0.0	-0.5	-1.0	0.5
MxPl/MnPl	26.9	26.6	26.2	25.9	25.4	25.5	25.1	24.7	24.3	24.1	1.6	**	0.3	-1.5	-1.4	-0.1
UI/MxPl	115.4	116.0	116.6	117.2	117.3	116.6	117.0	117.4	117.8	117.4	-0.8		-0.1	1.9	0.8	1.1
LI/MnPl	95.9	96.2	96.5	96.7	96.9	97.1	96.9	96.8	96.6	96.2	-0.3		0.0	1.0	-0.9	1.9
UI/LI	121.7	121.2	120.7	120.1	120.4	120.9	121.0	121.2	121.4	122.2	-0.5		-0.1	-1.3	1.3	-2.6
Linear measurements																
Li to APg	5.3	5.3	5.4	5.4	5.4	5.2	5.2	5.3	5.3	5.3	0.1		0.0	0.1	0.1	0.0
UFH	52.4	53.6	54.7	55.9	57.2	52.6	53.0	53.5	53.9	54.2	1.3	**	0.4	4.8	1.6	3.2
LFH	62.8	63.6	64.4	65.1	67.0	61.5	62.3	63.1	63.9	65.2	1.2	**	0.3	4.2	3.7	0.5
UL to E-line	4.0	3.4	2.8	2.1	1.3	2.2	1.6	1.1	0.5	0.1	1.7	***	0.8	-2.7	-2.1	-0.6
LL to E-line	4.3	3.8	3.3	2.7	2.2	2.6	2.1	1.6	1.1	0.8	1.7	***	0.7	-2.1	-1.8	-0.3
Wits Appraisal																
A, B on OP	-3.6	-3.7	-3.9	-4.1	-4.4	-3.8	-4.2	-4.6	-5.0	-5.2	0.7	**	0.3	-0.8	-1.4	0.6

[a]Reference values in this table with approval of the publisher of the original paper [10]; [b]Reference values based on increments obtained from another study [1,2]; [c]Increments 10 to 14 years.
*p<0.05; **: p<0.01; ***: p<0.001.

Table 7. Reference Values for SO [5] and VO [6] Analyses for 10-14 Year Old Males and Females

	Reference Values										Increments					
	Males					Females					Sex diff. at 12 year old			Males	Females	Sex diff.
Variables	10[b]	11[b]	12[a]	13[b]	14[b]	10[b]	11[b]	12[a]	13[b]	14[b]	Mean		SD-Score	10-14[c)]	10-14[c)]	10-14[c)]
Angular measurements																
NL/NSL	9.6	9.4	9.1	8.8	8.6	9.3	9.2	9.0	8.8	8.8	0.1		0.0	-1.0	-0.5	-0.5
ML/NSL	36.7	36.0	35.3	34.7	34.3	34.6	34.1	33.6	33.1	32.6	1.7	**	0.3	-2.4	-2.0	-0.4
OLs/NSL	22.5	22.1	21.6	21.2	20.8	22.3	21.3	20.4	19.4	18.7	1.2	**	0.3	-1.7	-3.6	1.9
OLi/NSL	16.6	16.2	15.9	15.6	15.3	17.1	16.3	15.4	14.5	14.1	0.5		0.1	-1.3	-3.0	1.7

(Table 7). Contd…..

Linear measurements															
A-OLp	74.7	75.4	76.1	76.9	77.2	73.3	73.7	74.1	74.5	75.5	2.0	***	0.5	2.5	2.2	0.3
Pg-OLp	79.4	80.8	82.3	83.7	84.1	80.6	81.0	81.3	81.6	82.7	1.0	*	0.2	4.7	2.1	2.6
A-Pg	-4.7	-5.4	-6.2	-6.8	-6.9	-7.3	-7.3	-7.2	-7.1	-7.2	1.0	**	0.3	-2.2	0.1	-2.3
Is-OLp	86.1	87.1	88.1	89.0	89.3	85.3	85.6	85.9	86.2	87.1	2.1	***	0.5	3.2	1.8	1.4
Ii-OLp	81.7	82.8	83.8	84.8	85.2	81.3	81.7	82.1	82.6	83.6	1.7	***	0.4	3.5	2.3	1.2
Is-Ii	4.4	4.3	4.3	4.2	4.1	4.0	3.9	3.8	3.6	3.5	0.4	**	0.3	-0.3	-0.5	0.2
Ms-OLp	51.7	53.3	55.0	56.6	57.1	52.4	53.1	53.9	54.6	55.6	1.1	**	0.3	5.4	3.2	2.2
Mi-OLp	54.5	56.1	57.7	59.3	59.8	55.4	56.1	56.8	57.5	58.5	0.9	*	0.2	5.3	3.1	2.2
Ms-Mi	-2.8	-2.8	-2.7	-2.7	-2.7	-3.0	-3.0	-2.9	-2.9	-2.9	0.2		0.1	0.1	0.1	0.0
Sagittal measurements															
Ii-OLs	2.3	2.3	2.2	2.1	2.1	2.2	2.0	1.8	1.6	1.6	0.5	**	0.3	-0.2	-0.6	0.4
Sp-Me	62.8	63.6	64.4	65.2	66.4	61.6	62.4	63.1	63.9	65.7	1.2	**	0.3	3.6	4.1	-0.5
Is-NL	28.3	28.6	28.9	29.2	29.6	27.8	27.8	27.7	27.6	28.3	1.2	***	0.4	1.3	0.5	0.8
Ii-ML	40.8	41.0	41.3	41.6	42.1	39.3	39.7	40.1	40.5	41.4	1.2	***	0.5	1.3	2.1	-0.8
Msc-NL	21.0	21.4	21.9	22.3	22.9	20.5	21.1	21.6	22.1	23.2	0.3		0.1	1.9	2.7	-0.8
Mic-ML	30.6	31.2	31.8	32.4	33.0	30.6	31.0	31.4	31.8	32.8	0.4		0.2	2.4	2.2	0.2

[a]Reference values in this table with approval of the publisher of the original paper [9]; [b]Reference values based on increments obtained from another study [1,2]; [c]Increments 10 to 14 years.
*p<0.05; **: p<0.01; ***: p<0.001.

Table 8. Reference Values for McNamara [7] Analysis for 10-14 Year Old Males and Females

	Reference Values										Increments					
	Males					Females					Sex diff. at 12 year old			Males	Females	Sex diff.
Variables	10[b)]	11[b)]	12[a)]	13[b)]	14[b)]	10[b)]	11[b)]	12[a)]	13[b)]	14[b)]	Mean		SD-Score	10-14[c)]	10-14[c)]	10-14[c)]
Angular measurements																
SNA	81.3	81.5	81.8	82.0	82.1	81.2	81.6	82.0	82.4	82.3	-0.2		-0.1	0.8	1.1	-0.3
FH/MdPl	28.5	28.1	27.8	27.5	27.1	27.4	26.8	26.1	25.4	25.0	1.7	*	0.3	-1.4	-2.4	1.0
Facial Axis Angle	-6.4	-5.9	-5.5	-5.1	-5.0	-4.6	-4.2	-3.8	-3.4	-3.0	-1.7	***	-0.4	1.4	1.6	-0.2
Linear measurements														0.0	0.0	0.0
NA_P	-1.0	-0.9	-0.8	-0.7	-0.7	-1.4	-1.0	-0.5	-0.1	0.0	-0.3		-0.1			
Co-GN	110.4	112.2	114.0	115.8	118.9	109.5	111.4	113.3	115.3	116.9	0.7		0.1	8.5	7.4	1.1
Co-A	86.3	87.1	87.9	88.7	90.5	84.0	85.0	85.9	86.9	87.6	2.0	***	0.4	4.2	3.6	0.6
MxMD-DF	24.1	25.1	26.1	27.1	28.5	25.5	26.4	27.4	28.4	29.2	-1.3	*	-0.3	4.4	3.7	0.7
ANS-Me	64.9	65.5	66.1	66.8	68.5	63.2	63.8	64.4	65.0	66.1	1.7	***	0.4	3.6	2.9	0.7
Pg-N	-8.7	-8.1	-7.5	-6.8	-6.4	-7.5	-6.2	-4.9	-3.6	-3.0	-2.6	***	-0.4	2.3	4.5	-2.2
Ul-A	6.9	7.1	7.3	7.5	7.6	7.1	7.5	7.9	8.2	8.4	-0.6		-0.2	0.7	1.3	-0.6
Ll-APg	6.3	6.3	6.4	6.4	6.4	6.2	6.2	6.3	6.3	6.3	0.1		0.0	0.1	0.1	0.0

[a]Reference values of 12-year old children with approval of the publisher of the original paper [8]; [b]Reference values based on increments obtained from another study [1,2]; [c]Increments 10 to 14 years.
*p<0.05; **: p<0.01; ***: p<0.001.

and Class I dental arch relationship with no or minor malocclusion. For the SO and VO analysis [15,16] no reference values were presented.

This paper presented consolidated reference values (Tables **6-8**) based of the most commonly used cephalometric analysis of a large representative population sample of southern Chinese children. The figures representing 12-year old southern Chinese children [25] for all four methods have been published earlier [11-13], but have now been also extended to include references values for 10 to 14-year old Chinese, also for McNamara analysis (Table **8**). Normative standards analysis of 10-,11-,13- and 14-year old were estimated from values obtained from measurement obtained and interpolated from template of Swedish population study [18,19] and subtracted and added, respectively, to the standards of the 12-year old of the present study, in an attempt to provide cephalometric standards for wider age range, separate for gender group. The results of these extrapolations reveals that practically all variables undergo changes from 10 to 14-years of age, and the magnitude of the changes might also differ with gender. Subsequently the size, and magnitude of changes of many of the commonly cephalometric variables are indeed depending on gender and age (Table **6-8**) as well as because of ethnic origin [1,11-13].

Besides a conventional statistical t-test of the differences between variables for the two genders the gender differences among the subjects (Tables **6-8**) were also expressed in SD-scores [20]. In other words, the differences were expressed not only in degrees and millimeters, but also in relation to their variation around the mean of the actual parameter. To use SD-scores to describe the extent to which a certain patient deviated for specific cephalometric variables can also be useful in clinical situations [20,26].

In the modified Björk analysis, there was a statistically-significant difference between males and females for nine out of the sixteen variables (Table **6**). Expressed in SD-scores [20] these gender differences were -0.4 to 0.8. In males, the mandible was significantly more retrognathic, the mandibular plane angle steeper, and lower face height larger. The distances of upper and lower lip to the esthetic line were statistically significant larger in male that means the females have a more fullness of lip. Previous cephalometric studies have indicated that there were some gender differences in the conventional cephalometric parameters among Chinese populations [8,27,28].

The Wits appraisal demonstrated significant gender differences (Table **6**), and there is a ethnic difference, the Chinese being more 'Class III' than Caucasian which is in agreement with previous studies [6,8,10,28-30].

For SO/VO analysis, there were statistically significant gender differences, for all variables being larger in boys than in girls, up to 2 mm or 0.5 SD-score, and 1.7 ^{o} or 0.3 SD-score (Table **7**). In a previous study [12] it was demonstrated that there was statistically significant ethnic differences for the majority of the cephalometric variables included in SO/VO analysis.

For McNamara analysis [7], there was a statistically-significant difference between males and females about half of variables (Table **8**), expressed in SD-scores these gender differences were -0.4 to +0.4. Although there was no significant difference in the length of the mandible between the genders, the mandible was significantly more retrognathic, the mandibular plane and facial axis angle were steeper, and lower face height was larger in males. Since effective maxillary length was larger, maxillo-mandibular difference was also smaller in males. In our previous paper [11] it was reported there were statistically significant ethnic differences for more than half of the cephalometric variables included in the McNamara analysis.

CONCLUSION

The paper provides a summary of various published cephalometric data for convenient use clinically; it seems to be justifiable to use specific Chinese norms, and separate for gender since this study has revealed that there were statistically significant differences in most cephalometric variables between Chinese males and females.

ACKNOWLEDGEMENTS

The lateral cephalograms were part of the oral health survey of 12-year old children collected by Dr. MS Cooke in 1984-85. That study was supported by the research grant no. 335.251.0001 of the Faculty of Dentistry, the University of Hong Kong.

REFERENCES

[1] Athanasiou A. Orthodontic Cephalometry. London: Mosby-Wolfe 1997.

[2] Broadbent BH. A new X-ray technique and its application to orthodontics. Angle Orthod 1931; 1: 45-66.

[3] Hofrath H. Die bedeutung der rontgenfern und abstandsaufnahme fur die diagnostik der kieferanomalien. Fortschr Orthod 1931; 1: 232-58.

[4] Kuramae M, Magnai MB, Boeck EM, Lucato AS. Jarabak's cephalometric analysis of Brazilian black patients. Braz Dent J 2007; 18: 258-62.

[5] Faure J, Oueiss A, Marchal-Sixou C, Braga J, Treil J. Three-dimensional cepahlometric: applications in clinical practice and research. Orthod Fr 2008; 79: 13-30.

[6] Jacobson A. The "Wits" appraisal of jaw disharmony. Am J Orthod 1975; 67: 125-38.

[7] McNamara JA, Jr. A method of cephalometric evaluation. Am J Orthod 1984; 86: 449-69.

[8] Yeong P, Huggare J. Morphology of Singapore chinese. Eur J Orthod 2004; 26: 605-12.

[9] Naranjilla MA, Rudzki-Janson I. Cephalometric features of Filipinos with Angle Class I occlusion according to the Munich analysis. Angle Orthod 2005; 75: 63-8.

[10] Cooke MS, Wei SH. Cephalometric standards for the southern Chinese. Eur J Orthod 1988; 10: 264-72.

[11] Wu J, Hagg U, Rabie ABM. Chinese norms of McNamara's cephalometric analysis. Angle Orthod 2007; 77: 12-20.

[12] Wu J, Hagg U, Wong R, McGrath C. Chinese and Caucasian Norms of Pancherz' Cephalometric sagittal (SO) and vertical (VO) occlusal analyses. Am J Orthod in press.

[13] Wu J, Hagg U, Wong R, McGrath C. Modified Björk analysis of lateral head radiographs of southern Chinese. Open Anthropol J 2009; 2: 40-7.

[14] Björk A. The face in profile - an anthropological X-ray investigation on Swedish children and conscripts. Svensk Tandläkare - Tidskrift 1947; (Suppl 40).

[15] Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. Am J Orthod 1982; 82: 104-13.

[16] Pancherz H. Vertical dentofacial changes during Herbst appliance treatment. A cephalometric investigation. Swed Dent J 1982; (Suppl 15): 189-96.

[17] Miethke RR. Zur Lokalisationsgenauigkeit kephalometrischer Referenzpunkte. Prakt Kieferorthop 1989; 3: 107-22.

[18] Persson M, Thilander B. [Templates for cephalometric analysis]. Invest-Odont AB 1987; 11pp.

[19] Thilander B, Persson M, Adolfsson U. Roentgen-cephalometric standards for a Swedish population. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod 2005; 27: 370-89.

[20] Karlberg P, Taranger J. The Somatic Development of Children in a Swedish Urban Community. Acta Paediatrica Scandinavia 1976; (Suppl 258): 7-76.

[21] Dahlberg G. Statistical methods for medical and biological students. London: Allen & Unwin 1940.

[22] Ricketts RM. Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod 1957; 27: 14-37.

[23] Downs WB. Variations in facial relationship: their significance in treatment and prognosis. Am J Orthod 1948; 34: 812-40.

[24] Johnston LE, Jr. Balancing the books on orthodontic treatment: an integrated analysis of change. Br J Orthod 1996; 23: 93-102.

[25] Cooke MS, Wei SH. A comparative study of southern Chinese and British Caucasian cephalometric standards. Angle Orthod 1989; 59: 131-8.

[26] Kjellberg H, Albertsson Wikland K. A longitudinal study of craniofacial growth in ideopathic short stature and growth hormone-deficient boys treated with growth hormone. Eur J Orthod 2007; 29: 243-50.

[27] Lou ZH. [Roentgenographic cephalometric study of 128 children with normal occlusion in Shanghai (in Chinese)]. Zhonghua Kou Qiang Ke Za Zhi 1981; 16: 100-3.

[28] Moate SJ, Darendeliler MA. Cephalometric norms for the Chinese: a compilation of existing data. Aust Orthod J 2002; 18: 19-26.

[29] Zimmer B, Kubein-Meesenburg D. A comparison of axiographic tracings before and after orthodontic-oral surgical interventions. Fortschr Kieferorthop 1989; 50: 301-8.

[30] So LL, Davis PJ, King NM. "Wits" appraisal in southern Chinese children. Angle Orthod 1990; 60: 43-8.

Received: May 12, 2009 Revised: August 12, 2009 Accepted: August 16, 2009