

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

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**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 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

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**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/MnPI (ML/NSL)  | The angle formed by the SN line and the mandibular plane  | X     | X     |          |
| FH/MdPI           | The angle formed by the FH line and the mandibular plane  |       |       | X        |
| SN/MxPI (NL/NSL)  | The angle formed by the SN line and the maxillary plane   | X     | X     |          |
| Mx/MnPI           | The angle formed by the maxillary and mandibular planes   | X     |       | X        |
| UI/MxPI           | The angle formed by the upper incisor and the maxillary plane   | X     | X     |          |
| LI/MnPI           | 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 subtract this value from 90°. Zero degree (90°) 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 MxPI  | X     |      |       |          |
| LFH               | Lower facial height: the distance from MxPI 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 condyion to the anatomic gnathion  |       |      |       | X        |
| Co-A              | A line is measured from the condyion 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 through 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 1 <sup>st</sup> molar  |       |      | X     |          |
| Mi-OLp   | Sagittal linear position of mandibular 1 <sup>st</sup> molar |       |      | X     |          |
| Ii-OLs   | Overbite   |       |      | X     |          |
| Msc-NL   | Vertical linear position of maxillary 1 <sup>st</sup> molar  |       |      | X     |          |
| Mic-ML   | Vertical linear position of mandibular 1 <sup>st</sup> molar |       |      | X     |          |
| A-Pg     | Sagittal jaw base relationship                               |       |      | X     |          |
| Is-Ii    | Overjet  |       |      | X     |          |
| Ms-Mi    | Molar relationship   |       |      | 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 stan-

dards [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:

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

**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° 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 values 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**

| Variables                   | Reference Values |                 |                 |                 |                 |                 |                 |                 |                 |                 | Increments               |              |                        |                        |                        |      |
|-----------------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--------------------------|--------------|------------------------|------------------------|------------------------|------|
|                             | Males            |                 |                 |                 |                 | Females         |                 |                 |                 |                 | Sex diff. at 12 year old |              | Males                  | Fe-<br>males           | Sex<br>diff.           |      |
|                             | 10 <sup>b</sup>  | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | 10 <sup>b</sup> | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | Mean                     | SD-<br>Score | 10-<br>14 <sup>9</sup> | 10-<br>14 <sup>9</sup> | 10-<br>14 <sup>9</sup> |      |
| <u>Björk Analysis</u>       |                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                          |              |                        |                        |                        |      |
| <i>Angular measurements</i> |                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                          |              |                        |                        |                        |      |
| 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 |
| <i>Linear measurements</i>  |                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                          |              |                        |                        |                        |      |
| 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 |
| <u>Wits Appraisal</u>       |                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                          |              |                        |                        |                        |      |
| 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  |

<sup>a</sup>Reference values in this table with approval of the publisher of the original paper [10]; <sup>b</sup>Reference values based on increments obtained from another study [1,2]; <sup>9</sup>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**

| Variables                   | Reference Values |                 |                 |                 |                 |                 |                 |                 |                 |                 | Increments               |              |                        |                    |                        |      |
|-----------------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--------------------------|--------------|------------------------|--------------------|------------------------|------|
|                             | Males            |                 |                 |                 |                 | Females         |                 |                 |                 |                 | Sex diff. at 12 year old |              | Males                  | Females            | Sex<br>diff.           |      |
|                             | 10 <sup>b</sup>  | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | 10 <sup>b</sup> | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | Mean                     | SD-<br>Score | 10-<br>14 <sup>9</sup> | 10-14 <sup>9</sup> | 10-<br>14 <sup>9</sup> |      |
| <i>Angular measurements</i> |                  |                 |                 |                 |                 |                 |                 |                 |                 |                 |                          |              |                        |                    |                        |      |
| 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  |

<sup>a</sup>Reference values in this table with approval of the publisher of the original paper [9]; <sup>b</sup>Reference values based on increments obtained from another study [1,2]; <sup>c</sup>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**

| Variables            | Reference Values |                 |                 |                 |                 |                 |                 |                 |                 |                 | Increments               |          |                    |                    |                    |      |
|----------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--------------------------|----------|--------------------|--------------------|--------------------|------|
|                      | Males            |                 |                 |                 |                 | Females         |                 |                 |                 |                 | Sex diff. at 12 year old |          | Males              | Females            | Sex diff.          |      |
|                      | 10 <sup>b</sup>  | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | 10 <sup>b</sup> | 11 <sup>b</sup> | 12 <sup>a</sup> | 13 <sup>b</sup> | 14 <sup>b</sup> | Mean                     | SD-Score | 10-14 <sup>c</sup> | 10-14 <sup>c</sup> | 10-14 <sup>c</sup> |      |
| 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/MdPI              | 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  |

<sup>a</sup>Reference values of 12-year old children with approval of the publisher of the original paper [8]; <sup>b</sup>Reference values based on increments obtained from another study [1,2]; <sup>c</sup>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 reference 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° 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 signifi-

cant 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.

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