IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 5 Ver. IX (May. 2016), PP 91-97
www.iosrjournals.org

Assessment of Individual Craniofacial Variation based on Correlation between Sagittal and Vertical Skeletal parameters in Chinese adults

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Abstract
Objective:*to assess individual craniofacial variation bases on correlation between sagittal and vertical cephalometric parameters among Chinese adults using harmony box derived from regression analysis.*
Materials and Methods: *Eighty-two subjects (46 females and 36 males) aged 18-26 years from China with harmonious facial appearance were selected. The cephalometric angular measurements of SNA, NL-NSL, NSBa, ML-NSL, and SNB were analyzed by1. Pearson's correlation coefficient to ascertain the association among these five variables under study, 2. bivariate linear regression analysis to determine varying norms of five correlated variables using harmony box and 3. multiple regression analysis and standard error of the estimate to establish harmony schema that illustrates theindividual craniofacial pattern.*
Result: *The five cephalometric variables displayed significant correlations to one another at 0.01 and 0.05 levels. The harmony box procured from linear regression equations with corresponding r² and standard error of estimate (SE) elucidates the floating norms for Chinese adults. Harmony schema was derived from multiple correlation coefficient R, adjusted r² and SE when predicting one of the five variables from the remaining four applying multiple regression model.*
Conclusion*: Individual craniofacial variation based on correlation between sagittal and vertical skeletal parameters was assessed among the Chinese adults in the form of harmony box.*
Keywords*: Harmony box; Harmony schema; Craniofacial patterns; Cephalometric parameters*

I. Introduction

1.1 Background

The horizon of orthodonticsconstitutes underlying jaw bases, dentition and their relationship to one another, and their orientation to the cranial base. If a harmonious association is formed among these constituents, a beautiful facial profile is an apparent outcome. Many studies and researches related to jaw proportions, dentofacial balance, growth and development in multiple dimensions and their measurements eventually led to the advent of standardized cephalometric technique in 1931 devised by Broadbent [1] in USA and Hofrath [2] in Germany independently.

Cephalometric analysis has been a breakthrough in identifying an individual's deviation from so-called normal values. These normal values are derived from an untreated sample of subjects from same ethnic group presumed as "ideal" or "well-balanced face with normal occlusion.[3,4]Comparative cephalometric studies have proven that differences in the craniofacial morphology exist among ethnic groups.[5-7]They also found that significant variations were not only the features of dentofacial deformities but also belonged to those called ideal or normal faces.[8,9]Several research to ensue norms based on ideal/near ideal or normal faces specific to age, sex and race still continue. Such approaches have continued to furnish valuable guidelines for orthodontic diagnosis, treatment planning and assessment of treatment outcome.[10-12]

Although Conventional cephalometric analyses have huge application regarding isolated cephalaometric parameters, the consideration for possible reciprocity among these variables could not be ruled out regardless of the type of comparative observation under study.[13]

Meanwhile, Solow[13]described thatcorrelation pattern exists among sagittal and vertical cephalometric skeletal variables through his popular concept of "craniofacial patterns". This implies, although all cephalometric variables of a subject fall at or beyond one standard deviation from population mean, they might be accepted on condition that they hold a certain correlation between one another.[14]As the sella-nasion reference plane is mutual, the five cephalometric parameters namely; SNA: maxillary prognathism, SNB: mandibular prognathism, NL-NSL: maxillary inclination, ML-NSL: mandibular inclination, and NSBa: cranial base angle; exhibited statistical correlation to each other "Figure 1". The skeletal components bear sizable influence on the facial profile. In connection to this, Hasund et., al[15]put forward an idea to amalgamate acceptable values for different facial types based on the principle of Bergen cephalometric analysis, thoughthe clinical use of Bergen analysis requires special caution. Eventually, these studies were later corroborated by Segner-Hasund[16] in a comprehensive analysis that assessed individual craniofacial pattern for European adults. These floating norms were represented with the help of graphical box-like configuration, the harmony box.[16]

Harmony box serves as a diagnostic tool to investigate the individual skeletal pattern by giving details of sagittal and vertical skeletal relationships with the aid of floating norms. It can unveil the craniofacial pattern of an individual and classify it as harmonious or disharmonious. The harmony box has three zones—retrognathic, orthognathic, and prognathic zones—depending upon the ANB values of subject.[15]A harmony line is formed by connecting the values of five cephalometric variables inside the harmony box. If the harmony line is straight, it implies that the face is harmonious, and the zone wherethe cephalometric values of the subject fall, determines the facial type. For every horizontal harmony line, a range of accepted variability is allowed, which is represented by the harmony schema.[15] The harmony schema can occupy any zone within the harmony box to include all five cephalometric variables of the subject. A subject whose cephalometric values lie within the confinement of the schema displays a harmonious skeletal pattern. However, if any value lies outside the schema, that parameter will cause the facial disharmony.[15]

The Chinese have multiplemajor and smaller races which form more than one-fifth of the world's population. They have 56 ethnic groups in mainland China, of which the Han Chinese forms the largest group. China has a total of 23 provinces. According to the National bureau of Statistics June 13, 2011, China has four economic regions: eastern, western, northeastern and central. The Central China comprises six provinces: Henan, Hubei, Anhui, Shanxi, Jiangxi, and Hunan. The total population of Central China accounts for 28.1% of the Chinese population.[17]

Studies related to floating norms in different population groups are the proof that they can be one of the vital diagnostic tools in the field of orthodontics. Sevilla-Naranjilla and Rudzki-Janson[18]studied floating norms for people of Philippines. Franchi, Baccetti, and McNamara[19] established floating norms for North American adults whereas

1.2Objectives

The objective of this study is to construct a harmony box based on the correlated cephalometric variables:

- to determine the normally occurring craniofacial morphology of Chinese
- in orthodontic diagnosis and treatment planning by analyzing the harmonious relationships of individual craniofacial patterns among the Chinese population.

II. Materials And Methods

The sample for this study recruited 82 subjects (46 females and 36 males) aged 18-26 years, from central China. Approval of the study was accomplished through the ethical committee. Consents were received from each subject. All the cephalographs were recorded by using same cephalometric apparatus (Orthophos XG 2D, Sirona Dental) taken by the single technician based on following criteria:

Exclusion criteria:

- Previous history of orthodontic treatment and orthognathic surgery

Inclusion criteria:

- Acceptable facial profile without apparent maxillofacial skeletal asymmetry
- Ideal or near-ideal occlusion with Angle class I molar and class I canine relationship

2.1Cephalometric measurements

These cephalographs were obtained from every subject adjusting their teeth in centric occlusion and lips relaxed at natural head position (NHP).

The digitization and measurement of selected lateral cephalographs were done by one investigator to yield five cephalometric angular measurements by applying cephalometric analysis software program (version 1.2). Despite all the measurements being angular, cephalometric enlargement did not impart any effect even if the magnification was standardized at 8% for each film.The same investigator repeated measurement of twelve randomly selected radiographs one week after initial measurements toevaluate method error exploiting Dahlberg[20]formula. The errors in degrees were found to be 0.92 for SNA, 0.93 for SNB, 0.77 for NSBa, 0.71 for ML-NSL and 0.84 for NL-NSL.

2.2 Statistical Analysis

Descriptive statistics of observations was calculated. Pearson correlation coefficient test was applied to determine the strength of association amongst the five variables. Bivariate linear regression analysis enabled the identification and characterization of association among these variables and construction of harmony box as well.

Whereas multiple regression analysis, especially the standard error of estimate SE, served to frame the harmony schema in the harmony box. The Sample size for this regression model was estimated sticking to principle of Green[21]. All the analyses were computed with IBM Statistical Package for Social Sciences (SPSS) Statistics, version 20. In the statistical evaluation, the level of significance was set at 0.01 and 0.05.

III. Result

The descriptive analyses of all measured categories are listed in “Table 1”. Independent t-test showed no statistically significant differences between the mean values of angles of male and female genders within the group. “Table 2”

Therefore, all measurements of both sexes were performed as combined in each group and were considered for analysis. “Table 3” shows a linear relationship between every five cephalometric variables. All the correlations between five variables were significant at 0.01 and 0.05 level.

In “Table 4”, linear regression equations were derived taking SNB as the predictor variable and are tabulated along with their corresponding coefficient of determination r^2 and standard error of estimate SE. “Table 5” illustrates the adjusted^2 and the SE as determined by predicting one of the five variables from the remaining four applying multiple regression analysis.

IV. Discussion

Many practitioners faced several limitations while treating individuals based on their ideal ‘norms’ especially among those who have the skeletal type of malocclusion. Enlow and Nanda-Ghosh[22]stated that although cephalometric norms have been brought forth for each race and ethnic group, still there is room for individual variations. Inadequate knowledge about morphologic variations of human craniofacial structures invites difficulties in diagnosis and treatment planning.[23-26] Hence, hefty endeavors were put to formulate ‘norms’ for an individual based on his/her skeleton and dental patterns. Subsequently, the concept of the craniofacial pattern was introduced which pointed out that any isolated angular or linear variable would not suffice a comprehensive cephalometric measurement, rather these variables should be described in relation to an individual’s facial type.[14,22]In this scenario, harmony box appears to be one of the appropriate provisions to serve as a pivotal auxiliary diagnostic tool to assess sagittal, vertical and transverse cephalometric parameters of a subject.

The present study illustrates the varying cephalometric norms in the form of harmony boxand harmonic schema to explain the individual craniofacial pattern among Chinese. Instead of comparing individual’s cephalometric measurements with established norms of a specific ethnic group as in conventional cephalometrics, the varying cephalometric norms applies the principle of correlation patterns among the five measured angular variables. Moreover, as long as the sagittal: SNA, SNB and vertical: NL-NSL, ML-NSL “Figure 2” andangular cephalometric variables of an individual maintain a mathematical correlation to one another, the skeletal pattern is considered acceptable.[13]

“Table 1” provides the mean sagittal and vertical cephalometric measurements for Chinese. In our result, Independent t-tests showed that there were no statistically significant differences between the mean values of these angles in male and female within the groups in all five variables since p value was greater than 0.05” Table 2”

“Table 3” tells about the statistical association between these sagittal and vertical cephalometric variables. The correlation coefficient values range between 0.22 and 0.91 which indicates that all correlations are highly significant. The higher the value of r, the higher is the correlation. The r value of 0.91 indicates the strongest association in between SNA and SNB at 0.01 level. Out of five variables, ML-NSL has the weakest correlation with remaining four variables whereas SNB exhibited the highest correlation coefficients with the remaining variables. ML-NSL shares the weakest relationship to NSBa (r = 0.22) which implies the change in ML-NSL has the least impact upon NSBa compared to the rest. Linear regressions of “Table 4” were employed to construct the harmony box displayed by “Figure 3” taking SNB as the predictor. And, “Table 5” illustrated standard errors of the estimates ‘SE’ when one of the variables SNA, NL-NSL, NSBa, ML- NSL and SNB is predicted from the other four using of multiple regression analysis.

Among the five variables, NSBa carried a positive correlation with ML-NSL and NL-NSL but embraced an opposite correlation with SNA and SNB. That means, a retrusive maxilla-mandibular position in relation to anterior cranial base increases the propensity for maxilla and mandible to be posteriorly inclined and the cranial base angle to get larger. However, for protrusive position of maxilla and mandible in relation to the anterior cranial base, there is the tendency of anterior maxilla-mandibular inclination and smaller cranial base angle.

The harmony schema shown in “Figure 4” depicts the range of variability permitted among five correlated cephalometric measurements for describing a harmonious face. In the present study, the range is narrow for SNA and SNB angles, and it is wider for remaining three variables which dictate limited variability allowed for SNA and SNB, compared to the other three variables. If at least one individual value lies outside the range, that will point the deviation from the harmonious skeletal pattern. For instance, although SNB and other vertical values fit into the schema, the value SNA may not. In this case, the sagittal anomaly is due tomaxilla (SNA). The shifting of the schema is allowed in different zones of harmony box to set up the inclusion of all five cephalometric variables of an individual.[18] The individual norms are therefore different for every subject as determined by his/her individual morphology.

An individual harmony line that links the values of various variables inside the box represents the harmonious skeletal patterns of a subject.[14]The harmonious alliance from correlation point of view would not necessarily require the cephalometric values to lie on a perfectly straight horizontal line.[14]The line may occupy the center of the box connecting the mean values of various measurements as shown in “Figure 4”. In this instance, the subject is said to have orthognathic and harmonious facial type.“Figure 5” displays the graphical representation of five cephalometric variables with the mid-line connecting the mean values of the measured variables of Chinese adults and the degree of variability represented by the standard error of estimate of multiple regression analysis.

“Figure 6” illustratesmean cephalometric values of the five correlated variables amongthe Chinese and Filipino adults sketched on the Chinese harmony box and schema.[18]All variables lie inside the harmony schema for Chinese adults and in the orthognathic zone of harmony box. The line connecting the values of Filipino is shifted upward which indicatesFilipino facial type is more retrognathic (except other values, ML-NSL and NL-NSL lie outside harmony schema) compared to Chinese adults although their craniofacial morphology closely resembles each other.

Though cephalometric analysis has a broader dimension of uses, Di Paolo et al[27] specified its role to single out the area of skeletal dysplasia. In addition to this, it should be ascertained whether the combinations of five cephalometric variables in harmony box is harmonious. The diagnostic diagram presented as the graphical box is the consequence of patterns of association among the observed cephalometric variables. The provision of three zones, based on ANB values, inside the box (retrognathic, orthognathic and prognathic) helps to differentiate the facial type as prognathic but still harmonious, orthognathic and harmonious and retrognathic and harmonious; depending upon the placement of individual harmony line.

It may not be appropriate to rely entirely upon varying cephalometric norms which advocate the measure of statistical correlation only among the five variables. S-N plane despite being more accurate and predictable alternate to other planes, the position of N (nasion) and rotation of jaws, age of the subject and degree of facial prognathism could still influence its reliability over derivatives of cephalometric floating norms.

Despite the availability of various reference planes, though more or less good, none is completely reliable because each plane is prone to an individual variation. The use of different reference planes can be expected to compensate for pronounced variations in one or the other reference planes, as if the measurement error is averaged.

The concept that using cephalometric population averages is too rigid and that there should be accepted variation dependent on other individual characteristics. This is often ignored in common practice due to the complexity of taking these variations into account. However, in today's technologically advanced environment, it is possible to incorporate these complexities into software programs.

V. Conclusion

Individual craniofacial variation based on correlation between sagittal and vertical skeletal parametersis assessed among the Chinese adults in the form of harmony box. Identification of individual craniofacial features will enable practitioners to locate the nature and severity of dysplasia and to improve treatment planning limited to individual needs of the case.

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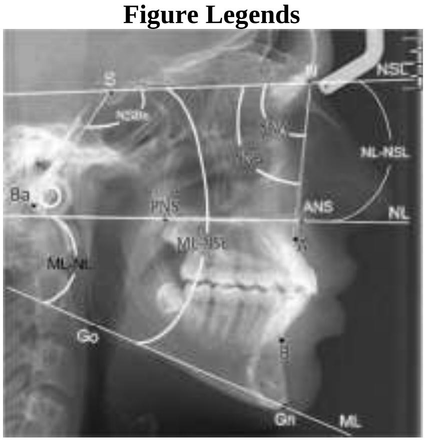
Figure Legends



- Figure 1: Cephalometric radiograph showing Points, Planes and Angles used in the analysis
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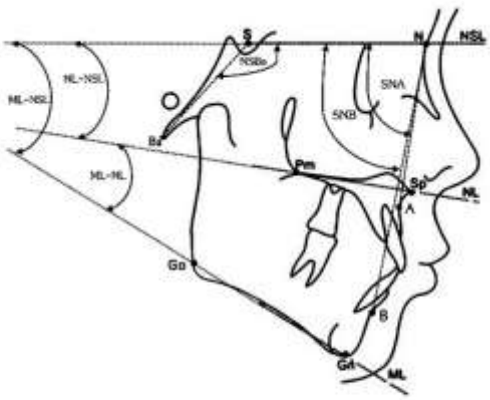

- Figure 2: Cephalometric tracing showing Points, Planes and Angles used in analysis

	SNA	NL-NSL	NSBa	ML-NSL	SNB
RETROGNATHIC	64.5	18.5	147.5	44.4	61.0
	65.5	17.9	146.6	43.6	62.0
	66.4	17.3	145.6	42.8	63.0
	67.3	16.7	144.7	42.0	64.0
	68.3	16.1	143.8	41.3	65.0
	69.2	15.5	142.9	40.5	66.0
	70.2	14.9	142.0	39.7	67.0
	71.1	14.3	141.0	38.9	68.0
	72.0	13.7	140.1	38.1	69.0
	73.0	13.1	139.2	37.4	70.0
	73.9	12.5	138.3	36.6	71.0
	74.9	11.9	137.4	35.8	72.0
	75.8	11.3	136.5	35.0	73.0
ORTHOGNATHIC	76.7	10.7	135.5	34.2	74.0
	77.7	10.1	134.6	33.5	75.0
	78.6	9.5	133.7	32.7	76.0
	79.6	8.9	132.8	31.9	77.0
	80.5	8.3	131.9	31.1	78.0
	81.4	7.7	131.0	30.3	79.0
	82.4	7.1	130.0	29.6	80.0
	83.3	6.5	129.1	28.8	81.0
	84.2	5.9	128.2	28.0	82.0
	85.2	5.3	127.3	27.2	83.0
	86.1	4.7	126.4	26.4	84.0
	87.1	4.1	125.5	25.7	85.0
	88.0	3.5	124.5	24.9	86.0
PROGNATHIC	88.9	2.9	123.6	24.1	87.0
	89.9	2.3	122.7	23.3	88.0
	90.8	1.7	121.8	22.5	89.0
	91.8	1.1	120.9	21.8	90.0
	92.7	0.5	120.0	21.0	91.0
	93.6	0.0	119.0	20.2	92.0
	94.6	-0.6	118.1	19.4	93.0
	95.5	-1.2	117.2	18.6	94.0
	96.5	-1.8	116.3	17.9	95.0
	97.4	-2.4	115.4	17.1	96.0
	98.3	-3.0	114.5	16.3	97.0
	99.3	-3.6	113.5	15.5	98.0
	100.2	-4.2	112.6	14.7	99.0

- Figure 3: The harmony box for Chinese adults
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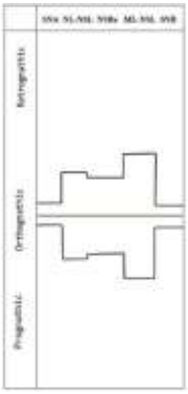

- Figure 4: The harmony schema for Chinese adults
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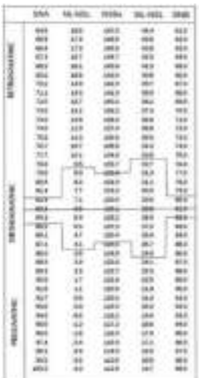

- Figure 5: The graphical box with harmonious combinations and range of accepted variability
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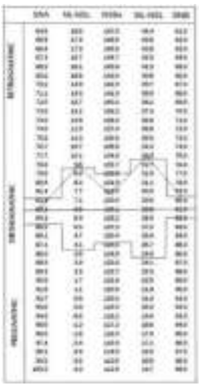

- Figure 6: Comparison between Chinese Adults and (connected harmony line) and Filipino Adults (dashed harmony line)

Table I: Descriptive statistics

Variables	Gender	Number	Mean	SD	Min	Max
SNA	Male	36	84.02	3.49	76.94	89.93
	Female	46	82.86	3.13	75.6	88.39
NSBa	Male	36	128.53	5.16	119.92	140.62
	Female	46	129.63	4.48	123.09	140.05
NL-NSL	Male	36	5.78	4.13	-1.82	12.92
	Female	46	7.27	2.24	3.24	12.68
ML-NSL	Male	36	27.28	5.01	17.00	36.50
	Female	46	30.43	4.54	22.00	41.50
SNB	Male	36	81.72	3.55	74.50	7.81
	Female	46	80.30	2.80	72.19	85.78

Table II: Linear correlation coefficients 'r' between SNA, NL-NSL, NSBa, ML-NSL and SNB cephalometric parameters

Variable	SNA	NL-NSL	NSBa	ML-NSL	SNB
SNA	1				
NL-NSL	-0.52*	1			
NSBa	-0.57*	0.54**	1		
ML-NSL	-0.36*	0.26**	0.22**	1	
SNB	0.91*	-0.57**	-0.62**	-.49**	**1**

*P<0.01; **P<0.05

Table III: Linear regression equation with corresponding r^2 and Standard error of the estimate (SE) in Chinese adults

Variables	Regression equation	r^2	SE
NL-NSL	= - 0.541*SNA+51.680	0.27	2.94
NSBa	= - 0.829*SNA+198.328	0.32	4.00
ML-NSL	= - 0.586*SNA+77.712	0.15	4.65
SNB	= 0.899*SNA+6.000	0.84	1.30
SNA	= - 0.396*NSBa+134.619	0.32	2.76
SNB	= - 0.419*NSBa+135.160	0.38	2.59
ML-NSL	= - 0.78*SNB+92.008	0.25	4.30

Table IV: Standard errors of the estimates when one of the variables SNA, NL-NSL, NSBa, ML- NSL and SNB is predicted from the other four by means of a multiple regression analysis.

Variables	r	r^2	SE
SNA	0.92	0.85	1.33
NL-NSL	0.62	0.38	2.80
NSBa	0.67	0.44	3.74
ML-NSL	0.56	0.31	4.32
SNB	0.94	0.88	1.14

Table V: Cutoff values for cephalometric parameters

Variables	Number	Mean	SD	Cutoff value
SNA	80	83.47	3.34	76.78 - 90.14
NL-NSL	80	6.48	3.43	-0.38 - 13.34
NSBa	80	129.05	4.84	119.37 - 138.73
ML-NSL	80	28.77	5.00	18.75 - 38.86
SNB	80	81.05	3.27	74.50 - 87.58