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Sagittal Skeletal Jaw Base and Dental Arch Relationships among Adult Orthodontic Patients: A CBCT Synthesized Cephalogram Analysis

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Abstract: *The aim of this study was to assess the sagittal skeletal jaw base and dental arch relationships among adult orthodontic patients. 152 (male: 69 and female: 83; 21.4±3.48 years of age) patients' dental study model casts and pretreatment 2D lateral cephalometric radiographs derived from CBCT 3D images were randomly selected. Paired t-test was performed to assess the difference between the examiners. Angle's classification corresponded with skeletal classification by ANB angle measurement in 76.9% of the total sample ($p<0.01$) whereas Angle's classification and skeletal classification by Wits appraisal measurement corresponded in 61.8% of the study sample ($p<0.01$). The skeletal classification by ANB angle measurement did correspond with skeletal classification by Wits appraisal measurement in 65.7% of the study sample and both Kappa and Chi-square test were significant with $p<0.01$. There was significant positive linear correlation between ANB angle and Wits ($p<0.001$) with the Coefficient, $r=0.745$. The predictability of Wits by ANB angle was determined by linear regression. The study concluded that there was statistical significance of relationships between sagittal skeletal jaw base and dental arch relationships among adult orthodontic patients.*

Keywords: *CBCT, Cephalometrics, Malocclusion, Orthodontics, Relationship, Sagittal*

I. Introduction

The recent use of 3D Cone Beam Computed Tomography (CBCT) technology has been advantageous compared to the 3D CT scan and conventional cephalogram. Due to its high radiation dosage, high billing cost, CT scan is not suitable for long term and continuous monitoring for diagnosis for orthodontic treatment and for assessment in craniofacial surgery. Conventional cephalogram (2D) is a representation of a three- dimensional (3D) structure and its own intrinsic limitations such as projective displacement, rotational errors and linear projective transformation[1,2,3]. CBCT-synthesized cephalogram measurements is similar to that performed on conventional cephalogram with great precision, accuracy and reproductibility [4,5,6].

Understanding the relationship of dental arch and supporting skeletal structure is a key for better diagnosis, treatment plan and outcome of the orthodontic treatment. Skeletal relationships in the sagittal plane do not always correspond with dental relationships and the dental arch relationship is mostly affected by the facial skeleton upon which the teeth are invested[7,8]. Edward Angle had assessed jaw relationship based on the permanent molars relationship but this was not representative for both jaw and dental relationship, it was representative only for the sagittal relationship of dentition[9].

Nowadays, many parameters are used to evaluate the sagittal jaw relationship. Since the introduction of the A and B point by Downs in 1948, the ANB angle measurement discovered by Riedel in 1952 is mostly used by the orthodontists to measure jaw disharmony[10-16]. Wits appraisal is a widespread linear measurement which help to get additional information for interpretation of ANB which is angular measurement; both ANB and Wits are commonly used by orthodontists and researchers[13, 14, 17-20]. Researchers showed that the ANB angle can be affected by age, the length cranial base and/or rotation of the jaws whereas wits appraisal can be affected by the misleading of occlusal plane, for those reasons several studies have suggested to use both measurements in combination[14,15,21-30].

The literature has shown the relationship between skeletal Jaw base and dental malocclusion is one that has been debated for years. Numerous researches had been conducted in different populations evaluating the ANB angle and Wits appraisal to elicit the relationship of the Jaw base and the dental arch[17,31-36]. Various authors named Rotberg 1980; Bishara et al 1983; Jacobson 1988, Sherman et al 1988; Ishikawa et al,2002; Fida,2008; Zhou,2012; found that there is correlation between the jaw base and dental arc and others based on their findings do not found the correlations or found in some aspects they do correlate and other aspect they don't correlate. Up to date no conclusive studies have been performed[7,12,22,24,29,37-39].

Numerous studies have assessed the sagittal Skeletal Jaw Base and dental arch relationship in different population. The use of CBCT was not yet popular and many of them were using conventional cephalometric evaluation and few of them included occlusal feature. This study evaluates both cephalometric and occlusal data in order to provide comprehensive understanding on the skeletal jaw base and dental arch relationship in sagittal component. In addition, most of all studies are done on data of young individuals bellow 18 years old or mixed young and adult which the results do not distinguish the individuals' age. Besides, studies assessing sagittal skeletal jaw base and dental arch relationship in adult orthodontic patients are extremely rare or poorly documented. The present study can shed some additional information on the understanding of sagittal dental and skeletal relationship in adults.

II. Methods and Materials

2.1. Study Design

This Retrospective Cross-sectional study was approved by the institutional review board of Tongji Medical College of Huazhong University of Science and Technology.

2.2. Inclusion and exclusion criteria

This study assessed all the patients treated at the department of orthodontics of Tongji Hospital and have been sent to the department of oral and maxillofacial radiology department of the same hospital for pre-treatment CBCT scan. The following were the criteria:

1. All must be adult patients (18 years and above) who got treatment at the department of orthodontics before the period of data collection,
2. Patients should never had orthodontic treatment before and not had nor having any congenital deformity, no syndromes i.e. Down's syndrome, no history of dental trauma or any trauma to a skeletal jaw base.
3. All pre-treatment study model and pre-treatment digital lateral cephalogram (obtained from 3D images) in good shape for being analyzed. .
4. The patients who did not fulfill all requirements for inclusion criteria were excluded in the study and the 152 patients' data remaining were processed for further analysis.

2.3. Data collection

The patients visited the department of orthodontics of Tongji Hospital before the data collection period and fulfilling the criteria of the selection. Pre-treatment study models and the details of the patients were obtained in the department of orthodontics and corresponding pre-treatment digital lateral cephalograms were obtained in the department of oral and maxillofacial radiology where they were kept in the server as 3D images. Those meeting the selection criteria were retained by the study to be processed for analysis.

2.3.1. Dental cast and lateral cephalogram study

Molar relationship was established in order to assess the sagittal relationship of the dental arch and classify them according the Angle's classification. The Angle class I/ molar Class I was defined as occurring where the mesiobuccal cusp of the upper first molar occluded with the mesiobuccal groove of the lower first molar or within the range of less than half a cusp width anteriorly or posteriorly. Angle/Molar Class II was defined as occurring where the mesiobuccal cusp of the upper first molar occluded anterior to the Class I position. Angle/Molar Class III was defined as occurring where the mesiobuccal cusp of the upper first molar occluded posterior to the Class I position[40].

Regarding 2D lateral cephalograms which derived from CBCT 3D images, two measures were to be analyzed: linear measurement by Wits appraisal and angular measurements by ANB angle.

Steiner's analysis was performed; ANB angle was established by the difference between SNA and SNB angles. Subject with ANB angle of 3.5±1.4º was classified as Skeletal class I by Angular measurement and the value a below was classified as class III and the value beyond as class II[41].

For the Wits appraisal, a functional occlusal plane was drawn through overlapping cusps of the first molar and premolar. Lines connecting both points A and B to the functional occlusal plane were drawn and the corresponding meeting points are named Ao and Bo. The distance in mm between those two points Ao-Bo determines the linear sagittal skeletal jaw base relationship and the value ranging from -0.6±2.6mm was considered as skeletal class I and the value below corresponded to skeletal class III and the value beyond was considered as class II Skeletal by linear measurement[41].

The figure bellow illustrates the measurement performed of ANB angle and Wits on a 2D lateral cephalogram obtained from 3D image using Invivo®Anatomage software.

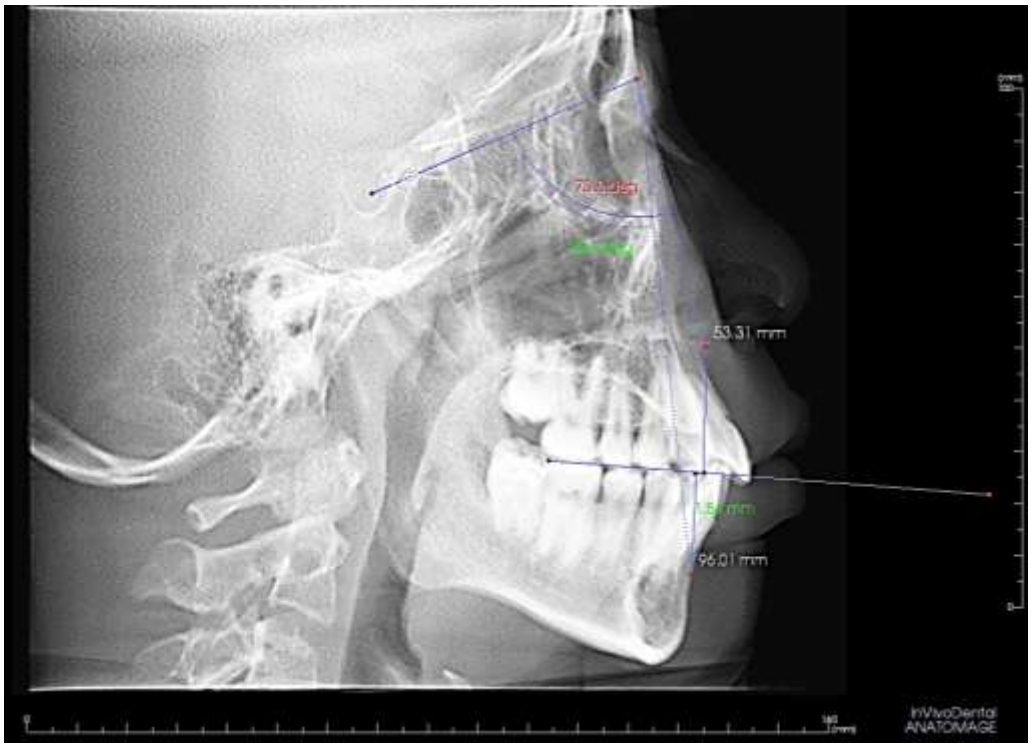

Figure 1. ANB angle and Wits appraisal measurements

2.4. Data analysis

The data were analyzed using SPSS V20 (IBM® SPSS® Statistics 20). Statistical analyses were done and the significance level was taken at $p<0.05$. Different statistics and tests were performed in the analysis of the data .Descriptive statistics were performed in order to calculate the mean, the standard deviations of ANB, SNA, SNB, Wits, Age. To evaluate inter-examiner reliability of the method, Paired t-test was used. Chi-square was used to assess the association existence between of Molar relationship and Skeletal Jaw relationship and between the linear Skeletal Jaw relationship and angular Skeletal Jaw relationship of the study sample. Cohen's Kappa coefficient was used to rank the level of correspondence between the linear Skeletal Jaw relationship and angular Skeletal Jaw relationship. Linear Correlation was established between ANB angle and Wits and linear regression was analyzed to assess the predictability of Wits according to ANB angle.

2.5. Method Error

To ensure the reliability of the method a random sample of 50 patients was re-exanimated for inter-examiner reliability, paired t-test was performed to assess the difference between the examiners and the level of significance was set at $p<0.05$. There were no statistical difference between the examiners $p>0.05$. A proper localization of landmarks on lateral cephalograms had helped to minimize the error. The use of sophisticated software for tracing contributed as well in minimizing the error.

III. Results

In this study 152 patients' pretreatment cast and cephalogram made of 69 males and 83 females with the age of 21.4±3.48 years old were retained to be analyzed (Table 1). The distribution of the age, molar relationship, skeletal jaw base relationship by angular measurement and skeletal jaw base relationship by linear measurement of the sample across the gender was not statistically significant (Table2).

Table 1. Sample's mean and standard deviation of SNA, SNB, ANB, Wits and the Age

		Age	SNA	SNB	ANB	Wits
N	**Valid**	152	152	152	152	152
	Missing	0	0	0	0	0
Mean		21.4013	82.8336	80.6395	2.2007	-.5191
Std. Deviation		3.48556	3.55611	1.80918	3.12023	3.69483
Minimum		18.00	75.90	76.10	-3.40	-6.90
Maximum		35.00	90.00	84.50	7.30	5.60

Table 2. Study characteristics across gender

Characteristic of the sample		**Gender of the patients**	
		Male	**Female**
Age	**18-24**	58(38.1%)	73(48%)^{NS}
	25-34	11(7.2%)	7(4.6%)
	35+	0	3(1.9%)
Molar relationships/Angle classification	**Class 1**	26(17.1%)	32(21.1%)^{NS}
	Class 2	21(13.8%)	28(18.4%)
	Class 3	22(14.5%)	23(15.1%)
Skeletal Relationship Classes by Angular measurement (ANB)	**Class 1**	39(25.7%)	48(31.6%)^{NS}
	Class 2	12(7.9%)	16(10.5%)
	Class 3	18(11.8%)	19(12.5%)
Skeletal Relationship Classes by Linear measurement	**Class 1**	40(26.3%)	42(27.6%)^{NS}
	Class 2	6(3.9%)	8(5.2%)
	Class 3	23(15.1%)	33(21.7%)

Angle's classification corresponded with skeletal jaw base relationship by angular measurement at 77% which was statistically significant at p <0.01. Angle's classification of malocclusion did correspond with skeletal jaw base relationship by linear measurement in two-third of the sample and the correspondence was statistically significant with p<0.01 as well (Table 3).

Table 3: Distribution of Molar relationship across skeletal jaw base classes by angular measurement and by linear measurement

		Skeletal Jaw base relationship by Angular measurement			**Skeletal Jaw base relationship by linear measurement**		
		Class 1	**Class 2**	**Class 3**	**Class 1**	**Class 2**	**Class 3**
Molar relationships	**Class 1**	55(36.2%)	0	3(2%)**	44(28.9%)	1(0.7%)	13(8.6%) **
	Class 2	21(13.8%)	28(18.4%)	0	32(21.1%)	12(7.9%)	5(3.3%)
	Class 3	11(7.2%)	0	34(22.4%)	6(3.9%)	1(0.7%)	38(25%)

Skeletal jaw base classes both by angular and linear measurement did correspond in classification at 66% and the correspondence was significant with p<0.001. The degree of correspondence or agreement in both classifications was rated by Cohen's Kappa coefficient which was 0.415 interpreted as moderate agreement rate. The rate established by Cohen's Kappa coefficient was statistically significant with p<0.001 as well (Fig. 2).
In this study, the correlation of ANB angle and Wits appraisal was evaluated (Table 4).There was a positive linear correlation between ANB and Wits (r =0.745). Linear regression was assessed for the predictability of Wits and was statistically significant p< 0.01 (Fig.3).

Table 4. Correlation of ANB and Wits

Correlations			
		Wits	**ANB**
Wits	Pearson Correlation	1	.745**
	Sig. (2-tailed)		.000
	N	152	152
ANB	Pearson Correlation	.745**	1
	Sig. (2-tailed)	.000	
	N	152	152

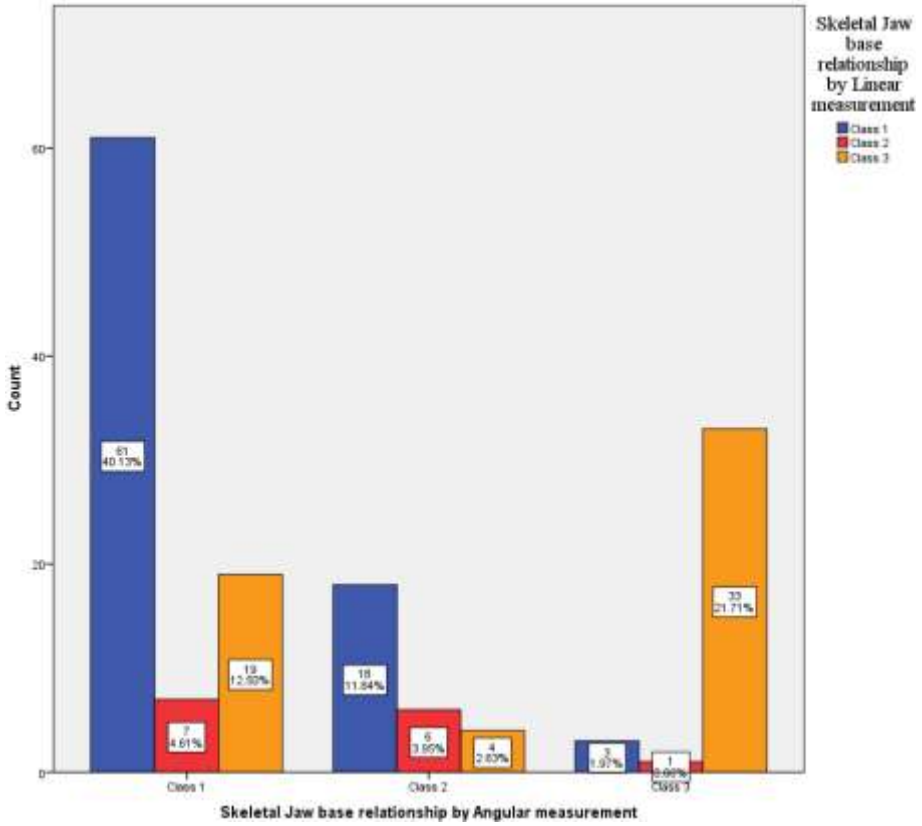

Figure 2. Skeletal relationship by linear measurement relationship and skeletal relationship by angular measurement

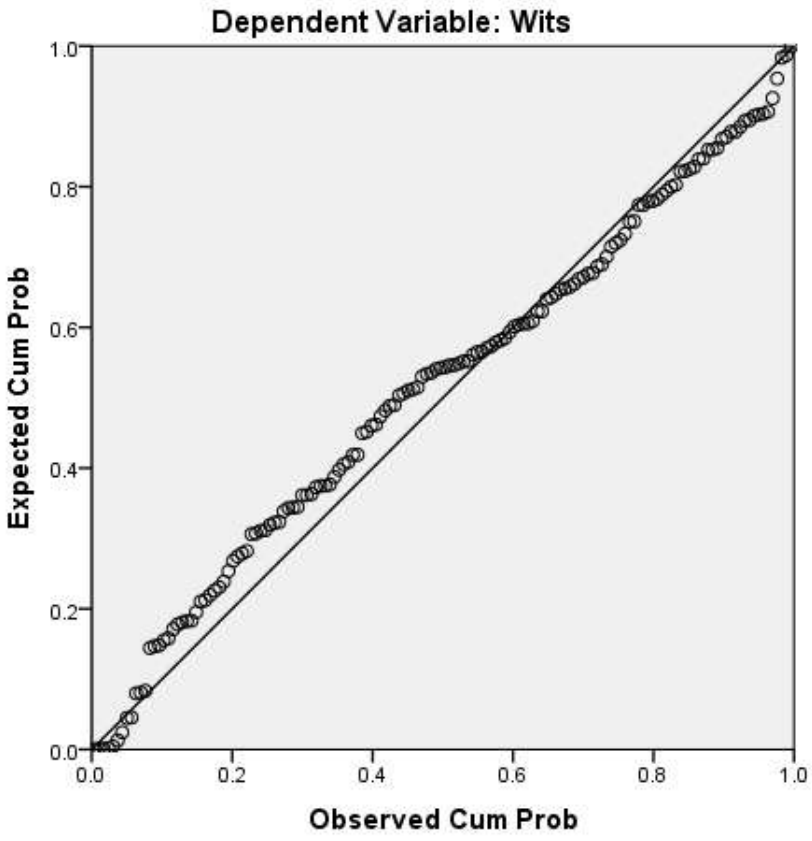

Figure 3. Predictability of Wits by ANB angle

IV. Discussion

The study showed that there was no gender difference in distribution of molar relationship, skeletal relationship both by angular measurement and linear measurement p>0.05. The similar findings were also reported by Aldrees study and Fida study as well, where the results showed that there were no gender difference seen in the distribution of the molar relationship and skeletal relationship using both ANB angle and Wits appraisal. There is a controversy whereby the study conducted by Khalid found that ANB angle and Wits were statistically different in both genders p<0.001. This might be due to the difference in sampling method where the current study sample of include all classes of malocclusion both dental and skeletal whereas the other study only selected patients with angle class-I occlusion and having well-balanced faces [42-44].

The correspondence in classification for both Angle classification and Skeletal Jaw base relationship by Angular measurement was significant in both Classifications with p<0.01. The level of correspondence in this study is higher than that provided by Zhou et al who found that only one-third correspond between molar classification and skeletal jaw base classification by angular measurement. On the other hand this study results have similarity with the study conducted in Switzerland by Milacic and Markovic in 1983 where they found that dental arch relationship corresponded to the sagittal skeletal jaw base relationship measured by ANB angle by 75% which is almost the finding in the current study which is 76.9% [38,39].

The results of this study also shows that molar relationship and skeletal relationship by linear measurement (Wits) had a strong significant correspondence in classifications with p<0.01. The sagittal Jaw base relationship based on linear measurement corresponded with Molar relationship in two-thirds of the sample. These findings are different compare to those of Zhou et al who reported only half of the subjects had an agreement with dental arch relationship and jaw base relationship assessed by angular and linear measurements[39].

The Correspondence in classification for both Angle classification and Skeletal Jaw base relationship by linear measurement computed, and found that there was strong correspondence between both classifications which was significant at p<0.001. The degree of correspondence or agreement was rated by Cohen's Kappa coefficient which was 0.415 interpreted as moderate agreement rate according to Viera. The agreement tested by Cohen's Kappa coeffient was significant, at p<0.01. The results of this study showed that a total of 100 individuals out of 152 or 65.7% which is almost two-thirds of the sample did match in classification of both skeletal classifications. This is similar to the results from Zhou et al who reported that two-thirds of the sample was categorized as having identical jaw-base relationships as assessed by both ANB and Wits analysis[39,45].

Although the skeletal classifications resulted from angular measurement of ANB angle and that of linear measurement based on Wits appraisal did correspond in many counts of the subjects. Both classifications do not show remarkable difference when it comes to class I skeletal relationships but the difference comes in class II and class III , this observation may be explained by the fact of Drawbacks of both angular ANB angle and Wits measurements where ANB angle is affected by patients' age, change of spatial position of the nasion either in the vertical or sagittal direction or both, the upward or downward rotation of the SN plane, the upward or downward rotation of the jaws, the change in the angle SN to the occlusal plane, rotational growth of the upper and lower jaws, growth in a vertical direction (distance N to B) and an increase of the dental height (distance A to B) may contribute to changes in angle ANB[8,15,22,24]. Wits appraisal has its own drawback such in case of the presence of steep curve of Spee, severe cant of the occlusal plane, skeletal asymmetry, open bites, missing teeth[29,37]. However these drawbacks for both wits and ANB angle were already taken in consideration before conducting this study. The difference in class III skeletal by angular and wits may also be explained by the Wits measurement biases in class III as was reported by Nanda[30].

The Results showed that there was a strong positive correlation between ANB angle and Wits which means that when the values of ANB angle increases the value of Wits also increases. The strength of correlation is relatively high with the Coefficient, *r*=0.745 and this correlation is highly significant p<0.01. From this correlation, the predictability of Wits through ANB angle value was assessed by linear regression correlation which found that there is significant linear correlation p<0.01; Wits value can be predictable having the ANB angle values. These results are quite similar to Zhou et al who reported that the regression between the ANB angle and the Wits appraisal was statistically significant and that the association was evident but their correlation coefficient (r-value), which represents the probability to predict the variables from one another, was relatively low (0.65) in their study compared to r= 0.745 of this study. This means that a certain value of the ANB angle may be associated with many values of the Wits appraisal, and thus the prediction between variables is quite higher than those in Zhou et al's study. On the other hand the study by Rotberg et al. showed that they could predict the "Wits" measurement with a 38 percent accuracy and the study by Järvinen *showed that* approximately 93% of the variation of the Wits could be explained by the variation of ANB angle [22,36,39].

V. Conclusion

The present study showed that there is significant relationships between sagittal skeletal jaw base and dental arch relationships among adult orthodontic patients and Wits appraisal can be predicted by ANB angle, however due to drawback of each, it is recommended to use both measurements concurrently. 3D CBCT images can be converted in 2D conventional cephalogram for accurate linear and angular measurements.

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