ORIGINAL ARTICLE

Seven parameters describing anteroposterior jaw relationships: Postpubertal prediction accuracy and interchangeability

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Seven parameters describing anteroposterior jaw relationships (the A-B plane angle, the angle of convexity, the ANB angle, the SN-AB angle, the Wits appraisal, the AF-BF distance, the APDI) were measured on pairs of prepubertal and postpubertal cephalograms of 44 normal occlusion subjects (20 males and 24 females). The mean ages at prepubertal and postpubertal stages were 10 years 5 months and 14 years 5 months in males and 8 years 10 months and 12 years 10 months in females, respectively. The purpose of this study was to compare prediction accuracy of future relationships by regression analysis and to evaluate interchangeability among the 7 parameters by correlation analysis. In the prepubertal assessment, the ANB angle and the angle of convexity showed better prediction accuracy for postpubertal jaw relationships. Higher interchangeability among the parameters was statistically substantiated between the SN-AB angle and the AF-BF distance, as well as among the ANB angle, the angle of convexity, and the A-B plane angle. The Wits appraisal and the APDI were less interchangeable with other parameters. The ANB angle, the Wits appraisal, and the APDI would complement each other for the geometrically distorting factors because of the low interchangeability due to their different geometric basis. The conjunctive use of the ANB angle, the Wits appraisal, and the APDI is recommended as a clinically appropriate method for assessment of jaw relationships in individuals. (Am J Orthod Dentofacial Orthop 2000;117:714-20)

Over the last 50 years, many cephalometric parameters have been proposed to describe anteroposterior jaw relationships, and studies have reported inherent geometric factors that affect the validity of the parameters.[1-13] The conjunctive use of different parameters has been recommended for the assessment of the anteroposterior jaw discrepancy in individual patients.[13-15] However, no clear guidelines for selection of the parameters have been established.

For the conjunctive use of jaw relationship parameters, the interchangeability or the redundancy among the various parameters should be clearly understood. Further, the advantages and disadvantages of each parameter should be evaluated in the light of clinical needs.

This study concerns 7 different parameters describing anteroposterior jaw relationships. In subjects with normal occlusion, the A-B plane angle,[16] the angle of convexity,[16] the ANB angle,[17] the SN-AB angle,[18] the Wits appraisal,[2] the AF-BF distance,[11] and the anteroposterior dysplasia indicator (APDI)[19] were measured on prepubertal and postpubertal cephalograms on a longitudinal basis. The purpose was 2-fold: (1) to compare prediction accuracy of postpubertal jaw relationships and to evaluate interchangeability among the 7 parameters and (2) to discuss clinically appropriate use of the jaw relationship parameters.

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MATERIAL AND METHODS

The present analysis was made with pairs of lateral cephalograms of 44 Japanese subjects (20 males and 24 females) obtained from the files of the Longitudinal Craniofacial Growth Study at Hokkaido University Dental School.[20] All subjects had clinically acceptable occlusions with a Class I molar relationship, mild or no anterior crowding, and overbite and overjet ranging from 1 to 5 mm. None had undergone orthodontic therapy. For the assessment at prepubertal and postpubertal stages, cephalograms taken 3 years before and 1 year after the maximum pubertal growth in body height were used. Table I shows the mean ages at which the radiographs were taken.

Fig 1 shows the cephalometric landmarks used in the study. The following jaw relationship parameters were measured.

1. The A-B plane angle.[16]
2. The angle of convexity.[16]

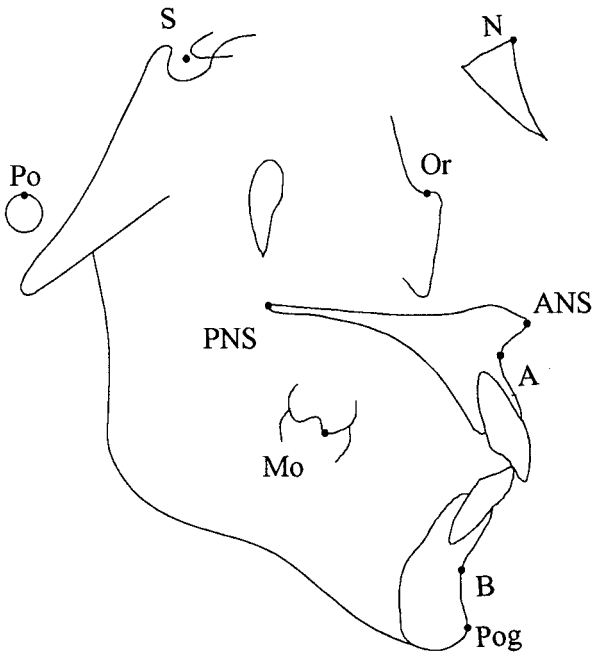

Fig 1. Cephalometric landmarks used in the study.

3. The ANB angle.[17]
4. The SN-AB angle.[18]
5. The Wits appraisal[2]: the occlusal plane was located by joining the midpoint of the overlap of the mesiobuccal cusps of the upper and lower first molars with the point bisecting the overbite of the incisors.[9,11,12]
6. The AF-BF distance.[11]
7. The APDI[19]: the facial plane angle plus or minus the A-B plane angle and again plus or minus the Frankfort-palatal plane angle.

Cephalograms were traced and all landmarks were marked on tracing paper by 1 investigator. Digitization was performed twice and the average value was used. For error measurements, 10 randomly selected cephalograms were traced and digitized twice at 2 weeks interval, and jaw relationships were measured in 2 different occasions. For each jaw relationship parameter, the combined error (S_e) in tracing, landmark location, and digitization was estimated by the formula $S_e^2 = \Sigma d^2/2n$, where d was the difference between the first and second measurements.[21]

The data were divided into 4 groups according to gender and stage; means and SD of the jaw relationship measurements were calculated for each of the 4 groups. To evaluate prediction accuracy of postpubertal jaw relationships from prepubertal assessment, regression analysis was performed. To compare the prediction accuracy among the 7 parameters using the standard error of the estimate, this value should be assessed relative to a variance of each parameter. However, different parameters would have distributions with different variances. In addition, 5 of the 7 parameters were angular measurements and the other 2 parameters were linear measurements. Therefore, for the statistical analysis in this study, all measured values in an individual subject were converted into Z scores[22] in relation to the means and SD of the respective measurements in the corresponding group. The Z score for each measurement was calculated from the following formula:

$$Z\ score\ (X) = (X - \bar{X}) / SD$$

where X is the measured value for an individual, and $\bar{X}$ and SD are the mean and standard deviation for the group.

Based on the Z scores, the correlation coefficient between the prepubertal and postpubertal assessment, coefficient of determination, regression equation, and standard error of the estimate were obtained for each jaw relationship parameter to compare postpubertal prediction accuracy. The standard error of the estimate was defined as the standard deviation of actual postpubertal values minus predicted values. To examine associations among the 7 parameters, the correlation coefficients and coefficients of determination were calculated between each pair of the parameters.

Table I. Mean ages at subject prepubertal and postpubertal stages

	Prepubertal	*Postpubertal*
Male n = 20	10y5m ± 7m	14y5m ± 7m
Female n = 24	8yl0m ± 13m	12yl0m ± 13m

RESULTS

The combined error for the angular measurements ranged from 0.17°(the ANB angle) to 0.30°(the APDI). The Wits appraisal and the AF-BF distance showed the measurement error of 0.35 mm and 0.32 mm, respectively.

Table II gives the means and SD of the cephalometric measurements of the 7 jaw relationship parameters for each of the 4 groups. All measured values in an individual subject were converted into Z scores in relation to the means and SD in the corresponding group.

Table III shows correlation coefficients between the prepubertal and postpubertal Z scores, coefficients of determination, regression equations, and standard errors of the estimate in each jaw relationship parameter. All parameters had statistically significant correlation coefficients of more than 0.8 ($P < .001$). The coefficients of

Table II. Means and SD of the jaw relationship measurements by gender and age group

	Male				*Female*			
	Prepubertal		*Postpubertal*		*Prepubertal*		*Postpubertal*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
AB plane (°)	–5.5	2.5	–5.2	3.1	–5.6	2.5	–5.1	2.9
Convexity (°)	8.9	4.2	7.2	5.1	9.8	3.5	7.8	4.6
ANB (°)	3.8	1.6	3.4	2.1	4.1	1.5	3.4	1.8
SN–AB (°)	71.1	4.4	73.0	4.6	72.0	3.9	74.2	4.8
Wits (mm)	0.8	2.1	0.9	2.7	–0.5	2.5	–0.2	3.1
AF–BF (mm)	9.8	3.3	9.4	4.2	9.0	2.6	8.1	3.1
APDI (°)	80.2	3.2	82.0	3.5	80.7	2.7	82.7	3.9

Table III. Correlation coefficients between prepubertal and postpubertal Z scores, coefficients of determination, regression equations, and standard errors of the estimate in the 7 jaw relationship parameters

	Correlation coefficient	*Coefficient of determination*	*Regression equation X: prepubertal Y: postpubertal*	*Standard error of the estimate*
AB plane	0.87***	0.76	$Y = 0.87\ X + 5 \times 10^{-16}$	0.49
Convexity	0.91***	0.82	$Y = 0.91\ X - 2 \times 10^{-17}$	0.42
ANB	0.89***	0.79	$Y = 0.89\ X - 1 \times 10^{-16}$	0.46
SN–AB	0.87***	0.76	$Y = 0.87\ X - 2 \times 10^{-15}$	0.49
Wits	0.80***	0.65	$Y = 0.82\ X - 0.02$	0.61
AF–BF	0.82***	0.67	$Y = 0.82\ X - 2 \times 10^{-16}$	0.57
APDI	0.86***	0.73	$Y = 0.86\ X - 3 \times 10^{-15}$	0.52

***$P < .001$.

Table IV. A correlation matrix for the 7 parameters calculated with Z scores (correlation coefficient/coefficient of determination)

	AB plane	*Convexity*	*ANB*	*SN–AB*	*Wits*	*AF–BF*	*APDI*
AB plane		–0.86***/0.74	–0.95***/0.90	0.74***/0.55	–0.69***/0.48	–0.76***/0.58	0.51***/0.26
Convexity			0.97***/0.93	–0.60***/0.36	0.48***/0.23	0.68***/0.47	–0.49***/0.24
ANB				–0.68***/0.46	0.57***/0.33	0.74***/0.55	–0.54***/0.29
SN–AB					–0.78***/0.61	–0.82***/0.67	0.69***/0.48
Wits						0.68***/0.46	–0.51***/0.26
AF–BF							–0.60***/0.36
APDI							

***$P < .001$.

determination ranged from 0.65 to 0.82. The angle of convexity and the ANB angle showed the coefficients of determination of approximately 0.8. The Wits appraisal and the AF-BF distance showed relatively low values, below 0.7. The standard errors of the estimate ranged from 0.42 to 0.61. The angle of convexity showed the smallest standard error of the estimate, and the ANB angle showed the second smallest value. The largest value was found in the Wits appraisal.

Table IV shows the correlation matrix for the jaw relationship parameters. The correlation coefficients were calculated based on both the prepubertal and postpubertal Z scores. All 21 pairs of parameters had statistically significant correlation coefficients ($P <$ .001). Closer interrelationships with correlation coefficients exceeding 0.8 were found between the A-B plane angle, the angle of convexity, and the ANB angle, and between the SN-AB angle and the AF-BF distance. In these pairs of the parameters, coefficients of determination ranged from 0.67 to 0.93. The remaining 17 pairs of parameters had correlation coefficients from 0.48 to 0.78. Coefficients of determination exceeding 0.5 were found between the A-B plane angle and the SN-AB angle, between the A-B plane angle and the AF-BF distance, between the ANB angle and the AF-BF distance, and between the Wits appraisal and the SN-AB angle. Except the correlation between the Wits appraisal and the SN-AB

angle, the Wits appraisal and the APDI showed correlation coefficients poorer than 0.7 with coefficients of determination ranging from 0.23 to 0.48.

DISCUSSION

The ANB angle and the Wits appraisal are the most commonly used parameters among measurements related to anteroposterior jaw relationships. The validity of these parameters has been investigated by many studies. Jacobson[2,5] showed that the ANB angle does not provide an adequate assessment of jaw relationships because rotational growth of the jaws and the anteroposterior position of nasion influence the ANB angle. Hussels and Nanda[8] noted 2 additional factors affecting the ANB angle, the vertical lengths from nasion to point B and from point A to point B. Roth[7] and Chang[11] showed that the Wits appraisal is affected by the vertical dimensions of the jaws and the occlusal plane inclination. To eliminate these distorting effects, methods of geometric correction of both parameters have been introduced,[6-9,13,23] but these involve complicated procedures. Use of the 2 parameters in conjunction with other parameters describing jaw relationships seems preferable. However, the interchangeability or the redundancy among various jaw relationship parameters and the underlying factors should be clearly understood. This study evaluated the interchangeability among the 7 jaw relationship parameters by correlation analyses. In addition, prediction of future jaw relationships was investigated with the 7 parameters.

Prepubertal and postpubertal cephalograms of each subject were selected and used so that developmental stages were matched with reference to the maximum pubertal growth in body height. For the statistical analyses in this study, the cephalometric measured values in individual subjects were re-scaled and converted into Z scores for each of the 4 groups. As described earlier, this procedure was required to compare the postpubertal prediction accuracy among the 7 parameters, by assessing the standard errors of the estimate relative to variances of each parameter. In addition, in clinical diagnostic procedures cephalometric measured values are generally assessed by comparing population standards and calculating deviations from the mean.[22] Therefore, the jaw relationship parameters were examined in the light of clinical application.

Correlation coefficients between the prepubertal and postpubertal Z scores of the 7 parameters were obtained. All parameters showed correlation coefficients better than 0.8 between the 2 stages. Coefficients of determination in the 7 parameters indicated that 65% to 82% of the total variation in the future jaw relationship is determined by the prepubertal one. Judy et al[24] reported that in Angle Class I male subjects,

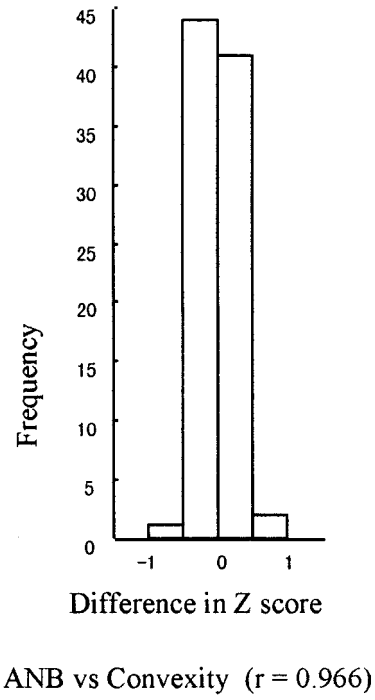

Fig 2. Histogram representing frequency distribution of differences in Z scores between the ANB angle and the angle of convexity. Differences in assessment within ±0.5 were found in 85 of the 88 cases.

there were significant correlations between child and adult readings in the AF-BF distance and the ANB angle with correlation coefficients exceeding 0.8. Horowitz and Hixon[25] stated that a correlation coefficient better than 0.8 may be used in clinical predictions. Therefore, the postpubertal Z score of the individual jaw relationship may be considered essentially predictable from the prepubertal Z score in normal occlusion subjects. However, the standard errors of the estimate calculated from the regression equations varied somewhat among the parameters. The standard error of the estimate was 0.42 in the angle of convexity and 0.46 in the ANB angle. Both parameters are considered to provide successful prediction of the postpubertal jaw relationship from the prepubertal one. To the contrary, the Wits appraisal showed the largest standard error, 0.61. Sherman et al[13] noted that changes in the Wits appraisal occurring during growth are not necessarily due to changes in the sagittal jaw relationship and are liable to be affected by changes in the angulation of the occlusal plane. The Wits appraisal uses a reference plane that is easily affected by tooth eruption or vertical development of the alveolar process, and this seems to result in its relatively poor prediction accuracy among the parameters. The

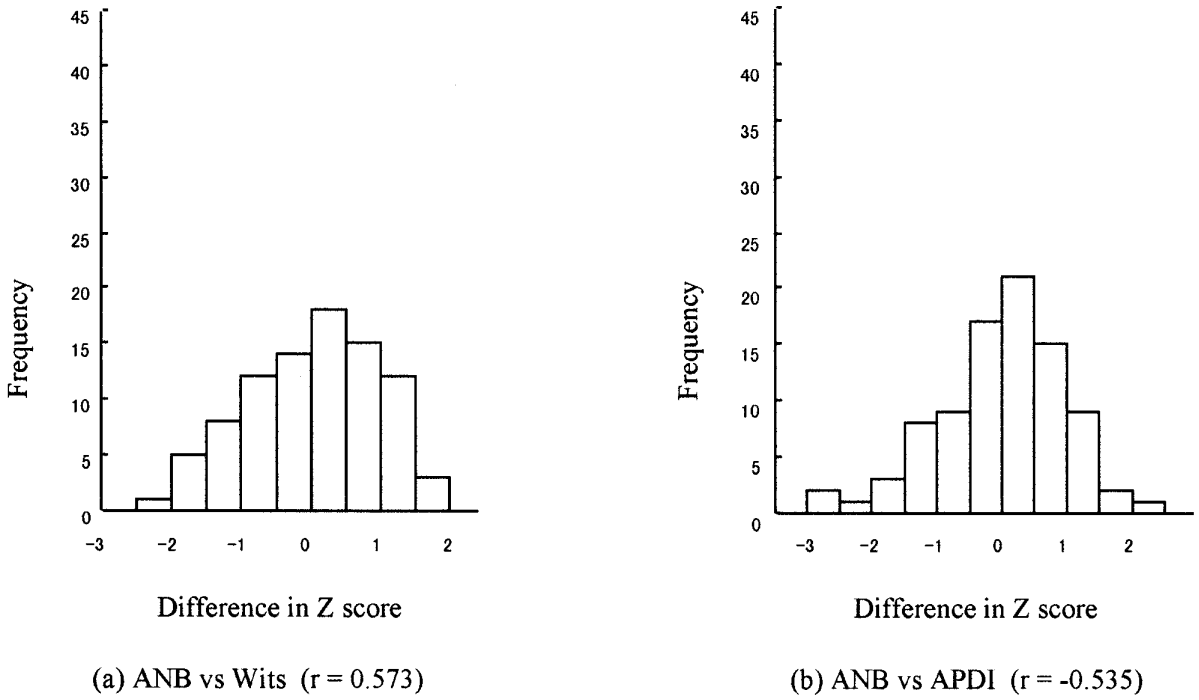

Fig 3. Histograms representing the frequency distribution of differences in Z scores (**A**) between the ANB angle and the Wits appraisal and (**B**) between the ANB angle and the APDI. Differences in assessment exceeding ±1.0 were found in 29 cases of (**A**) and in 26 cases of (**B**) among the 88 cases.

AF-BF distance also showed a larger standard error of the estimate. This parameter uses the Frankfort plane as a reference plane. This plane is considered a relatively unreliable reference for cephalometric analysis because of difficulties in locating the landmarks accurately on cephalograms.[26] This unreliability appears to affect the prediction accuracy of the AF-BF distance.

The interchangeability among the 7 parameters was evaluated by correlation analyses. Higher correlation coefficients, above 0.8, were found between the SN-AB angle and the AF-BF distance, and among the A-B plane angle, the angle of convexity, and the ANB angle. In these pairs of the parameters, 67% to 93% of the total variation in one of the parameters is determined by the other. Again, using the guidelines of Horowitz and Hixon,[25] these pairs of the parameters may be considered highly interchangeable in the assessment of anteroposterior jaw relationships. Here, when calculating differences in the Z scores between the angle of convexity and the ANB angle in 88 cases, the SD of the differences was quite small, 0.26. These parameters may be expected to show the same degree of anteroposterior jaw discrepancy in a patient (Fig 2). Other possible interchangeability with coefficients of determination better than 0.5 (from 0.55 to 0.61) was found between the A-B plane angle and the SN-AB angle, between the A-B plane angle and the AF-BF distance, between the ANB angle and the AF-BF distance, and between the Wits appraisal and the SN-AB angle. Except for the above pairs, other pairs of parameters would not be able to replace each other in the assessment of the anteroposterior jaw relationships. The Wits appraisal and the APDI showed low correlation coefficients in relation to other parameters. For the relation to the ANB angle, correlation coefficients were 0.57 with the Wits appraisal and –0.54 with the APDI. These were statistically significant but must still be considered low. The coefficients of determination were 0.33 and 0.29, respectively, which indicates that only about 30% of the total variation in 1 parameter is determined by the other. Although Oktay[27] reported strong correlations among the ANB angle, the Wits appraisal, and the APDI, a weak correlation between the ANB angle and the Wits appraisal has been shown in several studies.[11,12,14,28-31] When differences in the Z scores between the ANB angle and the 2 parameters were calculated, the SD of the differences was 0.93 for the Wits appraisal and 0.96 for the APDI. These suggest that differing assessments of jaw discrepancies would frequently occur with these pairs (Fig 3).

Considering the bases for the geometric distortion effects in each parameter, the interchangeability

between the 7 parameters can be evaluated. The Wits appraisal is affected by the occlusal plane inclination,[7,11] but not by the rotation of the jaws.[2,5] The APDI is a combination of 3 different measurements. Because of these characteristics, the Wits appraisal and the APDI are considered less interchangeable with other parameters. The rotation of the jaws can affect the A-B plane angle, the angle of convexity, the ANB angle,[2,4,5] the SN-AB angle, and the AF-BF distance.[12] The former 3 parameters can also be influenced by the anteroposterior position of nasion,[1-3,5,6] but the latter 2 are not affected by this factor. The similarities in the geometric influences among these 2 sets of parameters are considered to result in the closer relationships between the parameters.

For the conjunctive use of the jaw relationship parameters, redundancy among the parameters should be avoided. To predict postpubertal jaw relationships accurately, the ANB angle and the angle of convexity seem advantageous, but 1 of the 2 would be adequate because of the close relationship between them. Further, during the selection, the generally used ANB angle and the Wits appraisal also seem to be important factors that should be taken under consideration. The APDI showed low correlation coefficients in relation to both the ANB angle and the Wits appraisal. For these reasons, a clinically sound method for assessing the anteroposterior jaw relationships in individuals would be the conjunctive use of the ANB angle and the Wits appraisal along with the APDI. These 3 parameters would complement each other for the geometrically distorting factors because of the low interchangeability due to their different geometric basis as described above.

The results of this study were obtained from statistical analysis. Although predictability of the parameters was statistically substantiated, variability must be taken into consideration when assessing individuals. In that this study used normal occlusion subjects, direct applicability to deviant facial form is limited. Further investigation must be conducted to reexamine the jaw relationship parameters with samples including skeletally abnormal subjects.

CONCLUSIONS

Seven jaw relationship parameters were measured on pairs of lateral cephalograms of 44 normal occlusion subjects to evaluate prediction accuracy of future relationships by each parameter and interchangeability among the parameters. In the prepubertal assessment, the ANB angle and the angle of convexity showed better prediction accuracy for postpubertal jaw relationships. Higher interchangeability among the parameters was substantiated between the SN-AB angle and the AF-BF distance, as well as among the ANB angle, the angle of convexity, and the A-B plane angle. The Wits appraisal and the APDI were less interchangeable with other parameters. To assess the jaw relationships in individual patients, the conjunctive use of the ANB angle, the Wits appraisal, and the APDI is recommended.

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