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Properties of the ANB angle and the Wits appraisal in the skeletal estimation of Angle's Class III patients

Hiroshi Iwasaki*, Hiroyuki Ishikawa**, Lamiya Chowdhury*, Shinji Nakamura* and Junichiro Iida*

*Department of Oral Functional Science, Graduate School of Dental Medicine, Hokkaido University, Sapporo and **Department of Orthodontics, Fukuoka Dental College, Japan

SUMMARY The aims of the present study were: (1) to investigate the statistical differences in jaw relationship assessments with the ANB angle and the Wits appraisal in Angle Class III children, and (2) to suggest guidelines for the use of these two parameters in this group of children. Seventy-five Angle Class I children with anterior crowding (male, 37; female, 38) and 96 Angle Class III children with anterior crossbite (male, 38; female, 58) were examined. All had undergone treatment that started at 8 or 9 years of age. Pre-treatment lateral cephalograms were used cross-sectionally for the analysis. The mean age was 8 years 7 months ± 9 months in the Class I subjects, and 9 years 0 month ± 7 months in the Class III subjects. To compare the assessments using ANB angle and the Wits appraisal in the Angle's Class III subjects, nine measured values from each individual subject were converted into *Z* scores in relation to the means and standard deviations of the two parameters in the Angle Class I subjects.

The jaw discrepancy is assessed more severely using the ANB angle than by the Wits appraisal in these Angle Class III subjects. The paired *t*-test showed that the *Z* score of the ANB angle was significantly smaller than that of the Wits appraisal ($P < 0.001$). In Angle Class III subjects with a counter-clockwise mandibular rotation and a flattened occlusal plane, the ANB angle is a more critical cephalometric parameter than the Wits appraisal.

Introduction

In treatment planning for Class III children, the evaluation of the anteroposterior jaw relationship is an indispensable step, and this relationship is generally determined by cephalometric analysis. Since Downs (1948) introduced the A–B plane angle, other cephalometric parameters have been proposed to describe the anteroposterior jaw relationship along with the standard values. Of these parameters, the ANB angle (Riedel, 1952) and the Wits appraisal (Jenkins, 1955; Jacobson, 1975) are the commonly used parameters.

With regard to the validity of the ANB angle and Wits appraisal, geometric studies have pointed out a number of distorting factors. The ANB angle can differ because of variance in the length of the cranial base and/or rotation of the jaws (Taylor, 1969; Beatty, 1975; Jacobson, 1975, 1976; Rotberg *et al*., 1980; Freeman, 1981; Bishara *et al*., 1983; Rushton *et al*., 1991), and the Wits appraisal can be affected by the cant of the occlusal plane (Rotberg *et al*., 1980; Roth, 1982; Williams *et al*., 1985; Chang, 1987; Sherman *et al*., 1988). Because of these geometric effects, a conjunctive use of the ANB angle and the Wits appraisal has been recommended (Rotberg *et al*., 1980; Bishara *et al*., 1983; Jacobson, 1988; Sherman *et al*., 1988; Ishikawa *et al*., 2000). However, when there is a difference in the jaw relationship assessment between the two parameters, it is difficult to know on which parameter to base a selection.

This study examined the anteroposterior jaw relationships in Angle Class III children using both the ANB angle and the Wits appraisal. The purpose was: (1) to investigate statistical differences in the jaw relationship assessments of

the two parameters; and (2) to attempt to establish guidelines for the conjunctive use of the two parameters.

Subjects and methods

Seventy-five Angle Class I children with anterior crowding (male, 37; female, 38) and 96 Angle Class III children with anterior crossbite (male, 38; female, 58), all of the mongoloid race, were selected from the orthodontic records of the Hokkaido University Dental Hospital. All patients had undergone treatment that started at 8 or 9 years of age. Pre-treatment lateral cephalograms were used cross-sectionally for the analysis. The Angle Class I subjects showed excellent molar relationships or had less than half a cusp deviation whereas the Angle Class III subjects showed molar relationships beyond this range. No subject had congenital deformities or abnormal mandibular deviations. The mean age was 8 years 7 months ± 9 months in the Class I subjects, and 9 years 0 month ± 7 months in the Class III subjects.

Figure 1 shows the cephalometric measurements used in the study. The occlusal plane was set as the bisected occlusal plane, because of the higher reliability in identifying landmarks than with the functional occlusal plane (Millett and Gravely, 1991; Haynes and Chau, 1995). The overjet was measured parallel to the occlusal plane. In addition to the ANB angle, the Wits appraisal and three dental parameters, the following geometric distortion indicators were also measured (Ishikawa *et al*., 1999):

1. The SN–MP angle: an indicator of the rotation of the mandible.
2. The SN–PP angle: an indicator of the rotation of the maxilla.
3. The SN–OP and PP–OP angles: indicators of the cant of the occlusal plane.
4. The S–N distance: an indicator of the anteroposterior position of nasion.

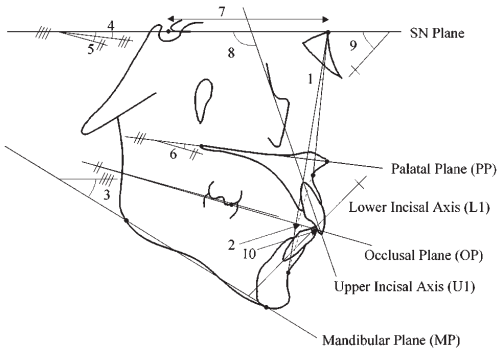


Figure 1 Cephalometric measurements used in the study. 1, ANB angle; 2, Wits appraisal; 3, SN–MP; 4, SN–PP; 5, SN–OP; 6, PP–OP; 7, S–N; 8, SN–U1; 9, SN–L1; 10, overjet.

Cephalograms were traced and all landmarks were marked on tracing paper by one investigator. For the error measurements, 10 randomly selected cephalograms were traced and digitized twice at two-week intervals (Logitec Digitizer Mypad-A3 Model K-510, Kanto Denshi Corporation, Tokyo, Japan). For each parameter, the combined error (Se) in the tracing, landmark identification, and digitization was estimated by the formula $Se^2 = \Sigma d^2/2n$, where d is the difference between the first and second measurements (Houston, 1983).

The means and standard deviations of the cephalometric measurements were calculated for each gender in the Class I and III groups, and gender differences were examined using a paired *t*-test. For data analysis, a personal computer (FM V-Desk Poewer T III 20M, Fujitsu Limited, Tokyo, Japan) and the Excel 97 SR-2 program (Microsoft, Inc., Redmond, USA) were used.

To compare the assessments using ANB angle and the Wits appraisal in the Angle Class III subjects, all measured values for a subject were converted into Z scores (Moyers, 1988; Stuart and Ord, 1994) in relation to the means and standard deviations of the two parameters in the Angle Class I subjects. The Z score was calculated with the following formula according to the method developed by Chowdhury *et al*. (1999):

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

where X is the measured value of Class III subject, and $\bar{X}$ and SD are the mean and standard deviation of the Class I subjects.

Based on the *Z* scores, the distribution in the ANB angle and the Wits appraisal was compared for the Angle Class III subjects. After the differences in *Z* scores between the two parameters were calculated for each subject, the facial morphology was compared between groups of subjects with smaller (less than 1 SD) and larger differences (below –2 SD), which were defined as Group 1 (G1) and Group 2 (G2), respectively.

Results

The combined error ranged from 0.17 degrees (ANB) to 1.94 degrees (SN–U1) for the angular measurements, and from 0.15 mm (Wits) to 0.28 mm (overjet) for the linear measurements.

Tables 1 and 2 show the means and standard deviations of the cephalometric measurements for the Angle Class I and III subjects, respectively. The skewness and kurtosis statistics for each gender group of the Class I and III subjects showed normal distributions for the variables. No statistically significant differences between genders were found by two-sample *t*-tests except in the S–N distance in the Angle Class I and III subjects. The male and female data, except the S–N distance, were pooled for each of the measurements, and the pooled data were used subsequently.

Table 1 The means and standard deviations of the cephalometric measurements and results of *t*-tests for gender difference in Angle Class I subjects.

Cephalometric measurements		Male (Mean ± SD)	Female (Mean ± SD)	*t*-test	Total (Mean ± SD)
ANB	(°)	4.26 ± 1.10	4.32 ± 1.13	NS	4.29 ± 1.12
Wits	(mm)	0.69 ± 2.16	0.14 ± 2.06	NS	0.41 ± 2.13
SN–MP	(°)	39.11 ± 3.95	37.94 ± 3.61	NS	38.52 ± 3.83
SN–PP	(°)	9.38 ± 3.43	8.57 ± 2.57	NS	8.97 ± 3.05
SN–OP	(°)	18.42 ± 3.64	18.70 ± 2.87	NS	18.56 ± 3.28
PP–OP	(°)	9.04 ± 2.96	10.13 ± 3.50	NS	9.60 ± 3.29
S–N	(mm)	61.30 ± 2.63	60.02 ± 2.10	*	–
SN–U1	(°)	103.77 ± 5.75	106.41 ± 3.96	NS	105.11 ± 5.10
SN–L1	(°)	50.88 ± 6.13	50.29 ± 4.43	NS	50.58 ± 5.34
Overjet	(mm)	3.55 ± 1.11	3.98 ± 1.35	NS	3.77 ± 1.26

SN, sella–nasion; PP, palatal plane; OP, occlusal plane; S–N, SN distance; U1, axis of upper incisor; L1, axis of lower incisor.
*$P < 0.05$; NS, not significant.

Table 2 The means and standard deviations of the cephalometric measurements and results of *t*-tests for gender difference in Angle Class III subjects.

Cephalometric measurements		Male (Mean ± SD)	Female (Mean ± SD)	*t*-test	Total (Mean ± SD)
ANB	(°)	–0.72 ± 2.05	–0.28 ± 1.85	NS	–0.45 ± 1.95
Wits	(mm)	–7.09 ± 2.91	–6.66 ± 2.84	NS	–6.83 ± 2.88
SN–MP	(°)	37.51 ± 4.69	37.75 ± 5.31	NS	37.65 ± 5.08
SN–PP	(°)	10.29 ± 3.06	9.67 ± 2.96	NS	9.91 ± 3.01
SN–OP	(°)	19.61 ± 4.18	19.21 ± 4.36	NS	19.37 ± 4.29
PP–OP	(°)	9.32 ± 3.79	9.55 ± 3.27	NS	9.46 ± 3.49
S–N	(mm)	61.93 ± 2.92	59.73 ± 2.41	***	–
SN–U1	(°)	102.03 ± 8.00	104.84 ± 7.13	NS	103.73 ± 7.61
SN–L1	(°)	56.10 ± 7.33	54.62 ± 7.93	NS	55.21 ± 7.74
Overjet	(mm)	–2.72 ± 1.31	–2.17 ± 1.32	NS	–2.39 ± 1.34

SN, sella–nasion; PP, palatal plane; OP, occlusal plane; S–N, SN distance; U1, axis of upper incisor; L1, axis of lower incisor.
*$P < 0.001$; NS, not significant.

Figure 2 shows histograms representing the frequency distribution of the *Z* scores of the ANB angle and the Wits appraisal in the Angle Class III subjects. The *Z* score was calculated based on the mean and standard deviation from the pooled data of male and female Class I subjects. The Class III subjects had an ANB angle between –9.57 SD and –1.30 SD with a mean of –4.25 SD, and for the Wits appraisal between –7.48 SD and –0.07 SD with a mean of –3.41 SD. From the paired *t*-test, the *Z* score of the ANB angle was significantly smaller than that of the Wits appraisal ($P < 0.001$).

The frequency distribution of the differences in the *Z* scores between the ANB angle and the Wits appraisal (ANB minus Wits) for the Class III subjects is shown in Figure 3. From the histogram, 50 cases between +1.0 SD and –1.0 SD were defined as G1, and 21 cases below –2.0 SD as G2. In G1 the jaw relationship assessment using the ANB angle was almost coincident with that of the Wits appraisal. However, in G2 the arch discrepancy was more severe when assessed using the ANB angle.

Table 3 shows means and standard deviations of the cephalometric measurements in the G1, G2, and Class I groups. One-way analysis of variance

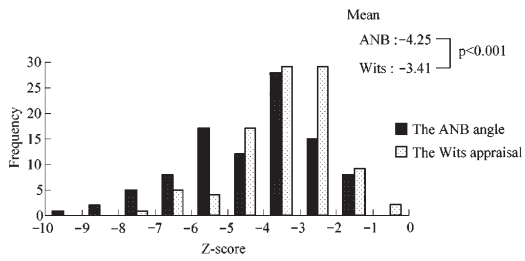


Figure 2 Histograms representing the frequency distribution of the ANB angle and the Wits appraisal in Angle Class III subjects. All the measured values are converted into *Z* scores in relation to the means and standard deviations in Class I subjects.

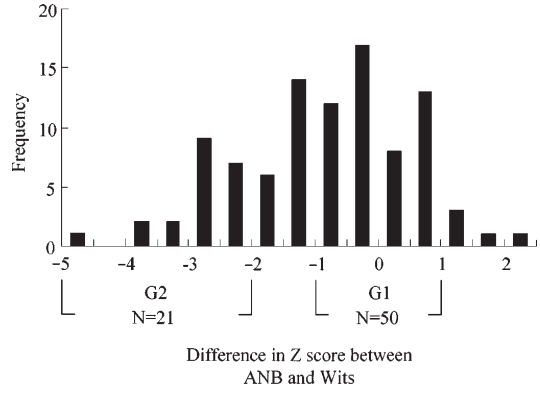


Figure 3 Histogram representing the frequency distribution of the difference in the *Z* scores between the ANB angle and the Wits appraisal for Class III subjects. Fifty cases between +1.0 and –1.0 SD were defined as Group 1 (G1), and 21 cases below –2.0 SD were defined as Group 2 (G2).

Table 3 Means of cephalometric measurements in G1, G2, and Class I subjects and results of ANOVA between each pair of three groups.

Cephalometric measurements			G1 (n = 50)	G2 (n = 21)	Class I (n = 75)	ANOVA		
						G1 vs G2	G1 vs Class I	G2 vs Class I
ANB	(°)		0.48 ± 1.44	–2.52 ± 1.69	4.29 ± 1.12	***	***	***
Wits	(mm)		–6.76 ± 2.73	–6.61 ± 3.13	0.41 ± 2.13	NS	***	***
SN–MP	(°)		38.59 ± 5.09	34.80 ± 4.45	38.52 ± 3.83	**	NS	***
SN–PP	(°)		9.93 ± 2.92	10.42 ± 3.00	8.97 ± 3.05	NS	NS	NS
SN–OP	(°)		20.66 ± 3.44	15.93 ± 3.93	18.56 ± 3.28	***	***	**
PP–OP	(°)		10.73 ± 2.44	5.51 ± 2.96	9.60 ± 3.29	***	*	***
S–N	(mm)	male	61.97 ± 3.09	62.97 ± 2.74	61.30 ± 2.63	NS	NS	NS
		female	59.46 ± 2.40	60.17 ± 1.96	60.02 ± 2.10	NS	NS	NS
SN–U1	(°)		103.27 ± 6.18	105.11 ± 9.87	105.11 ± 5.10	NS	NS	NS
SN–L1	(°)		53.88 ± 7.84	59.29 ± 6.11	50.58 ± 5.34	**	*	***
Overjet	(mm)		–2.18 ± 1.16	–2.98 ± 1.55	3.77 ± 1.26	*	***	***

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; NS, not significant.

(ANOVA) was performed to compare the variables in the three groups. For the ANB angle, the value in the G2 group was significantly smaller than in the G1 group ($P < 0.001$). The Wits appraisal showed no significant differences between G1 and G2. For the SN–MP angle, there were no significant differences between G1 and Class I groups, but the value of G2 was significantly smaller than in the Class I and G1 groups ($P < 0.001$, < 0.01, respectively). The SN–PP angle and the S–N distance showed no significant differences between the three groups. For the SN–OP and PP–OP angles, the value in G2 was significantly smaller than the Class I and G1 groups ($P < 0.01$, < 0.001). The SN–U1 angle showed no significant differences between the three groups. For the SN–L1 angle, the value in G2 was significantly larger than in the Class I and G1 groups ($P < 0.001$, <0.01, respectively), and the value for G1 was significantly larger than for the Class I group ($P < 0.05$). The overjet in G2 was statistically significantly smaller than in G1 ($P < 0.05$).

Discussion

In Angle Class III subjects, the anteroposterior relationship between the upper and lower arches worsens during pubertal growth (Susami, 1967; Jacobson *et al*., 1974; Schulhof *et al*., 1977; Sugawara *et al*., 1984; Nanda and Ghosh, 1995; Ishikawa *et al*., 1998), and the evaluation of the anteroposterior jaw relationship is of importance for diagnosis during this period. Clinically, the anteroposterior jaw relationship is quantitatively assessed by the use of lateral cephalograms. Of the various cephalometric parameters used to assess jaw relationship, conjunctive use of the ANB angle and the Wits appraisal is recommended, because it is difficult to evaluate the results from the two parameters equally (Rotberg *et al*., 1980; Bishara *et al*., 1983; Jarvinen, 1988; Rushton *et al*., 1991). Accordingly, it is significant to investigate differences in the jaw relationship assessments of the two parameters and to establish guidelines for their conjunctive use.

A comparison between the ANB angle and the Wits appraisal with distribution shows that the jaw discrepancy is more severe when assessed using the ANB angle than with the Wits appraisal in Angle Class III subjects (Figure 2). To evaluate the degree of difference in the jaw discrepancy estimation in individual subjects, the differences in the Z scores between the ANB angle and the Wits appraisal (ANB–Wits) for Class III subjects were calculated. There was variation in the differences in the Z scores of the ANB angle and the Wits appraisal for the Class III individual subjects. To establish the facial morphological features of the groups of subjects where these differences were small or large, two groups were selected. That is, the cases between +1.0 SD and –1.0 SD were defined as G1 and cases below –2.0 SD as G2. For the ANB angle, the estimate of the horizontal jaw relationship in G2 was significantly smaller than in G1, but there were no significant differences in the estimates using Wits appraisal of the two groups (Table 3). This result shows that G2 was where the jaw discrepancy was more severely assessed by the ANB angle than by the Wits appraisal. In evaluating the dental parameters (Table 3), a greater degree of the lower incisor retroclination was seen in G2, when compared with G1, while the negative overjet in G2 was larger than that in G1. This is thought to be due to the fact that the anteroposterior jaw relationship in G2 is worse than that in G1. From these results, it appears that in G2 the ANB angle is a more valid parameter to assess jaw relationships than the Wits appraisal.

To determine morphological features in the Class III cases, where the ANB angle is more suitable than the Wits appraisal, cephalometric parameters in both groups G1 and G2 were compared. The cant of the occlusal plane, which is used as the reference plane for the Wits appraisal was flatter in G2 than that in G1. Wits readings are known to alter with changes in the cant of the occlusal plane (Rotberg *et al*., 1980; Roth, 1982; Williams *et al*., 1985; Chang, 1987; Sherman *et al*., 1988). Therefore, it appears that in G2 where the cant of the occlusal plane was flattened, the Wits reading underestimated the severity of the skeletal Class III relationships, as a result of these geometric effects. Both maxillary and mandibular jaw rotations are

known to affect the assessment of horizontal jaw relationships by the ANB angle (Taylor, 1969; Jacobson, 1975, 1976; Bishara *et al*., 1983; Rushton *et al*., 1991). In this study, the inclination of the mandibular plane showed significant differences between the G1 and G2 groups, while the palatal plane showed no significant differences. It appears that in G2 the flatter mandibular plane is not the geometrically distorting factor that overestimates the ANB angle. These results suggest that the assessment of the horizontal jaw relationship using the Wits appraisal is underestimated in subjects with flattened occlusal planes, possibly due to mandibular counter-clockwise rotation.

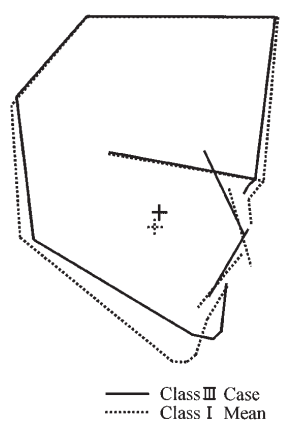
Figures 4 and 5 represent two typical examples showing large differences in the assessment using the ANB angle and Wits appraisal. All the measured values except overbite and overjet were converted into *Z* scores in relation to the means and standard deviations in Angle Class I subjects.

Subject A showed an ANB angle of –3.10 SD and a Wits appraisal of –0.07 SD, a difference of –3.03 SD. The ANB difference reflected the jaw discrepancy, whereas the Wits appraisal showed no jaw discrepancy. With regard to the cant of the occlusal and mandibular planes, there was an SN–OP angle of –2.48 SD, a PP–OP angle of –2.49 SD, and a SN–MP angle of –2.32 SD. The cant of the occlusal and mandibular planes was flattened.

Subject B showed an ANB angle of –4.27 SD and a Wits appraisal of –1.96 SD, a difference of –2.31 SD. With regard to the cant of the occlusal and mandibular planes, the SN–OP, PP–OP, and SN–MP angles were small, with deviations of –2.26, –3.53, and –1.43 SD, respectively. The overbite was +6.91 mm. The cant of the occlusal and mandibular planes was flatter than the means of the control group, and this subject showed mandibular over-closure with a deep overbite. In subject B, both the ANB angle and the Wits appraisal presented the jaw discrepancy. However, the *Z* score shows the ANB angle to be more severe than the Wits appraisal. In individual subjects with flattened occlusal and mandibular planes, the Wits appraisal to assess horizontal jaw relationships may result in no or little horizontal jaw discrepancy even when there is an obvious skeletal discrepancy.

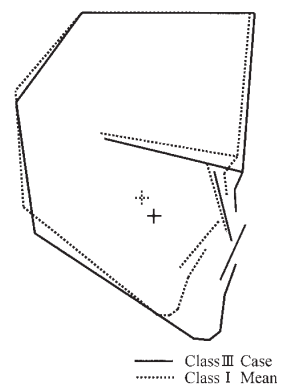
Conclusions

The present study found that in Angle Class III subjects with counter-clockwise mandibular rotation and flattened occlusal planes, the ANB angle is a more valid cephalometric parameter than the Wits appraisal to assess the skeletal anteroposterior discrepancy.



female	
ANB	−3.10
Wits appraisal	−0.07
Difference in Z score ANB vs Wits appraisal	−3.03
SN-MP	−2.32
SN-PP	0.03
SN-OP	−2.48
PP-OP	−2.49
S-N	0.05
SN-U1	2.26
SN-L1	1.78
	(Z score)
overbite	+1.11
overjet	−1.19
	(mm)

Figure 4 An example showing large difference in the jaw relationship assessment between the ANB angle and the Wits appraisal (case A).



male	
ANB	−4.27
Wits appraisal	−1.96
Difference in Z score ANB vs Wits appraisal	−2.31
SN-MP	−1.43
SN-PP	1.39
SN-OP	−2.26
PP-OP	−3.53
S-N	0.44
SN-U1	−0.29
SN-L1	2.48
	(Z score)
overbite	+6.91
overjet	−3.99
	(mm)

Figure 5 An example showing large difference in the jaw relationship assessment between the ANB angle and the Wits appraisal (case B).

Address for correspondence

Dr Hiroshi Iwasaki
Department of Oral Functional Science
Graduate School of Dental Medicine
Hokkaido University
Kita 13, Nishi 7, Kita-ku
Sapporo 060-8586, Japan

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