Longitudinal predictability of AF-BF value in Angle Class I patients

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Since the introduction of cephalometrics into orthodontic diagnosis and treatment planning,[1] great importance has been attached to the evaluation of the sagittal jaw relationship. Several cephalometric assessments of angular and linear jaw relationships have been developed to describe and quantify the anteroposterior relationship of the maxilla and mandible. Downs[2] defined points A and B and used the angle A-B plane-to-facial plane to assess the relationship of the anterior limit of the denture bases to each other and to the profile. Riedel[3] used the sella-nasion (SN) plane and described the angles SNA and SNB as measuring the relative anteroposterior position of the jaws. Steiner[4] agreed with Riedel that the SN plane could be used as a reference line because both points are midsagittal osseous structures that are easily visible in lateral cephalographs. However, he suggested that the angular difference between SNA and SNB—the angle ANB—was an important indicator of skeletal sagittal discrepancy. While the angle ANB has become one of the most commonly used measurements in cephalometric analysis, some investigators have shown that it is affected by several factors and might not accurately represent the anteroposterior relationship of the jaws.[5-10] Factors affecting the ANB angle include the patient's age,[10] variation of the spatial position of nasion,[6,10,] vertical rotation of the SN line,[10,11] relationship to the Frankfort horizontal (FH),[12] the rotational effect of the jaws rela-

Abstract

AF-BF is a linear cephalometric measure of the anteroposterior jaw relationship in the sagittal plane. A retrospective, longitudinal study was made to determine the mean Caucasian American AF-BF values at ages 8 and 18 years for 30 male and 32 female participants of the Bolton Growth Study. Mean AF-BF values (± s.d.) for males were 7.3 ± 2.7 mm at 8 years and 6.5 ± 4.2 mm at 18 years. Mean AF-BF values (± s.d.) for females were 6.7 ± 2.1 mm at 8 years and 5.2 ± 2.9 mm at 18 years. No significant difference was found between the mean AF-BF values for males and females at either age group ($P < 0.05$). The decrease in AF-BF mean values with increasing age both for males and females was statistically significant. The correlation (r) for the AF-BF values was 0.49 ($P < 0.05$) for females and 0.86 ($P < 0.05$) for males. With increasing age, the mean difference between ANB values for females was 1.40 ± 1.60 and 1.10 ± 1.40 for males. The correlation of ANB angle and AF-BF provides a clinically useful tool for the cephalometric assessment of anteroposterior sagittal discrepancies of maxillary and mandibular denture bases.

Key Words

Cephalometrics • Wits analysis • Orthodontics • Skeletal Class I • Sagittal discrepancy • Caucasian American

Submitted: February 1994 **Revised and accepted:** September 1994 Angle Orthod 1995;65(5):359-366.

Table 1
Reported AF-BF values

Author	Population	Gender	n	Sample age (years)	AF-BF (±s.d.) (mm)
Chang (1987)	Taiwanese	Male	40	Adults	3.43 ± 2.93
		Female	40		3.87 ± 2.63
Oktay (1991)	Turkish	Male	63	9 - 14	8.62 ± 4.72
		Female	82	9 - 14	7.3 ± 4.37

Figure 1
The AF-BF value. The linear difference between perpendicular projections from points A and B along the Frankfort Horizontal (FH).

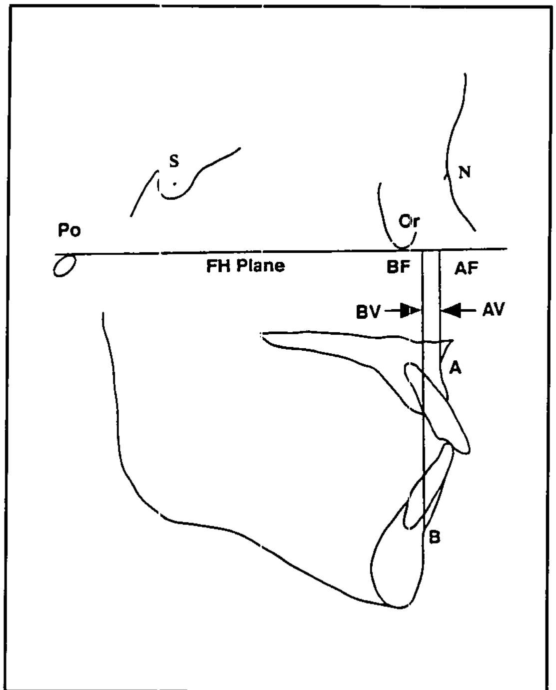

Figure 1

tive to the cranium,[6] and maxillary inclination and prognathism.[13]

An alternative measurement based on a linear evaluation of the distance between points A and B projected onto the occlusal plane is termed the "Wits" analysis.[5] The Wits value, or AO-BO, is the linear measurement between the perpendiculars drawn from point A and point B to the functional occlusal plane. While the Wits analysis has been shown to be less affected by variations in craniofacial physiognomy,[9,14,15] variation of the occlusal plane may affect the Wits appraisal.[8]

To reduce the dependence of sagittal measurements on the functional occlusal plane (FOP), Chang[8] advocated a linear measurement of the distance between points A and B projected onto the Frankfort horizontal plane (Figure 1). The points of origin of the perpendiculars on the Frankfort horizontal plane projected to points A and B were labeled AF and BF, respectively, and the measurement between the points along FH was called the AF-BF distance. Since the introduction of this measurement, only two authors have reported norms based on differing populations[8,10] (Table 1). Because a large proportion of orthodontic patients in the United States are Caucasian children and adults, the need exists to report AF-BF standards for these groups.

The purpose of this study was threefold: To estimate the AF-BF values for a Caucasian American population, to evaluate the relative stability of these values during growth, and to compare this indicator with ANB values.

Material and methods

A retrospective, longitudinal study was undertaken to establish gender and age norms for a specific population. Lateral cephalographs and study casts of 62 Caucasian American subjects, 32 females and 30 males, were evaluated. All materials used in this study were part of the original Bolton Study sample at Case Western Reserve University, Cleveland, Ohio. The Bolton Study was an extensive, longitudinal project which commenced in 1928 and continued until 1959. It was established to characterize the normal developmental growth process in subjects considered to be esthetically ideal. The target ages for the patient samples in this investigation were 8 and 18 years. These ages were chosen to circumvent the influence of pubertal effects on the analysis. Each subject had a Class I molar relationship based on Angle's classification. This information was verified by examination of the study casts of each subject. The age ranges, intervals between the initial and final cephalographs, and their means are shown in Table 2.

The original cephalographs had been produced by the Bolton cephalometric technique, using an anode-to-object distance of 5 ft. The object-to-film distance had been recorded for each radiograph together with the enlargement factor. These enlargement factors were used to calculate the absolute AF-BF value for our study.

The lateral cephalographs nearest each subject's 8th and 18th birthdays were selected, and features were traced on acetate by DLJ using a method similar to that described by Chang.[8] Using the tracing overlaid on the radiograph, six cephalometric landmarks were identified and marked as follows (Figure 1):

A (subspinale): The deepest midline point on the premaxilla between the anterior nasal spine and prosthion

B (supramentale): The most posterior point in the concavity between infradentale and pogonion

Table 2
Sample population demographics

Gender	Mean age (years)	Range (years)
Male		
Adult	18.2	17.0 - 20.2
Child	8.0	7.5 - 9.0
Interval between cephalograms	10.2	8.1 - 12.2
Female		
Adult	18.0	17.0 - 19.3
Child	8.3	7.9 - 9.9
Interval between cephalograms	9.1	8.3 - 11.3

Table 3
Sources of operator error

Source of error	n	Mean difference (± s.d) (mm)	Range	R^2	r
Intraoperator error					
Manual					
Female	20	-0.1 ± 0.3	-0.5 - 0.3	0.99	0.99*
Male	20	0.1 ± 0.2	-0.2 - 0.4	0.99	0.99*
Digitized					
Female	20	0 ± 0.3	-0.3 - 0.3	0.99	0.99*
Male	20	0 ± 0.3	-0.6 - 0.4	0.99	0.99*
Interoperator error					
Manual	20	-0.4 ± 0.4	-1.1 - 0.3	0.98	0.98*
Digitized	20	0 ± 0.6	-1.7 - 0.9	0.97	0.98*

*P<0.001

S (sella): The midpoint of sella turcica

N (nasion): The intersection of the internasal suture with the nasofrontal suture in the midsagittal plane

Or (orbitale): The lowest point on the lower margin of the bony orbit

Po (porion): The upper margin of the external auditory canal; anatomic porion

AF-BF values were calculated from cephalometric tracings using both manual and digitized methods. Perpendicular lines were drawn from points A and B to Frankfort horizontal. An electronic digital caliper (Max-Cal, Fowler and NSK, Japan) was used to measure the AF-BF values to the nearest 0.1 mm. Each acetate tracing was also digitized using a digitizing pad (Dentofacial™ software, Dentofacial Planner Corporation, Toronto, Canada), cursor, and personal computer (IBM PS/2 Model 70 386, International Business Machines Corporation, Boca Raton, Fla, USA) and Dentofacial™ software (Version 5.32, Dentofacial Planner Corporation, Toronto, Canada). From the digitized landmarks, Frankfort horizontal (FH) was constructed, perpendicular lines from points A and B to FH drawn, and the linear distance between these two points on FH (AF-BF) and angles SNA, SNB, ANB and MPA (mandibular plane angle) were calculated.

Manual and digitized intraoperator error was assessed by comparing the AF-BF measurements made by the principal investigator on a random sub-sample of 40 subjects (20 males and 20 females) with the AF-BF measurements made by the same investigator in a blinded fashion. Both manual and digital interoperator errors were determined by comparing the AF-BF measurements of a random sub-sample of 20 subjects (10 males and 10 females at age 8) with the AF-BF measurements obtained by a second orthodontist. The orthodontists had similar orthodontic education and clinical experience. The mean, standard deviation, range, r, and R^2 values for each of the six sets of comparative measurements were calculated.

Descriptive statistical analyses included means, standard deviations, upper and lower confidence limits, and predicted Y values calculated at the 90% level of confidence. Coefficients of determination (R^2) were used to compare the longitudinal data, and the two-tail unpaired t-test was used to evaluate sex differences. The statistical analyses were performed on a personal computer using a specific software package developed for analysis of scientific data.[16] The level of significance was set at alpha < 0.05.

Results

The mean manual and digitized intraoperator error difference and range for selected male and female cases in the sample population are shown in Table 3. Table 3 also shows the mean manual and digitized interoperator error and range. Coefficients of determination and correlation coefficients were all greater than 0.97 ($P<0.001$).

The mean difference between manual and computed AF-BF values and ranges for the popula-

Table 4
Manual vs digitized AF-BF values

Category	n	Mean difference (± s.d.)(mm)	Range (mm)	R^2	r
Female	64	-0.1 ± 0.4	-1.0 - 0.6	0.98	0.99*
Male	60	-0.2 ± 0.6	-2.5 - 1.1	0.97	0.99*

*P<0.001

Table 5
Gender and age comparison between computed AF-BF values

Category	n	Mean AF-BF (± s.d.) (mm)	Range (mm)	Difference (mm)	t
Child					
Male	30	7.3 ± 2.7	1.8 - 13.9	0.6	-0.98*
Female	32	6.7 ± 2.1	2.6 - 10.6		
Adult					
Male	30	6.5 ± 4.2	4.7 - 15.8	1.3	-1.43*
Female	32	5.2 ± 2.9	0.1 - 11.5		
Overall					
Male	60	6.9 ± 3.5	-4.7 - 15.8	0.9	-1.61*
Female	64	6.0 ± 2.7	-0.1 - 11.5		

*P> 0.10

Table 7
ANB vs AF-BF values

Category	n	Mean AF-BF (± s.d.) (mm)	Mean ANB (±s.d.) (degrees)	R^2	r
Female	64	6.0 ± 2.7	3.2° ± 2.1°	0.52	0.72*
Male	60	6.9 ± 3.5	3.8° ± 2.3°	0.61	0.78*

*P<0.001

Table 6
Computed ANB values

Category	n	Mean ANB (± s.d.)(degrees)	Range (degrees)
Females			
Overall	64	3.2 ± 2.1	-2.1 - 7.0
Child	32	3.9 ± 1.8	-0.2 - 7.0
Adult	32	2.5 ± 2.1	-2.1 - 6.0
Males			
Overall	60	3.8 ± 2.3	-1.5 - 8.7
Child	30	4.3 ± 1.9	1.3 - 8.7
Adult	30	3.2 ± 2.5	-1.5 - 7.7

tion sample are shown in Table 4. For females the mean difference between manual and computed AF-BF values was -0.1 ± 0.4 mm, with a range of -0.1 to 0.6 mm. For males the mean difference was -0.2 ± 0.6 mm, with a range of -2.5 to 1.1 mm. R^2 was 0.98 for females and 0.97 for males with corresponding r values of 0.99 for both males and females. Table 5 shows that the mean computed AF-BF difference comparing females and males was 0.9 mm (t = -1.61); between children the difference was 0.6 mm (t = -0.98) and between adults it was 1.3 mm (t = -1.43). The t values of these comparisons indicate no significant differences existed between these groups.

Considering the changes in AF-BF with increasing age, the mean difference between computed AF-BF values for females (n = 32) was 1.5 ± 2.7 mm, with a range of -4.7 to 7.6 mm, producing an R^2 of 0.24 and r of 0.49 (P <0.005). The mean difference between computed AF-BF values for males (n = 30) was 0.9 ± 2.3 mm, with a range of -2.0 to 8.0 mm, producing an R^2 of 0.74 and r of 0.86 (P <0.001). Figures 2A and 2B show the linear regression and upper and lower confidence limits (90%) for the predicted adult AF-BF value based upon the child AF-BF value (predictor) for males and females.

Table 6 shows the computed mean ANB values, standard deviations, and range for age and sex of the sample population. The difference between the ANB means for females and males was 0.6 mm (t = -1.52), for children it was 0.4 mm (t = -0.85), and for adults it was 0.7 mm (t = -1.20). The t values of these comparisons indicate no significant differences exist between these groups.

Considering the changes in ANB angle with increasing age, the mean difference between ANB values for females (n = 32) was 1.4° ± 1.6°, with

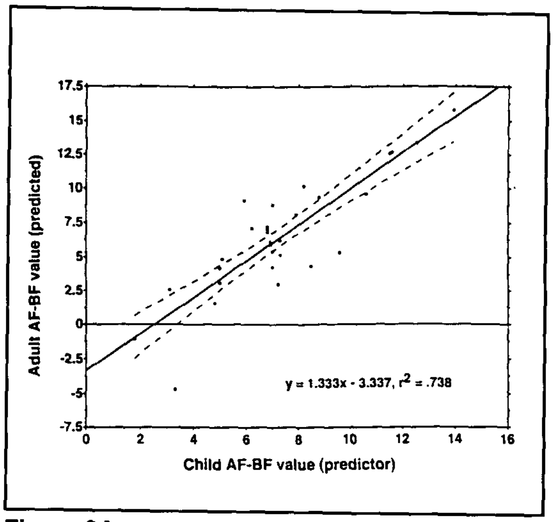

Figure 2A

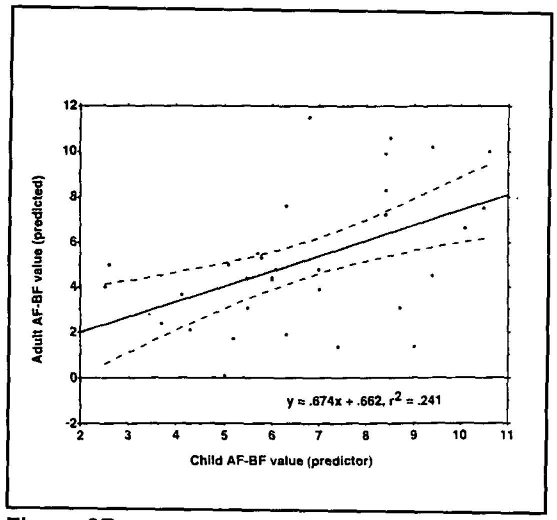

Figure 2B

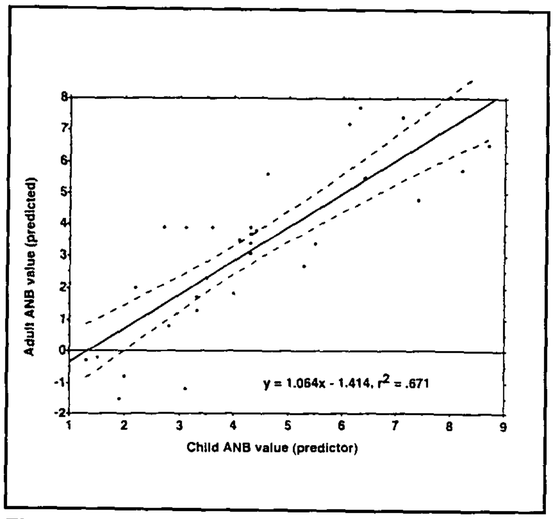

Figure 3A

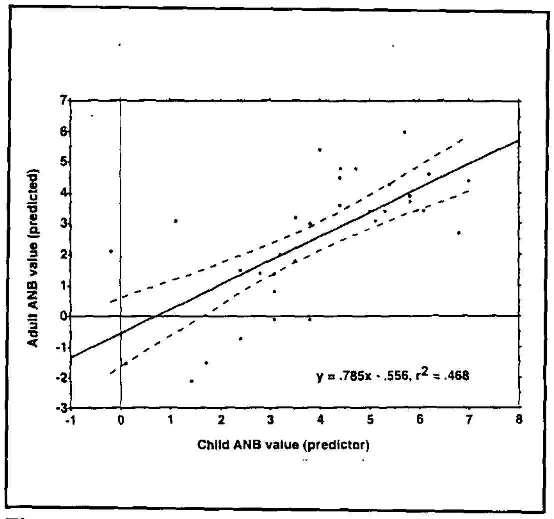

Figure 3B

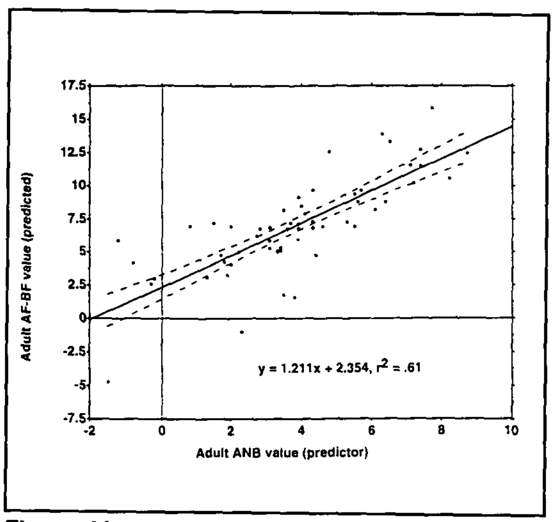

Figure 4A

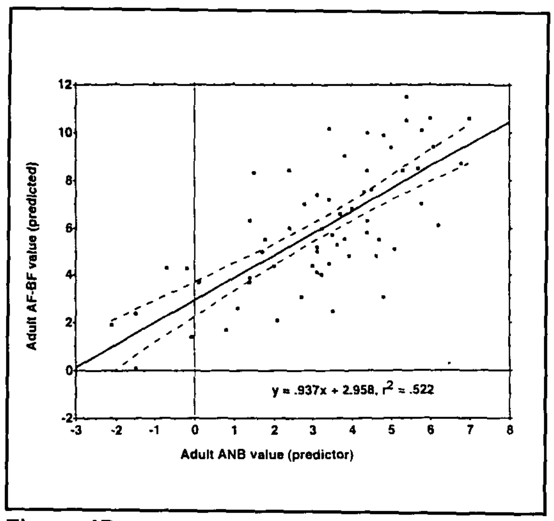

Figure 4B

Figure 2A-B
Child vs. adult AF-BF linear regression.
A. Males, with regression line ($R^2 = 0.74$) and upper and lower 90% confidence limits.
B. Females, with regression line ($R^2 = 0.24$) and upper and lower 90% confidence limits.

Figure 3A-B
Child vs. adult ANB linear regression.
A. Males, with regression line ($R^2 = 0.67$) and upper and lower 90% confidence limits.
B. Females, with regression line ($R^2 = 0.47$) and upper and lower 90% confidence limits.

Figure 4A-B
ANB vs. AF-BF linear regression
A. Males, with regression line ($R^2 = 0.61$) and upper and lower 90% confidence limits.
B. Females, with regression line ($R^2 = 0.52$) and upper and lower 90% confidence limits.

a range of -3.2° to 8°. The R^2 for this relationship was 0.47, with r = 0.69 (P <0.001). The mean difference between ANB values for males (n = 30) was 1.1° ±1.4°, with a range of -1.4° to 4.3°. The R^2 for this relationship was 0.67, r =0.82. Figures 3A and 3B show the linear regression and upper and lower confidence limits (90%) for the predicted adult ANB value based upon the child ANB value (predictor) for males and females.

Table 7 shows the overall comparison between computed mean ANB angle and AF-BF values. Figures 4A and 4B show the linear regression and upper and lower confidence limits (90%) for the predicted AF-BF value based upon the predictor, the ANB values for males and females.

Discussion

The linear measurement AF-BF reportedly describes the linear relationship between point A and point B relative to a constructed reference plane, FH. On the basis of a southern Chinese population, Chang contends that AF-BF portrays the sagittal relationship of the jaws more accurately than more traditional methods, such as the angle ANB and the Wits appraisal.[8]

We quantified the sources of error in this study and found that the computed method produced consistently low intra- and interoperator errors compared with the manual method. Mean AF-BF values calculated digitally for males and females differed from those derived manually, and although probably clinically insignificant (maximum s.d. = ± 0.6 mm), remain as the scientific research method of choice for cephalometric data acquisition and comparison.

The primary purpose of our study was to estimate AF-BF values of Caucasian Americans. Comparing these values with the findings of the two previous authors shows some differences. While the AF-BF means are similar but slightly less for a Turkish population,[10] they are substantially higher than the values obtained for the southern Chinese group.[8] Standard deviation values obtained indicate approximately the same variation in the Caucasian American population as found in the southern Chinese population. However, variation in the Turkish population appears markedly higher. No statistical differences were found for AF-BF values between sex either overall or at any age group.

The second objective was to determine if the AF-BF value remains stable with increasing age. Correlations between the AF-BF value for adults and children showed a statistically significant decrease in values from age 8 to 18. The mean ANB value also decreased with increasing age, and this correlation was statistically significant. To better quantify individual variability of stability with increasing age, upper and lower confidence limits (UCL, LCL) were used. As an example, one could be 90% confident that a group of 8-year-old Caucasian American females who had a mean AF-BF value of 6 mm and a mean ANB value of 4° would, as 18-year-olds, have a mean AF-BF value between 3 mm and 5 mm and a mean ANB value between 1.5° (LCL) and 3° (UCL) (Figures 2B and 3B). Because orthodontists deal with individuals, the individual upper and lower prediction limits should be consulted. This wide range of predicted adult ANB and AF-BF values should alert the orthodontist to exercise caution during treatment planning for growing individuals. Our results agree with previous reports of a significant decrease in AF-BF and ANB with increasing age. Williams et al. found that ANB and the Wits appraisal decreased from age 11 to 18.[17] Jarvinen reported that ANB and the Wits appraisal declined proportionally with age.[18] In contrast, some authors have found sagittal measurements remained stable with age.[19, 20]

AF-BF is a simple value to measure either manually or with the aid of digital software programs. It provides the orthodontist with another useful tool to assess sagittal relationships. The AF-BF value is perhaps most helpful in the assessment of skeletal tendencies in high mandibular plane angle individuals. However, one must remember that a cephalograph is a static measurement, taken at one point in time.[21] As the prediction limits demonstrate in this study, great variability exists when assessing individuals. Caution must be exercised when trying to predict the effect of growth upon the facial skeleton. Complete diagnostic evaluation must be performed, of which cephalometrics is only one part.

Conclusions

This study presents AF-BF normal values for a Class I (Angle) Caucasian American population at two different ages.

1. Mean AF-BF values (± s.d.) for males were 7.3 ± 2.7 mm at 8 years and 6.5 ± 4.2 mm at 18 years.
2. Mean AF-BF values (± s.d.) for females were 6.7 ± 2.1 mm at 8 years and 5.2 ± 2.9 mm at 18 years.
3. No significant difference was found between the mean AF-BF values for males and females at either age group.
5. There was a significant decrease in AF-BF

mean values with increasing age both for males and females.

6. The correlation (r) for the AF-BF values was 0.49 ($P < 0.05$) for females and 0.86 ($P < 0.05$) for males.
7. The correlation between ANB and AF-BF values can be particularly helpful in the assessment of patients with high mandibular plane angles.

Disclaimer

The views expressed in this paper are exclusively those of the author and do not reflect those of the United States Army Dental Corps, The United States Army, or the Department of Defense.

Acknowledgments

The authors would like to thank Dr. B. Holly Broadbent, Jr. and Ms. Mumaw for their help and hospitality during the data collection phase at the Bolton Growth Study Center, Case Western Reserve University.

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This represents part of the work performed by the first author for the MS degree in Oral Biology, University of Louisville.

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