The Saddle Angle: Constancy or Change?

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For a long period there has been considerable interest in the saddle angle (Ba-S-N) among craniometrists, growth research workers and orthodontists. Despite all that has been done, there are many conflicts and gaps in the literature. In particular, analyses of long-term serial data, such as those made during the present study, have not been reported.

Necessarily, all prenatal studies have been based on cross-sectional data and, as might be expected, the points used to measure the "saddle angle" differ slightly among the investigations. In a very early study Virchow[1] reported findings that have been interpreted often as showing an increase in the saddle angle. He measured the angle between the planum ethmoidale and the clivus. Pankow[2] and DeCourt and Pankow[3] also measured the saddle angle in the same fashion and reached similar conclusions.

An increase in the saddle angle during the prenatal period was reported by Ford[4] who had few specimens available; this conclusion is in agreement with the findings from several other studies.[5-10] There is fairly general agreement that the increase during prenatal life (4 mos.-term) is about 15° to 19°. However, many of these investigators had few fetuses available and not all excluded pathological material. A contrary conclusion was reached by Lavelle[11] who reported a study of 280 fetuses from apparently normal pregnancies. He found an increase of only 4° which is in agreement with the report of Burdi[12] who studied fetuses carefully chosen as nonpathological.

In the postnatal period there is a need for studies based on long-term serial data. The present review will be restricted to the few such investigations reported. There are findings that the saddle angle remains unchanged or decreases slightly from birth to 3 months[13] and that it does not alter from 3 months to 8 years.[14] In a large group of boys (N = 223) examined at both 12 and 20 years, Björk[15] found a mean increment of only 0.7° but the increments were quite variable (s.d., 1.9°). The largest increase was 5° and the largest decrease was 5.5°. Brodie Jr.[16] reported that, in a group of 30 children studied from about 13 to 18 years, 12 had no change in the saddle angle and in only 5 did the change exceed 4°.

Materials and Methods

The present data were obtained from 1112 standardized lateral cephalometric radiographs taken during a longitudinal study conducted in a southwest Ohio white community. The radiographic portion of this continuing investigation began in 1936. The participants are normal in health and of middle socioeconomic status. Most have a Class I occlusion (76 boys, 53 girls), almost all the remainder have a Class II occlusion (22 boys, 11 girls). The radiographs used were taken within one month of the target examination ages given in Table I and were selected for adequacy of positioning and image definition.

The radiographs were traced by one individual and the cephalometric reference points were checked by another. The angle Ba-S-N was recorded to the nearest 0.5° by several observers whose errors were small (interobserver differences, N = 208, mean .28°, s.d., 32°; intraobserver differences, N = 99,

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TABLE I

Age (yrs)	BOYS					GIRLS				
	n	Mean	S.D.	Max.	Min.	n	Mean	S.D.	Max.	Min.
0.0	16	140.47	3.34	146.5	134.5	19	137.87	4.97	145.0	128.5
1.0	29	134.78	4.64	142.5	124.5	25	133.00	4.15	141.0	127.0
2.0	29	133.71	4.33	142.5	125.0	20	132.13	3.65	140.5	126.5
3.0	33	132.08	4.58	139.5	121.5	22	132.00	4.31	139.5	123.5
4.0	39	132.12	4.18	141.0	122.5	35	131.26	4.63	140.5	122.0
5.0	37	132.49	4.09	140.0	121.0	30	131.28	4.66	138.5	123.0
6.0	38	131.53	4.37	140.5	121.5	41	130.40	4.41	138.0	121.0
7.0	38	131.70	4.59	139.5	122.5	42	131.02	4.01	138.0	122.0
8.0	42	131.65	3.99	139.5	120.0	36	131.42	4.17	139.5	122.5
9.0	59	131.53	4.30	140.0	121.0	38	131.36	4.96	143.5	120.5
10.0	50	131.45	4.42	140.0	121.0	37	130.47	4.66	139.0	119.5
11.0	57	131.49	4.81	140.0	120.0	37	130.68	5.71	146.5	119.5
12.0	47	131.04	4.40	139.0	122.5	35	130.57	4.65	139.5	120.5
13.0	56	131.05	4.77	139.0	121.5	39	130.73	5.29	139.5	121.0
14.0	42	131.15	4.84	138.0	119.5	30	130.45	5.18	139.0	120.0
15.0	58	130.59	4.75	140.0	117.5	35	129.91	5.99	147.5	119.0
16.0	34	130.71	4.97	139.0	119.0	22	130.84	5.46	139.0	118.0
17.0	48	131.04	4.96	139.5	121.0	27	130.48	6.63	149.0	118.5
18.0	24	128.63	5.19	138.0	120.0	12	130.71	4.80	137.0	122.5
20.0	33	130.20	4.72	141.5	122.5	16	130.34	7.67	147.0	120.0
22.0	32	130.17	5.47	141.5	119.0	19	129.63	7.20	147.5	120.5
24.0	21	131.33	4.76	140.5	123.5	14	130.25	5.93	136.0	120.0
26.0	20	128.83	3.21	136.0	123.0	17	128.82	6.06	136.5	119.5
28.0	25	129.90	4.47	137.5	121.5	12	130.71	5.50	136.0	119.0
30.0	22	129.52	4.12	137.0	122.5	13	130.23	4.44	137.5	120.5
32.0	15	129.13	4.95	138.0	120.0	12	130.21	6.31	136.5	119.0
34.0	15	129.97	4.31	137.0	122.5	10	130.45	5.90	138.0	119.0
36.0	13	128.85	4.91	137.5	119.5	10	128.30	5.64	136.5	118.5
38.0	14	131.39	5.78	138.0	119.0	7	129.21	6.03	137.0	119.0
40.0	10	129.20	7.17	138.0	119.0	7	126.79	4.61	131.5	120.0

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mean .18°, s.d., .25°). These levels of reliability are similar to those reported by others.[17-19] Considerable checking occurred after the measurements were made because the serial nature of the data allowed the recognition of unexpected increments.

Findings

Levels. The data were distributed normally within age- and sex-specific groups. Consequently, the distributions have been described using means and standard deviations (Tables I and II). Data are available at half-yearly intervals but those recorded close to half birthdays have been omitted from the tables. The means decrease by 5° or more from birth to 2.0 years in each sex whether the groups of Class I or Class II participants are considered. Later changes are slight except for a gradual decrease in Class I individuals and a marked decrease in Class I girls from 36 to 40 years. The latter is doubtfully valid because of the small sample size at these ages. The small sample size would explain the irregularity of the age trends of the means after about 24 years. The mean values tend to be smaller in the Class I boys than in the Class II boys. There is considerable variability in both groups, the range from the minimum to the maximum within an age- and sex-specific group being about 18°.

The sex differences are small within both classifications at all ages but there are consistent slight tendencies for the saddle angle to be larger in the boys until about 18 years. At later ages the sex difference is in the reverse direction but the sample sizes are small, particularly in the Class II group. In general, as a rule of thumb, the mean saddle angle in Class I individuals is 139° at birth, 132° from 2 to 12 years, 131° from 12 to 24 years, and 130° from then to 40 years.

between 4° and 5°. In boys they are larger in the Class II group at most ages until after 9 years when the standard deviations become larger in the

Most of the standard deviations are Class I group. In the girls satisfactory comparisons of a corresponding nature are impossible because of the small number of girls in the Class II group. The standard deviations are similar for each sex in the Class I occlusion groups until 8 years, after which they are larger for girls.

Increments. Increments were calculated for saddle angle measurements during rather long age intervals. The intervals used were: (1) from the first visit (mean age 2.3 years) to 8 years, (2) from the first visit to 16 years, (3) from the first visit to the last visit (mean age 29.6 years), (4) from 8 years to 16 years, (5) from eight years to the last visit, and (6) from 16 years to the last visit. For this part of the analysis each first visit was earlier than 6 years and each last visit was later than 16 years. The age intervals studied were chosen to allow interpretations concerning prepubescent, pubescent, adolescent and adult periods, and some combinations of these.

In each sex and in both occlusal groups almost all the median increments are negative showing a tendency for the flexure of the cranial base to become less marked with age. Consequently, data for both groups have been combined in Table III. The tendency toward less flexure is more marked during the intervals that began at the age of the first radiographs ("1st to 8," "1st to 16," and "1st to last"). Contrariwise, the median increments after 16 years ("16 to last") are zero or near zero. Clearly, the saddle base angle decreases before puberty but then becomes rather stable.

Not only the median increments but also the outlying percentiles of these in-

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TABLE II

Saddle Angle Sizes in Class II Occlusion

Age (yrs.)	BOYS					GIRLS				
	n	Mean	S.D.	Max.	Min.	n	Mean	S.D.	Max.	Min.
0.0	--	---	---	---	---	5	139.40	5.21	147.0	133.5
1.0	8	134.63	5.28	141.5	126.0	4	132.50	3.63	136.0	127.5
2.0	10	132.00	4.63	140.0	125.5	7	131.14	3.61	134.0	123.5
3.0	14	133.29	6.30	148.5	125.5	7	131.86	4.59	135.5	122.0
4.0	14	132.39	6.54	148.5	125.0	7	130.79	5.06	135.5	120.0
5.0	14	131.96	6.45	148.0	124.0	8	131.25	4.25	135.0	121.5
6.0	12	132.38	6.25	144.5	124.5	5	129.80	5.90	134.5	119.5
7.0	16	132.34	6.09	145.0	124.0	8	130.94	5.17	136.5	119.5
8.0	14	133.11	5.65	145.0	124.5	9	131.00	4.13	135.0	120.5
9.0	16	132.84	5.07	144.0	124.5	9	131.94	1.26	134.0	129.5
10.0	15	132.87	3.86	141.5	125.0	9	130.83	3.96	134.0	121.0
11.0	15	132.00	4.88	141.5	124.5	9	130.61	4.20	134.0	120.0
12.0	16	132.69	4.59	141.5	125.5	7	132.43	1.67	134.5	129.5
13.0	15	133.60	4.24	142.0	126.0	7	132.64	2.19	135.5	128.5
14.0	11	132.86	3.88	142.5	128.5	4	131.63	2.02	134.0	129.5
15.0	16	133.03	4.74	143.5	126.5	6	131.83	1.03	133.0	130.0
16.0	13	132.88	4.36	142.5	127.0	--	---	---	---	---
17.0	14	130.96	2.71	135.0	126.0	8	130.38	4.42	132.5	119.5
18.0	7	131.93	5.05	142.5	127.0	4	133.88	1.03	135.0	132.5
20.0	8	130.69	5.07	137.5	124.0	6	132.08	3.06	137.5	128.0
22.0	9	130.44	3.89	135.5	123.5	5	129.40	5.38	133.0	120.0
24.0	9	128.89	3.53	134.0	123.5	4	130.25	7.82	138.0	119.5
26.0	9	131.72	3.33	136.0	125.5	5	129.30	5.62	133.5	119.5
28.0	7	131.07	2.59	136.5	128.5	4	132.25	4.33	138.0	127.5
30.0	8	132.19	3.74	137.5	125.5	4	131.75	4.11	137.0	127.0
32.0	7	130.57	3.97	135.5	125.0	--	---	---	---	---

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TABLE III

Distribution of Increments

Age Interval	N	Percentiles 10	50	90	Max.	Min.
			BOYS			
1st to 8	57	—10.79	—2.00	0.50	4.5	—13.5
1st to 16	57	— 8.45	—3.00	1.30	4.0	—16.5
1st to last	83	—12.00	—4.50	0.85	5.5	—17.0
8 to 16	54	— 4.18	—1.00	1.38	2.5	— 7.5
8 to last	70	— 4.50	—1.50	0.70	3.0	— 7.5
16 to last	71	— 2.00	—1.00	1.00	3.5	— 3.0
			GIRLS			
1st to 8	46	—10.50	—4.00	1.20	3.5	—15.5
1st to 16	31	—11.00	—2.50	3.00	5.5	—15.5
1st to last	53	—12.00	—5.00	1.70	5.0	—16.5
8 to 16	30	— 3.50	—1.00	3.00	3.5	— 4.0
8 to last	49	— 4.05	—0.50	2.10	4.5	— 5.5
16 to last	32	— 1.66	0.00	1.00	2.0	— 2.5

crements are of interest. Commonly, in the larger groups (N > 10) the decrease in flexure exceeds 10° at the tenth percentile level. The largest decrease is 17°, if the age interval begins at the first radiograph. However, at the ninetieth percentile level the change is almost always a slight increase in flexure, the largest increase being 5.5°. There are no consistent sex differences in the patterns of these increments.

Changes in Individuals. It is clear from the ranges of the increments (Table III) that large changes occur in some individuals. The data relating to four boys selected because they have large changes in the saddle angle between the first and last cephalometric examinations are shown in Figure 1. The total decreases are large ranging from 6 to 17.0°. In each boy the decrease is rather gradual until about two years after the age of peak height velocity. Subsequent changes are slight.

Interrelationships. A complete age to age intercorrelation matrix was calculated for boys and girls separately combining data for all occlusion groups. Selected coefficients are presented in Table IV. These are very high even for widely separated ages reflecting the general stability of the saddle angle and also the accuracy of the recorded measurements. Most of the sex differences in these coefficients are small and the directions of the differences vary.

The correlation coefficients between increments in saddle angle size for different age intervals within individuals are low (from —.28 to + .19). This would be expected because, in most individuals, the saddle angle changes only slightly with age after infancy. Consequently, the increments in this measure are small and, of course, each recorded increment is influenced by the errors of measurement at the beginning and the end of the interval. These error factors could reduce the correlation coefficients.

Correlations were calculated at 4, 8, 12, 16, and 20 years for the total sample between the size of the saddle angle and length of nasion-basion, cranial vault length (the maximum endocranial length measured from glabella), and stature (Table V). The coefficients with Ba-N length are positive in both sexes at each age. They increase with age until, at 20 years, about 25 percent of the variance of the saddle angle in boys and about 36 percent of the corresponding variance in girls are ac-

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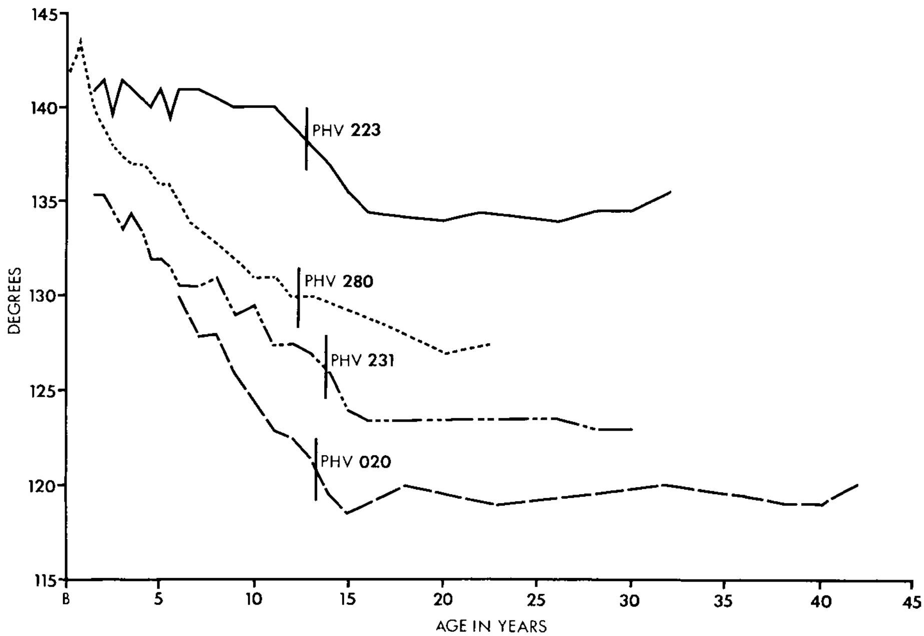

Fig. 1 Serial saddle angle sizes in four boys, each of whom showed unusually large decreases. PHV = peak height velocity.

TABLE IV

Selected Intercorrelations between Saddle Angles at Different Ages

Age (yr.)	1.0	5.0	10.0	15.0	20.0
1.0		.86	.72	.76	.54
5.0	.87		.91	.85	.72
10.0	.75	.91		.93	.86
15.0	.54	.84	.92		.95
20.0	.70	.79	.97	.97	

The sample size is 20 or more except in girls for 1.0 v. 15.0 (N = 13), 1.0 v. 20.0 (N = 14), 5.0 v. 20.0 (N = 14), 10.0 v. 20.0 (N = 11) and 15.0 v. 20.0 (N = 14). The coefficients above the line refer to boys; those below the line refer to girls.

counted for by the variations in the length of Ba-N.

The correlation coefficients between the size of the saddle angle and either cranial vault length or stature are close to zero although there is a trend for the correlations with cranial vault length to be positive and for those with stature to be negative.

TABLE V

Correlation Coefficients for Saddle Angle Size vs. Ba-N, Cranial Vault Length and Stature (Class I and Class II Combined)

	Boys		Girls	
Ba-N	N	r	N	r
4 yrs.	66	0.18	46	0.34
8 yrs.	71	0.29	52	0.36
12 yrs.	74	0.33	45	0.55
16 yrs.	71	0.40	35	0.59
20 yrs.	49	0.52	25	0.63
Cranial vault length				
4 yrs.	66	0.00	46	0.11
8 yrs.	71	0.07	52	0.22
12 yrs.	73	0.06	45	0.30
16 yrs.	71	0.14	35	0.01
20 yrs.	48	—0.03	25	0.12
Stature				
4 yrs.	66	—0.20	46	—0.10
8 yrs.	71	—0.07	52	—0.06
12 yrs.	74	—0.08	45	0.02
16 yrs.	71	—0.10	35	0.01
20 yrs.	48	—0.20	25	—0.05

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Discussion

The present investigation has demonstrated a marked tendency for the saddle angle to decrease rapidly during infancy and then slowly until a few years after puberty. It has been reported that the cranial base is not deformed during parturition.[13] Consequently, birth moulding is unlikely to be responsible for the marked changes found during infancy in the present study. This change in the angle is not due to flexion at sella but reflects differential remodelling associated with the growth of the cranial base. As part of this remodelling there is resorption on the endocranial surface of the clivus.[20,21] This, together with the downward and forward rotation of the basiocciput and the absence of marked changes in the level of the pituitary fossa or of nasion during growth would lead to decreases in the saddle angle. After puberty there is a marked tendency for the angle to be stable. There are no real sex differences in the correlations across age for levels or for increments showing that there are no sex-associated differences in the patterns of change before puberty and relative constancy after puberty.

The means and standard deviations from the present study are close to those reported by Lindegard[22] and Ingerslev and Solow[23] for young adults. While the means for the Ohio children studied are very close to those reported by Koski[24] for Finnish children at a few ages, the present standard deviations are considerably higher. In the boys studied, the standard deviations tend to be larger in the Class II group. When data for Class I children are compared, variability is found to be similar in each sex until 12 years; later it is slightly larger in girls. The sex differences in the size of the saddle angle are small although the angles are consistently slightly larger in boys until 17-20 years. At later ages the means tend to be larger in the girls. The small sex differences during childhood are in agreement with the findings of Koski[24] while those for adults are in agreement with several earlier reports.[19,23-25]

The high correlation coefficients between saddle angle sizes at different ages found in the present study agree with the data of Björk[15] who reported a coefficient of 0.91 in boys for 12.0 years vs. 20.0 years. This is much higher than the value of 0.52 reported by Oliver[26] for children examined at 10.5 and 17.0 years. Such findings would be expected from the small sizes of the increments. Most of these increments are negative showing that the saddle angle tends to decrease with age, particularly at young ages and in those with Class II occlusion.

Brodie[14] considered the shape of the cranial base had no influence on occlusion. This is in agreement with the findings of Weidenreich[27] who, in a study of skulls, found no relationship between the saddle angle and facial prognathism. Many, however, have expressed an opposite view[1,15,22,28-35] for which there is considerable evidence. For example, Björk,[30] in male conscripts aged 21-22 years, found the mean saddle angle was almost 4° larger in those with less pronounced prognathism than in those with more pronounced prognathism. It has been reported also that the saddle angle is small in Class III occlusion.[36] In the present study the mean saddle angles tend to be larger in Class II boys than in Class I boys; due to the small number of Class II girls, a corresponding comparison could not be made satisfactorily for that sex.

In the present study there are only minor differences in the increments of saddle angle size between the Class I and Class II groups.

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The finding that there are small negative correlations between the size of the saddle angle and endocranial vault length is in agreement with the report of Brown[37] for young adult males. The small negative correlations between the size of the saddle angle and stature are similar to the findings of Solow.[29]

Summary

Serial cephalometric radiographs of 165 children have been used to analyze age-associated changes in the saddle angle (Ba-S-N). There are mean decreases in this angle of about 5° from birth to 2 years in those with either a Class I or a Class II occlusion; later changes are slight. The mean values tend to be slightly smaller in Class I boys than in those with Class II. Generally, the means are slightly larger in boys than girls but in adults this sex difference is in the reverse direction while remaining slight. It is reasonable to conclude that change is dominant in the first two years. Even after pubescence the angle is not constant but the changes are much smaller. The variability of the angle is greater for Class II than Class I individuals and its variability is greater in girls than boys after 12 years.

Almost all the median increments are negative; that is, the flexure of the cranial base decreases with age particularly if the increments begin at the first available radiograph. This tendency is more marked in Class II then Class I occlusion. The increments are markedly variable in each occlusion group with large changes occurring in some individuals.

Correlations between the saddle angles at different ages are high; this shows a marked constancy of the relative levels for individuals. The correlations between increments are small; presumably this reflects the small sizes of these increments relative to the error terms. In the present group the saddle angle is positively correlated with Ba-N length, but the correlations between the saddle angle and either cranial vault length or stature are near zero. These findings show that there is marked constancy within individuals after the age of 2 years although, as noted earlier, there is marked variability in the size of the angle at particular ages and the serial data for some unusual individuals show large changes that are generally decreases.

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