Relation of Basion to Articulare

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The distance between Basion and Articulare is evaluated serially and cross-sectionally between the ages of five and twenty. It is concluded that this is a stable relationship that makes Articulare a reliable cranial base landmark. This stability also makes the relationship of articulare to basion a useful indicator of condyle position when comparing different films of the same subject.

Opinion has always been divided concerning the most suitable plane for superimposition of serial cephalometric radiographs.

Some, as Brodie,[1] preferred the plane of the anterior cranial base, as represented by Sella-Nasion (S-N). Both sella and nasion are easily identified points, and superimpositions on this line produce consistent patterns. These correspond to what is observed clinically, so long as the cranial base angle, or saddle angle (Ba-S-N) remains unchanged. If the saddle angle does change, superimposition on S-N plane can produce an apparent progressive protrusion or retrusion of the lower face that is not observable clinically.

The problems created by the change of saddle angle are avoided by superimpositions using the full cranial base as originally suggested by Broadbent.[2] Whereas the anterior termination is also nasion, the posterior termination is Bolton point or basion. Those who

have used Bolton point will agree that it is not always easy to see. Reference must often be made to previous radiographs to be sure that one is using the same Bolton-like concavity in every case.

Basion has been suggested as a substitute for Bolton point, but early headholders often had large metallic ear rod supports that obscured basion. Radiographic film, technique and printing processes can also make clear definition of basion uncertain. Indeed, it was claimed by Björk[3] in 1947 that "Basion cannot be identified in an x-ray film and the same is the case with the craniometric point porion."

Into this atmosphere Björk introduced articulare (Ar), "the intersection of the shadow of the undersurface of the basi-occiput with that of the posterior border of the neck of the mandible with the teeth being in centric relation" (fig. 1). Initially he defined the point with respect to the temporal rather than the occipital bone as is now accepted.

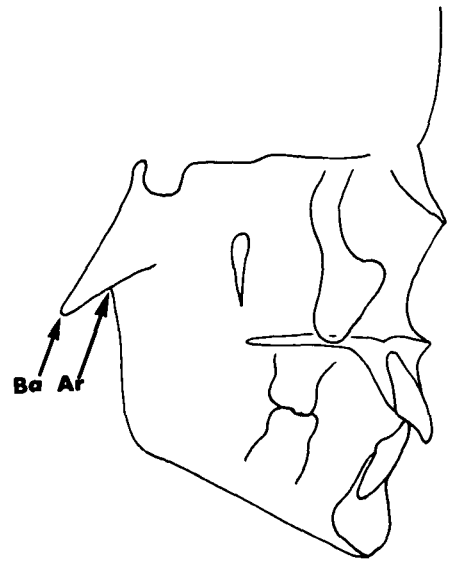

Fig. 1
Relation of Basion (Ba) to Articulare (Ar)
Ba—The most anterior point on the margin of the foramen magnum.
Ar—The intersection of the image of the undersurface of the basi-occiput with those of the posterior borders of the necks of the condyles, with the teeth being in centric relation.

Björk was particularly interested in profile changes, so the sella-nasion line was unsuitable. He needed to use the full cranial base to minimize the effect of saddle angle change. As stated above, he could not identify basion. Frankfort could not be used because of difficulty with porion. Bolton, he argued, "is often difficult to locate," but articulare "on the other hand always shows up clearly. . . ."

It may seem strange that such a fundamental reference point should be accepted seemingly on the sole recommendation that it "always shows up clearly." Nevertheless, articulare did seem to work in practice.

With the passage of time articulare was seen to possess other virtues too. As the ability to locate basion improved, workers in the field began observing how the distance between basion and articulare in the same person did not seem to change. (Coben[4]) Articulare seemed to possess a stability similar to that of basion, so Björk's use of articulare as the posterior limit of his cranial base plane seemed justified on more solid grounds than mere ease of identification.

At first sight the constancy of the distance basion to articulare is unexpected. On the one hand is basion, a point on the basi-occiput, a bone forming part of the cranial base, and on the other is articulare, an artificially constructed point formed by the intersecting shadows of the occipital bone and the mandible. The mandi-

ble is not only a bone of the face but a highly movable bone.

The paradox is resolved in part when one considers the very important rider in the definition of articulare "with the teeth being in centric relation." This immediately fixes the mandibular condyle in the glenoid fossa, reducing the role of the mandible to that of indicator of fossa location.

Now one only has to have constancy between the squamous temporal bone and basion. Again, one could wonder if even this were possible. There appear to be so many sutures and synchrondoses at which bony changes could occur lying between basion and the glenoid fossa. Nevertheless, really only one of these is important, namely the suture lying between the squamous temporal bone and the occipital bone (fig. 2). Unless there is activity at this suture, no change in anteroposterior relation between basion and the glenoid fossa is possible. One also notices that the suture tends to be oriented toward a saggital plane, so a large part of any growth would be expressed as an increase in skull width rather than in the anteroposterior dimension.

Bony changes at basion could also conceivably alter the relation, and on this opinions differ. On the one hand, Enlow's histological studies[5] indicate that the area is inactive. On the other hand, Powell and Brodie[6] reasoned that because the anterior cranial fossa became stable between the third and seventh year of age, denying change in sella, all increases in the length of the clivis subsequent to closure of the spheno-occipital synchrondosis (13-16 yrs males, 11-14 yrs females) must be due to bony apposition at basion. If the anteroposterior diameter of the foramen magnum were not to be reduced by this apposition, resorption would be necessary at opisthion. This they considered possible.

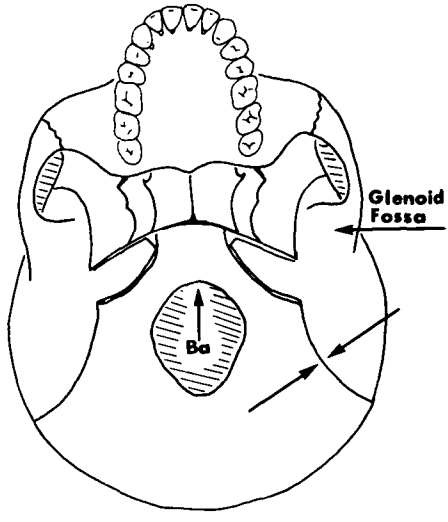

Fig. 2 Basion and the glenoid fossa cannot change their relative positions unless there is activity at the suture indicated by the arrows, at Basion, or at the glenoid fossa.

Changes certainly occur in the glenoid fossa over the years. For one thing, it deepens. If it deepens by an invasion of its floor into the cranial cavity, the relation of the condyle to the squamous temporal bone as a whole would be altered. If it deepens by bony apposition around its margins, the change in relation of the condyle to the squamous temporal would be minimal. The extreme thinness and relative avascularity of the floor of the fossa would make one think the latter process more likely.

If the distance from basion to articulare does indeed remain constant, more may be gained than just the availability of an alternative point for cephalometric evaluation. For example, such a stable reference point could be used:

1. For the precise detection of mandibular displacements such as may occur subsequent to prosthetic, operative, or orthodontic treatment.
2. As a test for constancy of mandibular positioning in serial cephalometric studies.
3. To probe the validity of comparing one sample of cephalometric radiographs with another.
4. To review the accuracy of existing growth study data.

The following study was designed to test the hypothesis of a stable relationship between basion and articulare.

Sample

The sample consisted of the serial cephalometric radiographs of children enrolled in the Melbourne University Child Growth Study.[5] In all, 334 radiographs of 48 males and 425 radiographs of 57 females between age 5

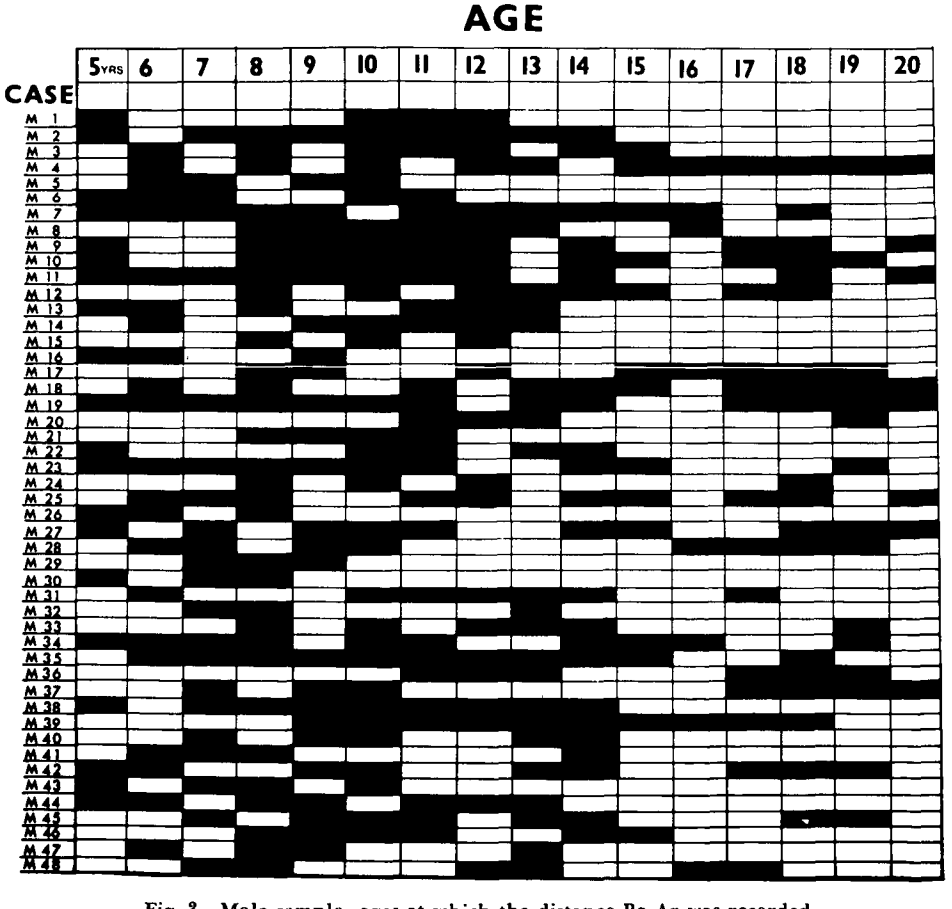

Fig. 3 Male sample—ages at which the distance Ba-Ar was recorded are indicated by the blacked-out rectangles.

years and 20 years inclusive were measured. The time span over which the distance Ba-Ar was measured varied from a minimum 2 years to a maximum of 15 years (figs. 3 and 4).

Not all of the radiographs of these children exposed over the years could be used in this study. Any of the following three factors was regarded as disqualifying:

1. Teeth not in centric relation at the time the radiograph was exposed.
2. Child not correctly positioned in the headholder.
3. Radiograph not of sufficient quality to allow clear definition of the points under study.

Concerning the factors above, the common practice of repositioning the image of an open or resting mandible in the course of tracing could not be allowed in this work, since the repositioning technique depends partly on keeping the distance Ba-Ar the same

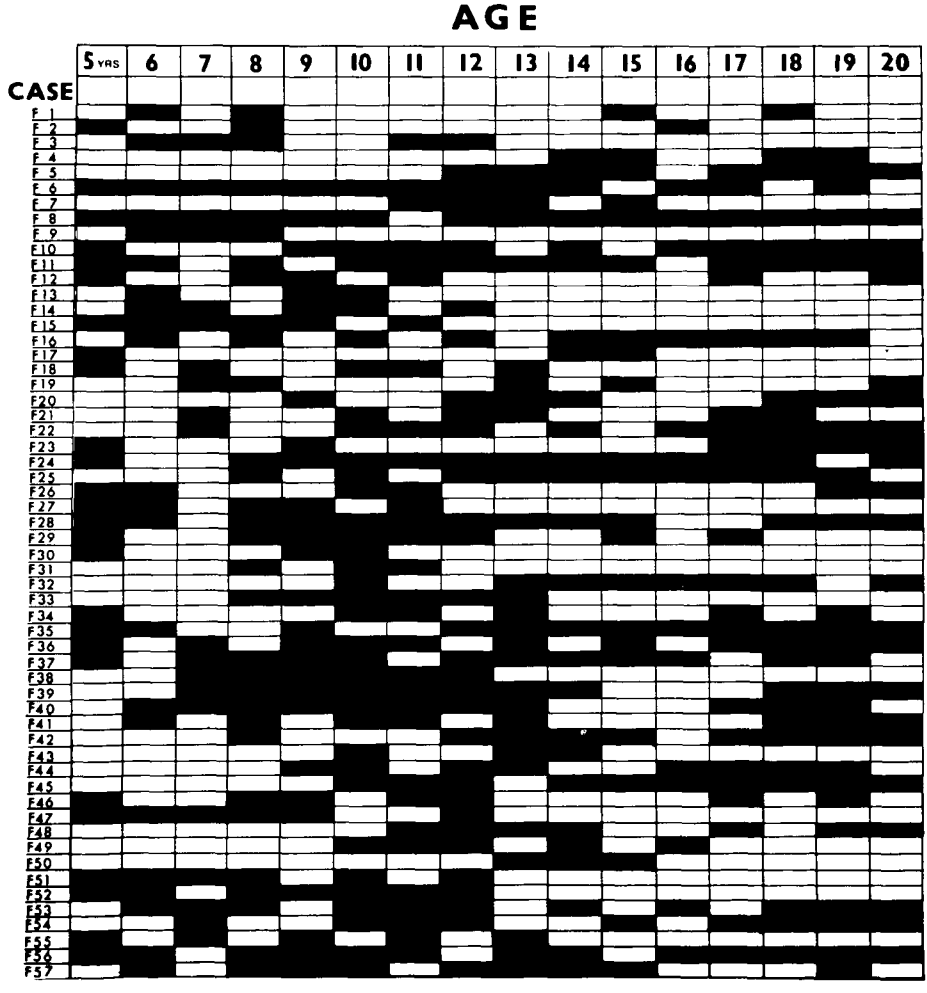

Fig. 4 Female sample—ages at which the distance Ba-Ar was recorded are indicated by the blacked-out rectangles.

length as in other radiographs. One would be begging the question.

Correct positioning in the head-holder is essential. Whereas the technique of bisecting bilateral images to construct a midline image that is virtually independent of head positioning is acceptable in many applications, it could not be accepted in this study. A tipping or rotation of the head causes the undersurface of the occipital bone to reveal more of the neck of one mandibular condyle and less of the neck on the other side. Anatomically different parts of the neck of the mandible would intersect the image of the occipital bone. Bisection would result in a similar midline articulare, but not with the same precision as the bisection of the distance between accurately oriented structures.

Method

The distance Ba-Ar was measured with a dial caliper calibrated in 0.1 mm increments. It is doubted that the points of the instrument could be placed over the points to be measured with that precision, even with the aid of a magnifying glass. As in most studies, sharpness of image and operator error reduce precision.

In this study, other variables negated any possible benefits of remeasuring a sample to determine what the operator error might be. While there were some series which were easy to measure and in which the system error, including operator error, would be slight, there were others in which the measurements were difficult to make and the system error would be higher. Indeed, as indicated, there were some radiographs in which it was thought a usefully accurate measurement could not be obtained at all. The problem of error will be discussed more fully later.

A Broadbent-Bolton cephalometer was employed, so radiographic enlargement could be calculated and allowed for. All measurements appearing in this study have been converted to absolute units.

The figures were analyzed in three separate ways.

First, the measurements of each child were examined.

Second, a regression analysis was used to establish the slope and position of the line obtained by plotting the length Ba-Ar against the age of the child (fig. 5). If the slope or the gradient of this line is zero, it indicates that the distance Ba-Ar has neither increased nor decreased over the period studied. If a positive slope results, the distance is increasing; conversely, a negative slope indicates that the distance is decreasing.

Third, the data were analyzed in a cross-sectional manner, in which the mean distance Ba-Ar for each age was determined and examined. The author is very aware of the pitfalls which lie in interpreting cross-sectional data in a longitudinal manner. That technique was used in this study not as

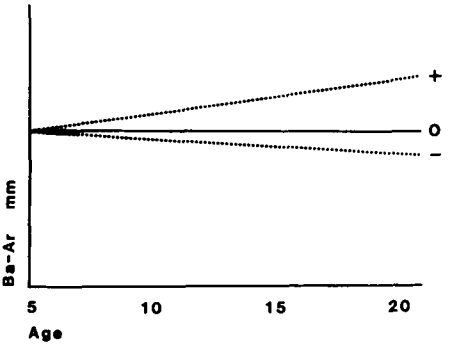

Fig. 5 Hypothetical length Ba-Ar, plotted as a best-fit regression line against age. If the length Ba-Ar increases over the years, the gradient is regarded as positive; if it decreases, the gradient is regarded as negative.

the sole method of examining the data but only as supportive evidence that afforded another avenue for examination and exploration of the magnitude and effect of system error on methods (1) and (2).

Findings

1. *Analysis of each child's measurements:*

Males: Of the 48 males, the difference between the first and last measurement was 1 mm or less in 41 (zero in three). The changes for the other seven were −3.5, −1.5, −1.2, −1.1, −1.1, +1.1, and +1.8 mm.

The intervening measurements did show a slightly greater variation, as could be expected, but the dimension Ba-Ar taken overall did not seem to change. The variation covered a span ranging from a minimum of 0.2 mm to a maximum of 3.5 mm. Over the years, the measurements of 45 of the 48 males fluctuated less than 0.9 mm about a mean position.

Females: The females showed a pattern similar to that of the males. The difference between the first and last measurement recorded for the distance between Ba-Ar was 1 mm or less (zero in four instances) for fifty-two of the fifty-seven. The remaining five showed variations of −1.7, −1.3, −1.2, −1.1, and +1.2 mm.

Again, the intervening measurements showed the expected random variation, but the measurement Ba-Ar did not seem to change overall. The variation in individual subjects covered a span ranging from a minimum of 0.1 mm to a maximum of 1.9 mm.

Discussion of Individual Changes

Even if the distance from basion to articulare did in fact remain constant it would be unrealistic to expect a series of measurements such as these to register 0.0 mm change throughout. We are concerned with a human being measuring the distance between two radiographic shadows, and with one possible exception, the figures are considered to be commensurate with a "no change" situation.

The exception is case M12, where a variation of 3.5 mm was recorded. This boy's measurements are shown in table 1. One notices that if it were not for the big decrease between the years 8 and 10 the variation would only be 1.1 mm over an eight-year span. The skeptic could be forgiven for suspecting that the radiograph exposed at 8 years was made with a slight mandibular thrust present, rather than with the teeth in centric relation. The slope of the posterior cranial base magnifies the effect of any anteroposterior shift of the mandible on the distance Ba-Ar. It requires a mandibular protrusion of much less than 2½ mm to cause the recorded 2½ mm increase in the distance Ba-Ar. Mandibular thrusts of this magnitude are not always easy to detect clinically, particularly in a child who

TABLE 1

Ba-Ar for case M12 from age 8 to 18. Were it not for the big decrease between the years 8 and 10, the variation would only be 1.1 mm over an eight-year span.

AGE	*Ba-Ar (mm)*
8	11.1
9	
10	8.7
11	
12	8.5
13	8.4
14	8.4
15	8.2
16	
17	7.9
18	7.6

is in the process of erupting incisors or shedding deciduous molars.

2. *Examination of Changes in Ba-Ar with Age*

A regression analysis was used to establish the best-fit lines, plotting the length of Ba-Ar against the age of each child (fig. 5). The gradient was then tested to see whether it possessed a significant positive or negative slope.

The slope of the line for 41 of the 48 males did not differ significantly from zero. This indicates that the distance Ba-Ar neither increased nor decreased over the period studied. Of the remaining seven, five showed positive gradients (0.047** 0.054* 0.097* 0.105* 0.119* mm per year) and two showed negative gradients (−0.052* −0.266** mm per year).

The gradient for 43 of the 57 females did not significantly differ from zero, indicating neither increase nor decrease in the distance Ba-Ar. Of the remainder, six were positive (0.052* 0.068* 0.076* 0.076* 0.109** 0.230* mm per year) and eight were negative (0.152** 0.132** 0.083** 0.080** 0.068* 0.064* 0.049** 0.023* mm per year).

Discussion of Individual Age Gradients

Whereas eighty percent of the sample taken as a whole presented with a zero gradient, indicating constancy of the distance Ba-Ar, twenty percent did not. Two typical of the twenty percent are shown in table 2. If the figures are taken at their face value it does indeed appear as if the distance Ba-Ar constantly increases in case M4 and constantly decreases in case M27, albeit by less than one millimeter over a period of 14 years and 15 years respectively. But is one justified in taking such figures at their face value?

It is recognized that a degree of error must exist in any such measurement. Some are going to be higher than the actual dimension and some are going to be lower. If the high errors and the low errors were equally spread out over the age range they would not affect the gradient. But if by chance the high errors occurred early, leaving the low errors to occur later, it would tend to give the line a negative gradient. Conversely, if by chance the low errors happen to find themselves placed in the earlier years the line would have a positive gradient. With this hypothesis of a chance factor influencing the results one would expect equal numbers of both. It is interesting to see that when we combine the male and female samples, as is reasonable in such an analysis, equal numbers show increases and decreases (table 3).

TABLE 2

Serial examples of Ba-Ar measurements for two cases, presenting positive and negative gradients.

AGE (*Years*)	*Case M4* *Gradient +0.047***	*Case M27* *Gradient −0.052**
5		14.1
6	11.8	
7		14.3
8	12.2	
9		13.9
10	12.2	14.2
11		14.3
12	12.0	
13	12.6	
14		14.3
15	12.2	13.8
16	12.4	
17	12.6	
18	12.6	13.7
19	12.5	13.2
20	12.7	13.6

* Significant at .05 level.
** Significant at .01 level.

3. *Analysis of Cross-Sectional Data*

The mean of the distance Ba-Ar was calculated for every age from 5 to 20. The results are shown in table 4 and Fig. 6.

If the distance from Ba-Ar does not change between age 5 and age 20, the mean for a sample of 5-year olds should be the same as the mean for a sample of 20-year olds. Paradoxically, the converse does not apply. If the mean distance Ba-Ar does not alter from age to age, it *may* indicate that the distance Ba-Ar in fact does not alter. It may also be a result of the distance Ba-Ar increasing in some people to an extent equal to decreases in others.

Although one cannot claim from the figures under discussion that there was no change in the distance Ba-Ar from age 5 to age 20, they do offer strong circumstantial evidence.

These figures also indicate the extent to which system error played a part in the previous two analyses. The mean number of males in each age class is 22, and the mean number of females is 28. When dealing with numbers as high as these it is possible for errors to cancel out, and this is what appears to have occurred.

Measurements of individual children showed a far greater fluctuation in the distance Ba-Ar than is recorded as variations in the means at various ages, suggesting that the fluctuations seen in the first analyses are due principally to system error.

TABLE 3
Distribution of Individual Age Gradients

	N	zero	(+)	(−)
Males	48	41	6	8
Females	57	43	5	2
Total	105	84	11	10

Conclusions

It has been shown on anatomical grounds that it is possible for the anteroposterior relation between the basilar part of the occipital bone and the glenoid fossa of the temporal bone to remain essentially unchanged subsequent to the bony union of the two

TABLE 4
Mean absolute values of Ba-Ar (mm)

	MALES			*FEMALES*		
AGE	*Number*	*Mean*	*S.D.*	*Number*	*Mean*	*S.D.*
5	20	11.7	1.4	26	11.1	1.9
6	22	11.5	1.5	22	11.3	2.1
7	22	11.5	1.7	20	11.2	1.7
8	32	11.3	2.1	31	11.3	2.1
9	25	11.1	2.1	28	10.9	2.0
10	33	11.1	2.2	35	11.3	2.0
11	28	11.5	2.2	31	11.3	2.0
12	25	11.6	1.7	34	11.4	2.1
13	24	11.7	1.7	29	11.2	2.2
14	24	11.8	1.8	26	11.2	2.3
15	14	11.4	2.0	22	11.5	2.2
16	8	11.1	1.7	16	10.6	1.8
17	15	11.2	2.0	25	10.8	2.2
18	19	11.5	1.9	27	11.2	1.9
19	15	11.1	1.5	29	10.8	1.7
20	8	11.6	1.8	23	11.1	2.1

individual bones. Similarly, it is anatomically possible for the anteroposterior relation of basion and articulare to remain unchanged, and this possibility was investigated using three separate analyses. While each analysis can stand alone, to a degree they are interrelated. When considered as a whole, their significance becomes more than the sum of the parts.

The first analysis, gross data, indicates that even though the distance Ba-Ar did not seem to change in any one direction, it did vary, albeit not much more than half a millimeter, either side of a mean position. How much this represented a true variation and how much represented system error could not be assessed from this analysis alone.

The second analysis, regression analysis, indicated some eighty percent of the sample neither increased nor decreased. Half of the remainder showed increases, while the other half showed decreases.

The third analysis, cross-sectional, presented an opportunity to assess system error in addition to giving circumstantial evidence of a cross-sectional nature. It is now believed that the variations shown in the first

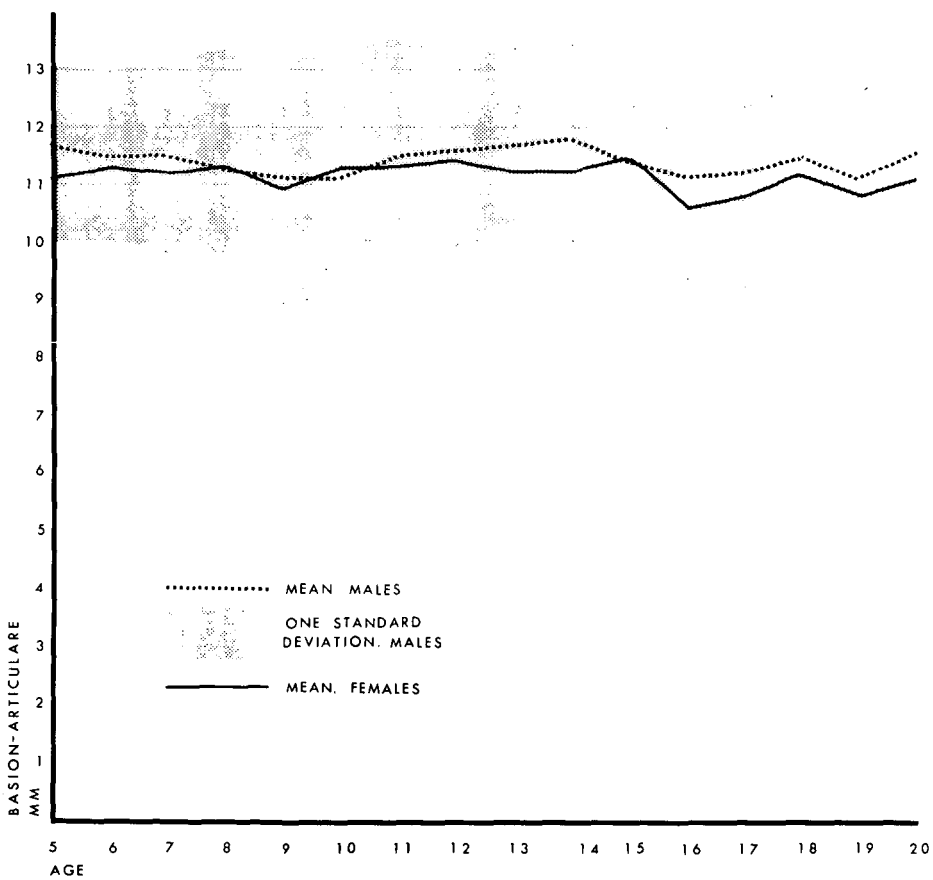

Fig. 6 Cross-sectional behavior of Basion-Articulare from age 5 to 20.

analysis and the ten percent increases and decreases seen in the second were indeed due to system error.

It is therefore concluded that at least from the age of 5 to the age of 20 the distance from basion to articulare remains essentially constant.

Suggested Practical Applications

1. Detection of mandibular displacements.

If the distance Ba-Ar alters during the course of treatment or observation, then, assuming that the radiographs have been correctly evaluated, the condyles have most likely changed their positions in the glenoid fossae.

2. As a test for constancy of mandibular positioning in serial cephalometric studies.

If, when examining a series of cephalometric radiographs of the same person, it is noticed that the distance Ba-Ar is different in one radiograph, it can be reasonably assumed that the condyles were not always located in the glenoid fossae in the position of centric relation. The mandible was either protruded or opened.

3. To probe the comparability of the cephalometric radiographs of two different groups.

If one sample comprised of the radiographs of a number of individual people possessed a mean distance Ba-Ar which is significantly different from that of another, then either:

a. the radiographs were exposed under different circumstances e.g. mandible at rest or open.
b. radiographic enlargement has not been adequately considered.
c. different ethnic samples may be involved in the two groups.

Whatever the reason, one should use caution in comparing measurements of two groups possessing significantly different mean distances between basion and articulare.

4. To review the accuracy of existing growth study data.

The variations recorded in the distance Ba-Ar for individual subjects give a good indication of the accuracy with which the radiographs have been made and measured. This is a particularly useful and readily applied test in those studies in which a technician feeds data directly from the radiograph into a computer.

Similarly, a cross-sectional evaluation should find the means for all ages to be similar. If, for example, the mean distance Ba-Ar is higher in a younger group than in an older group, it could indicate that a significant percentage of the younger children were either thrusting their mandibles forward or had their teeth apart at the time the radiographs were exposed. This is not an uncommon occurrence in the young.

References

1. Brodie, A. G.: On the growth pattern of the human head from the third month to the eighth year of life. Am. J. Anat., 68:209-262, 1941.
2. Broadbent, B. Holly: Bolton standards and technique in orthodontic practice. Angle Orthodontist, 7:209-233, 1937.
3. Björk, A.: The Face in Profile. Svensk Tandlarkare Tidskrift. 40: 30, 1947.
4. Coben, S. E.: The Integration of Facial Skeletal Variants. Am. J. Ortho. 41:407-434, 1955.
5. Enlow, D. H.: The Human Face. An Account of the Postnatal Growth and Development of the Craniofacial Skeleton. New York, Hoeber Med. Div., Harper & Row, 1968.
6. Powell, T. V. and Brodie, A. G.: Closure of the spheno-occipital synchrondosis. Anat. Rec., 147:15-24, 1963.
7. Roche, A. F. and Sunderland, S.: Melbourne University Child Growth Study. Med. J. Aust., 1:559-562, 1959.