# A Radiographic Cephalometric Study of the Central Australian Aboriginal*

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## INTRODUCTION

The Australian aboriginal holds a unique position in anthropology, showing the characteristics of at least two of the three main races of man. Indeed, Sir Arthur Keith has said, "of all the races of mankind now alive, the aboriginal race of Australia is the only one which in my opinion, could serve as a common ancestor for all modern races."[25] Thus, it was of interest to compare cephalometric measurements of a living tribe of Central Australian aboriginals with those of other living races.

The racial origin and purity of the Australian aboriginal have been the subject of much discussion. In 1887, Turner[36] believed the Australian aboriginals to be a pure race, but admitted wide variations. Later, Klaatsch[26] believed there was one race, but that local differences were specializations due to the environmental conditions. As we shall see, Morant[30] subscribed to the idea of two racial groups.

Due to the paucity of skeletal material and the absence of stone implements, the majority of investigators believe that man did not evolve on the continent of Australia. The closely allied Dravidian race of S. E. Asia seemed to suggest that racial migration took place. Indeed, evidence was offered by the presence of another placental, the wild dog (canis dingo), similar to that of S.E. Asia.

On the basis of racial investigations in Australia, Birdsell[2] suggested three major migrations from the mainland of Asia, via the Sahul shelf. The Oceanic Negrito arrived during the early part of the Fourth Glacial period and, according to Birdsell, were characterized by "moderate round headedness, low nasal relief and a very short and narrow face." The arrival of the second major migration, during the mid-portion of the Fourth Glacial period, displaced the first wave southward. These later arrivals, the Murrayian group, were described by Birdsell as having a long, low, and narrow cranial vault. The general facial impression, he added, was "that of a coarse and rough hewn caucasoid type". The third racial group to enter the Autralian continent from the north, the Carpentarian element, arrived late in the Fourth Glacial period or Early Recent period. The cranium was of moderate length and height combined with extreme narrowness. With regard to the face, Birdsell stated. "The teeth are large, prognathism is marked, and the chin of the mandible ill-developed."

All these racial elements are blended in varying degrees, in different regions, to form the present day Australian aboriginal. Birdsell believed the aboriginals from the Central Desert area, the region of this study, to be a mixture of two racial elements, the Murrayian and Carpentarian.

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Although many craniometric investigations have been undertaken in collections of adult skulls to determine inter-racial differences, the scarcity of infant and adolescent crania has prevented the comparison of growth patterns in different races. In the latter respect, the techniques of radiographic cephalometry offer distinct advantages in being applicable to large numbers of healthy infants and adolescents.

As early as 1863, T. H. Huxley[24] pointed out the dolicocephalic cranial form of the Australian aboriginal skull and commented on the degree of prognathism of the maxilla. Huxley, one of the earliest interested in craniometry, superimposed tracings of the sagittal sections of the crania of several races on the "basi-cranial axis", a line joining basion and the spheno-ethmoidal junction. Although his choice of a reference line was excellent, the use of a single specimen for the comparison of racial groups did not allow for intra-racial variation.

Somewhat later, Turner[37] directed attention to the relationship of the cranium to the dental arches in the Australian aboriginal. He reported on the large size of the teeth and the dimensions of the palate and observed the protrusion of the upper incisor teeth with a high frequency of edge-to-edge occlusion of the incisor teeth. Turner speculated that this occlusion might have been produced in two possible ways, either compensation by modification of the form and size of the lower jaw, or a change in the construction of the skull itself. By comparing aboriginal and European mandibles, he eliminated the former possibility and assumed that changes in the skull influenced the relationships of the face.

Following a complete analysis of the cranium and face in the Roth Collection of aboriginal skulls in Australia, Klaatsch[26] drew attention to the curvature of the cranium in norma lateralis. He analysed this and stated, "the variations of the frontal, parietal and occipital as components of the sagittal curve of the cranium, may become interesting in further examinations of the racial specialization of mankind from an ancestral stage." He pointed out the reduced size of the anterior nasal spine, the degree of alveolar prognathism, the large teeth and the extremely large dental arches which allowed space for the eruption of a fourth molar. After comparing the Australian aboriginal cranium with the Neanderthal skull and Pithecanthropus erectus, Klaatsch concluded . . . . . "the positive anatomical facts are overwhelming in emphasis of the fact that the Australian Aboriginals are a relic of the oldest type of mankind."

Since the profile had always been of interest in the determination of racial differences, Luthy[29] employed an angular analysis of points on the profile to the Frankfort Horizontal. Of all the races compared, the Australian aboriginal was found to be most prognathic both in total face and middle face prognathism. He mentioned that alveolar prognathism was usually the same for both jaws. However, his conclusions on the Australian aboriginals were based on thirteen skulls from collections in Europe. Perhaps, a criticism may be leveled at the use of skull collections on two points; first, the sex of the skull was often unknown and, secondly, skulls sent to the collections most frequently possessed unusual features.

In a thorough investigation of the dentition and palate of the Australian aboriginal Campbell[15] concluded that the teeth and palate were "probably larger than any other living race." It is interesting to note that of the six hundred and thirty skulls examined by Campbell only fifty nine were infants and adolescents.

In 1927, Hellman[21] examined the face and occlusion of the Australian aboriginal skull and compared the findings with Hindu and American White skulls. Linear and angular measurements were taken from the nasion-porion plane, registered at porion. Hellman showed the Australian aboriginal face to be further forward than the other two races, a finding similar to that of Luthy in 1912.

Stressing the need for statistical investigations of different races, Morant[30] pooled the data from previous craniometric studies on the Australian aboriginal. Analysis of this aggregate data led Morant to conclude that the Australian aboriginal was composed of two slightly different racial types; but, on the facial measurements recorded, there was no difference between the faces of the two types. Morant also computed the degree of variability of the Australian aboriginals, finding them less variable than a modern white race of the 17th century from a local area, but more variable than Egyptian skulls from the 26-30th dynasty.

The Australian aboriginal skull possesses characteristic non-metrical features. Burkitt and Hunter[11] mentioned the development of the supraorbital ridge, the unusual formation of the nasal bones, and the rounded orbital margin which they believed due to excessive masticatory function from the coarse diet. They also observed the curved inferior border of the mandible with the convexity downward and the ascending ramus almost at right angles to the body. In a later study, Burkitt and Lightoller[12] examined the inferior border of the nasal aperture and noted the frequency of a small nasal spine in the Australian aboriginal. The degree of alveolar prognathism, the axial inclination of the teeth, the size of the teeth and proximity of the apices to the inferior nasal border, and the mode of occlusion, were suggested as influences on the form of the anterior nasal spine.

The application of a radiographic technique to craniometry was advanced by Pacini[31]. He showed the accuracy of the method to be within the limits of error allowed in the 1906 Monaco Agreement of Anthropologists. Only radiographs in norma lateralis were discussed, and readily discernible midline structures formed the basis for a method of analysis.

With the subsequent development of a cephalometer by Broadbent,[6] a new tool was added to the armamentarium of the physical anthropologist. The cephalometer obtained radiographs of living individuals in both norma lateralis and norma frontalis. This technique allowed the comparison of skeletal material with the living head and permitted the selection of previously inaccessible facial and cranial landmarks. But, for the anthropologist, the disadvantage of the Broadbent--Bolton cephalometer was the size of the equipment which did not allow for field work in racial investigations. Even so, Broadbent[7] and Brodie[9] have studied the growth of the head in the young American white male.

Recently, Bjork[3] used the principles outlined by Broadbent and designed a portable cephalometer. The distance from the median plane of the head to the film was fixed, and the x-ray tube, also at a fixed distance, was aligned perpendicular to the film surface by an optical system.

With this cephalometer Bjork first examined a large number of Swedish boys and conscripts for variation in form of the cranial base and face. The difference in age between the two groups permitted appraisal of the changes which occurred with growth. Then, in 1948, Bjork[4,5] extended his investigations of racial prognathism to the Bantu, a primitive tribe of mixed origin in South Africa. Adult males

and boys were examined, using the same method as that applied to the Swedes. Again, variation and growth were studied. Comparison with the Swedish material led to the conclusion that racial variation was not in the degree of prognathism, but rather in the nature of the prognathism. Little was said of the growth changes in the Bantu.

The present investigation was undertaken to compare the Central Australian, an archaic caucasoid, with these other living races.

## Material

Mr. John Heath obtained lateral head radiographs of fifty-six Central Australian aboriginals and stated,[20] "the radiographs are of certified pure blood aboriginal children and young adults." The aboriginals investigated lived in the Hermannsburg Mission and Haast Bluff reserve area, about 200 miles N.W. of Alice Springs. Alice Springs is in the lower central part of Northern Territory, about 160 miles north of the border of South Australia. The tribes most likely represented in this investigation are the Pintubi and Pitjandjara. Mr. Heath's material is the subject of the present investigation.

Analysis of the material showed the age range and sex distribution in the following groups.

| *Age* | *No. Males* | *No. Females* | *Total No.* |
|---|---|---|---|
| 4 - 11 years ..... | 12 | 15 | 27 |
| 12 - Young Adults. (about 20 yrs.) | 9 | 20 | 29 |
| | — | — | — |
| | 21 | 35 | 56 |

This division gives two age groups, a young group with a mean age of 7.5 years and an adolescent group with a mean age about 15 years.

## Method

Mr. Heath obtained lateral head radiographs by the use of a head holding device and a portable x-ray machine supplied by a gasoline driven generator. The distance of the tube to film surface was thirty-six inches. For the present investigation the radiographs were accurately reproduced on five inch by seven inch negatives in the Illustration Department, University of Illinois, and then the negatives were traced.

The whole group was examined and then subdivided into sex and age groups to determine any significant differences. Throughout the investigation angular readings and proportional measurements were used. This allowed the comparison of form irrespective of size and permitted comparison of the racial groups.

Since the cranial outline of the Australian aboriginal had been well investigated, it was decided to examine both calvarium and face from the point of view of mean values, variation within the group and such growth changes as would be indicated in such a small sample. Thus, the investigation was divided into three parts, namely, analysis of the cranial outline, analysis of the facial structures and profile, and comparison of the findings in the Australian aboriginal with those of other races.

### *Analysis of the cranial outline*

In addition to the overall height and length of the cranium, expressed as an index, the cranial outline was reduced to a simply constructed geometric form. In this construction, it was decided to follow the suggestion of Wilder[39] that the joining of the points nasion, bregma, lambda and basion would result in a quadrangle which represented the cranial outline. Since basion was obscured by the radiographic technique, Bolton point was used as the posterior end of the cranial base. At the site of greatest convexity of the cranial outline opposite each

face of the quadrangle, a secondary point was located (see glossary of terms). By including the cranial base angle, NSBo, and joining the constructed points to the quadrangle points, a polygon was constructed which fully expressed the cranial outline, figure 1. The degree of curvature of the frontal, parietal and occipital bones was read from the inside angles of the polygon while the inclination of the frontal and occipital bones was read from the inner angles of the quadrilateral.

Since the anterior cranial base, SN, was to be used for the facial analysis, it was decided to use this plane as the base for the construction of the cranial polygon. For the purposes of illustration, the cranial points were plotted relative to the SN plane. All the points used were in the midline.

Variation of the frontal region of the cranial outline was examined by superimposition on the SN plane Each age group was divided into crania with angles greater or less than the mean angle SNF for the group. The resulting mean polygons were compared and individuals showing the greatest variation used to illustrate differences in cranial form.

Mean measurements and standard deviations were also recorded from the young and adolescent age groups, then compared statistically to determine age changes.

*Analysis of the facial structures and profile*

Facial landmarks were located using the techniques set down by Brodie,[9] Bjork[3] and Downs.[18] These techniques are well known and need not be discussed in detail. The points used are explained in the glossary of terms and illustrated in figures 1 and 2. As in the case of the cranium, illustrations were constructed by plotting facial points to the SN plane.

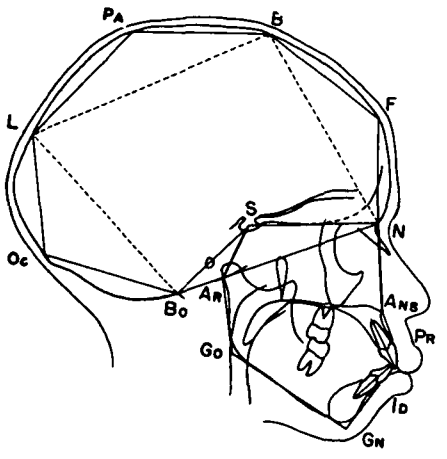


Fig. 1 The cranial polygon and Bjork's facial polygon.

Since the facial structures were to be compared with previous racial studies, the geometric form devised by Bjork[3] was employed to examine the face. As pointed out by Bjork, this polygon showed the effects on the profile of varying facial structures and the cranial base. In addition, the lengths of the maxillary (Ptm to Ans) and mandibular (Go to Po) bases were expressed as proportions of the anterior cranial base (SN).

The facial profile was analyzed by

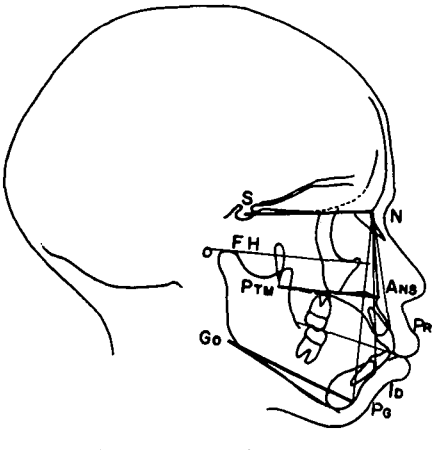


Fig. 2 The facial profile angles and the horizontal planes.

angular reading to the SN plane registered at nasion. These have been outlined by Bjork[4]:

"1. Maxillary basal prognathism: The angle formed by the cranial base and a profile line through nasion and the nasal spine.
2. Maxillary alveolar prognathism: The angle formed by the cranial base and a profile line through nasion and prosthion.
3. Mandibular alveolar prognathism: The angle formed by the cranial base and a profile line through nasion and infradentale.
4. Mandibular basal prognathism: The angle formed by the cranial base and a profile line through nasion and pogonion."

An index of the convexity of the face, the facial profile angle, was obtained by joining the points, N, A and Pg. In addition, Downs'[18] analysis of the facial profile was applied to twenty aboriginals between the ages ten years and young adult, equally divided in sex.

In order to compare the Australian aboriginal with Brodie's[9] findings in the North American white male, the angular relationships of certain horizontal planes to the anterior cranial base were measured. These consisted of the palatal plane, the occlusal plane and the mandibular plane already described by Brodie. The percentage of upper facial height (NAns) to total facial height (NGn) was calculated.

Measurements within the dental area were limited to angular readings of the maxillary first permanent molar (NS6), the edge of the central incisor (SN1), the relationship of the long axes of the upper and lower incisor teeth and the angular relationship of the lower incisor to the mandibular plane.

Variation within the Australian aboriginals was examined by deriving the means of those individuals more and less prognathic than the mean angle SNAns, in the respective age groups. As in the cranium, individual cases in each group were examined to determine whether the same structural variation was operative as that reported by Bjork.

Changes occurring with age were observed from comparison of the mean values of the young adolescent age groups. To find out whether the difference between the means in the aboriginal subdivisions was greater than that due to chance, the 't' value was calculated. The 5% level of significance was used, which meant that the value of 't' had to exceed 2.00 to be significant.

*Comparison with other races*

After the establishment of mean measurements and variation in the living Australian aboriginal head, the data and illustrations of the face were compared with those of Bjork in the Swede[3] and Bantu.[4] It was found necessary to compare the two age groups of aboriginals with the age groups in Bjork's studies since changes in measurements were observed between child and adolescent aboriginal.

Similarly, individual variations in the aboriginal age groups were compared with the Swede and Bantu, and the cross sectional growth changes of the facial structures compared with the findings of Bjork and Brodie.

Employing Downs' analysis of the facial profile, the selected aboriginals were compared with the American White[18] and the American Chinese, Japanese and Negro.[17]

GLOSSARY OF TERMS

*Cranial*

B Bregma. The point of junction of the coronal and sagittal sutures.

Bo Bolton point. The deepest point in the condyloid fossa.

F The point of greatest curvature on the frontal arc from line BN.

L Lambda. The point of junction of the lambdoid suture and the sagittal suture.

N Nasion. The mid point of the fronto-nasal suture.

Oc The point of greatest curvature on the occipital outline from the line LBo.

Pa The point of greatest curvature on the parietal outline from the line BL.

S The center of sella turcica.

Basic Quadrilateral The quadrilateral constructed from the points N,B,L,Bo.

Cranial Polygon The polygon constructed from the points N,F,B,Pa,L,Oc,Bo,S.

*Facial*

A Subspinale. The deepest point on the contour of the alveolar projection, between the spinal point and prosthion.

Ans Anterior nasal spine.

Ar Articulare. "The point of intersection of the dorsal contours of processus articularis mandibulae and os temporale. The mid-point is used where double projection gives rise to two points," Bjork.[3] Test roentgenograms on several White skulls showed the shadow of the dorsal contour of the mandible to cross the inferior surface of the basilar portion of the occipital bone.

B Supramentale. The deepest point on the contour of the alveolar projection between infradentale and pogonion.

Gn Gnathion. The deepest point on the chin, Bjork.[3] A point on the chin half way between pogonion and menton, Brodie.[9]

Go Gonion. The point of intersection between the base and ramus tangents to the mandible. The mid point was used where double projection gave rise to two images.

Id Infradentale. The point of transition from the crown of the medial mandibular incisors to the alveolar process.

1 Maxillary central incisor.

$\overline{1}$ Mandibular central incisor.

$\underline{6}$ Maxillary first permanent molar, the mesial contact point.

Or Orbitale. The deepest point on the left infraorbital margin.

Pg Pogonion. The most prominent point of the chin.

P Porion, (cephalometric). The mid point of the upper edge of the external acoustic meatus.

Pr Prosthion. The transition point between the crown of the most prominent medial incisor in maxilla and the alveolar projection.

Ptm Pterygomaxillary fissure. The point at which the maxillary tuberosity abuts against the pterygoid process of the sphenoid.

F-H. Frankfort Horizontal. The plane formed by the right and left poria and the left orbitale.

Palatal plane The line joining the anterior and posterior nasal spines.

Occlusal plane The line joining the bisection of the incisor overbite to the bisection of the occlusal overbite of the first permanent molars.

Mandibular plane The line tangent to the midline projection of the body of the mandible to the most inferior portion of the symphysis of the mandible.

Facial plane The line joining nasion to pogonion.

Y axis The line joining the center of sella turcica to gnathion.

## Findings

*Analysis of the cranial outline*

In lateral view, the cranial vaults of the Australian aboriginals were long and low, as shown by the height/length index of 70.3 for the group. This overall proportion was reflected in the mean angular measurements from the basic quadrilateral and cranial polygon (Table 1, figure 3).

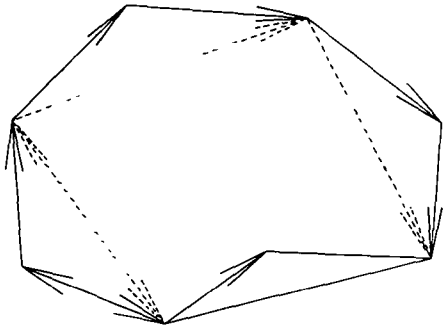

Fig. 3 The mean cranial polygon for the total group with angular ranges indicated.

Contrary to usual craniometric findings, there was little difference between the cranial outlines of the male and female. Age changes seen to occur in the cranial form were a decreased inclination and curvature of the frontal bone due to alteration at nasion (Table II, figure 4).

As was expected, variation of the angle SNF was accompanied by variation of the remainder of the cranial outline. Unfortunately, the number of aboriginals in each subdivision of the age groups was too small to permit statistical evidence of correlation between various angles. The study of the extreme variants, in each age group, showed changes in the cranial base, namely, increased length SN and decreased cranial base angle, BoSN, with the more recessive forehead. Indeed, the cranial outline of this type of individual appeared displaced backward relative to the plane of orientation, SN. (Table III).

Using Schwalbe's[34] analysis of the cranial outline, Berry and Robertson[1] have reported on the Australian aboriginal, while Slome[35] has examined the Bushman. The present adaptation of Wilder's[39] cranial analysis has only one angle in common with Schwalbe's method, the angle of parietal curvature, BPaL. This curvature, according to Berry and Robertson[1], has a mean value of 135.7° in the adult aboriginal and a mean measurement of 129° in the European. Slome's measurement of parietal curvature, (mean 135.6°), in the adult Bantu, was similar to that reported in the aboriginal. In the present study, the group of aboriginal children and adolescents showed a mean measurement of parietal curvature of 131°. The finding of a low standard deviation for this angle, BPaL, confirmed Slome's observation that the parietal curvature varied within narrow limits.

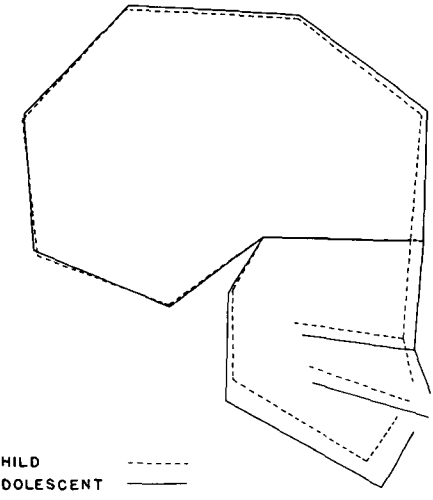


Fig. 4 The mean cranial and facial polygons of the aboriginal child and adolescent. (Superposed on the SN plane and registered at S.)

TABLE I

The Proportional and Angular Readings of the Cranium for the Total Group and the Male and Female Subdivisions

| | *Total Group (51)* | | | *Male (20)* | | | *Female (31)* | | | *'t'** |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | |
| Proportion | | | | | | | | | | |
| Height/length ..... | 70.3 | 67 — 79 | 2.23 | 71.0 | 68 — 75 | 1.95 | 69.96 | 67 — 79 | 2.21 | 1.38 |
| Angles | | | | | | | | | | |
| Basic quadrilat. ..... | | | | | | | | | | |
| BoNB ..... | 76.7 | 71 — 83 | 2.72 | 78.0 | 72.5— 83 | 2.8 | 76.0 | 71 — 81 | 2.2 | 1.42 |
| BLBo ..... | 71.8 | 66.5— 80 | 2.83 | 71.0 | 67 — 76 | 2.3 | 72.0 | 66.5— 80 | 3.12 | 1.13 |
| NBL ..... | 98.5 | 90 —106 | 3.57 | 98.0 | 90 —102.5 | 3.6 | 99.0 | 91 —106 | 3.52 | 1.26 |
| LBoN ..... | 112.9 | 104 —121 | 4.19 | 113.17 | 106 —120 | 4.55 | 112.77 | 104 —121 | 4.29 | 0.33 |
| Cranial Polygon | | | | | | | | | | |
| SNF ..... | 92.0 | 84 —100 | 3.83 | 92.05 | 86 — 99 | 3.85 | 91.85 | 84 —100 | 3.88 | 0.18 |
| NFB ..... | 124 | 116 —135 | 3.93 | 124.27 | 116 —135 | 4.68 | 123.64 | 116.5—129 | 3.42 | 0.55 |
| FBPa ..... | 146 | 140 —155 | 3.36 | 145.5 | 140 —155 | 3.91 | 146.5 | 140 —151 | 2.95 | 1.04 |
| BPaL ..... | 131 | 124 —137.5 | 2.71 | 129.7 | 124 —134.5 | 2.82 | 131.7 | 128 —137.5 | 2.35 | 2.73 |
| PaLOc ..... | 131 | 122 —141 | 4.89 | 129.1 | 123 —141 | 5.17 | 132 | 122 —140 | 4.47 | 1.97 |
| LOcBo ..... | 115.5 | 106.5—128 | 4.76 | 116.97 | 110 —127.5 | 4.23 | 114.61 | 106.5—128 | 4.55 | 1.92 |
| OcBoS ..... | 122 | 111 —132.5 | 5.12 | 122.35 | 113 —131 | 5.55 | 121.4 | 111 —132.5 | 4.88 | 0.69 |
| Cranial base | | | | | | | | | | |
| BoSN ..... | 142 | 127 —152 | 4.74 | 141.04 | 127 —147.5 | 4.51 | 142.82 | 131 —152 | 4.8 | 1.13 |
| Length S-N ..... | 61.75 | 54 — 71.1 | 3.62 | 61.54 | 54 — 66.6 | 3.74 | 61.88 | 54.9— 71.1 | 3.59 | 0.33 |

*The 5% level of signficance of 't' is 2.00.

TABLE II

The Proportional and Angular Readings of the Cranium for the Child and Adolescent Groups

| | *Child (27)* | | | *Adolescent (29)* | | | *'t'** |
|---|---|---|---|---|---|---|---|
| | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | |
| Proportion | | | | | | | |
| Height/length .. | 70.76 | 67 - 79 | 2.52 | 69.92 | 67 - 74.5 | 1.83 | 1.60 |
| Angles | | | | | | | |
| Basic quadrilat. | | | | | | | |
| BoNB ..... | 77.8 | 71 - 83 | 3.05 | 75.76 | 72.5- 78.5 | 1.81 | 2.89 |
| BLBo ..... | 71.4 | 66.5- 80 | 3.11 | 72.02 | 67 - 77 | 2.53 | 0.78 |
| NBL ..... | 97.55 | 90 -104.5 | 3.70 | 99.60 | 93 -106 | 3.17 | 2.12 |
| LBoN ..... | 113.23 | 104 -121 | 4.56 | 112.62 | 107.5-120 | 3.85 | 0.54 |
| Cranial polygon | | | | | | | |
| SNF ..... | 93.46 | 84 -100 | 3.57 | 90.34 | 84 - 98 | 3.50 | 3.15 |
| NFB ..... | 122.96 | 116.5-130 | 3.13 | 124.88 | 116 -135 | 3.85 | 1.93 |
| FBPa ..... | 145.5 | 140 -150 | 3.26 | 146.78 | 142 -155 | 3.39 | 1.37 |
| BPaL ..... | 130.4 | 124 -135 | 2.51 | 131.5 | 125.5-137.5 | 2.84 | 1.46 |
| PaLOc ..... | 130.11 | 123 -140 | 4.41 | 131.44 | 122 -141 | 5.35 | 0.97 |
| LOcBo ..... | 115.9 | 106.5-127.5 | 4.64 | 115.12 | 106.5-128 | 4.50 | 0.48 |
| OcBoS ..... | 122.94 | 115 -132.5 | 5.31 | 120.65 | 111 -128.5 | 4.76 | 1.70 |
| Cranial base | | | | | | | |
| BoSN ..... | 142.72 | 133 -152 | 4.68 | 141.7 | 127 -150 | 4.83 | 0.80 |
| Length S-N ..... | 59.29 | 54 - 64.8 | 2.79 | 63.93 | 56.7- 71.1 | 2.77 | 6.20 |

*The 5% level of significance of 't' is 2.00.

*Analysis of the facial structures and profile*

The mean values, ranges and standard deviations of measurements from the facial structures and profile are recorded in Table IV. It was interesting that the mean percentage of upper facial height to total facial height

TABLE III

The Proportional and Angular Measurements of Individuals Exhibiting Variation in the Cranial Outline.

| | *Child* | | *Adolescent* | |
|---|---|---|---|---|
| | *No. 45 F 11 yrs.* | *No. 41 F 11 yrs.* | *No. 29 F Ad.* | *No. 56 F Ad.* |
| Proportion | | | | |
| Height/length ..... | 69 | 71 | 68 | 71 |
| Angles | | | | |
| Basic quadrilat. | | | | |
| BoNB ..... | 71 | 80 | 73.5 | 76 |
| BLBo ..... | 71 | 75.5 | 73 | 75 |
| NBL ..... | 101.5 | 97 | 103 | 95 |
| LBoN ..... | 116.5 | 107.5 | 110.5 | 114 |
| Cranial polygon | | | | |
| SNF ..... | 84 | 100 | 84 | 96 |
| NFB ..... | 125 | 122 | 129 | 125 |
| FBPa ..... | 149 | 145 | 150 | 142.5 |
| BPaL ..... | 131.5 | 131 | 134 | 133.5 |
| PaLOc ..... | 125 | 136 | 136.5 | 127.5 |
| LOcBo ..... | 116 | 111 | 106.5 | 118 |
| OcBoS ..... | 126 | 127 | 123.5 | 127.5 |
| Cranial base | | | | |
| BoSN ..... | 138 | 152 | 142 | 149 |
| Length S-N (mm) .... | 63 | 55.8 | 63 | 63 |

TABLE IV

The Proportional and Angular Readings of the Facial Analysis of the Australian aboriginals.

| | *Total Group (56)* | | | *Male (21)* | | | *Female (35)* | | | *'t'** |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | |
| Angles | | | | | | | | | | |
| Bjork's polygon | | | | | | | | | | |
| NSAr | 118.6 | 101.5—130.5 | 5.51 | 116.7 | 101.5—125 | 5.80 | 119.9 | 101.5—130.5 | 5.11 | 1.90 |
| SArGO | 149.13 | 130 —168.5 | 8.42 | 150.38 | 130 —168 | 9.64 | 148.38 | 133 —168.5 | 9.98 | 0.85 |
| ArGoGn | 123.25 | 104 —137 | 6.93 | 124.35 | 105 —135 | 7.08 | 122.82 | 104 —137 | 6.59 | 0.81 |
| GoGnId | 87.37 | 76 — 99.5 | 5.14 | 86.55 | 76 — 95.5 | 4.37 | 87.88 | 77 — 99.5 | 5.83 | 0.89 |
| SNAns | 86.82 | 76 — 96.5 | 3.94 | 86.64 | 78 — 95 | 3.66 | 86.92 | 76 — 96.5 | 4.32 | 0.25 |
| NAnsPr | 158.17 | 141.5—172 | 7.13 | 159.9 | 148 —172 | 6.4 | 157.1 | 141 —170.5 | 7.40 | 1.43 |
| Facial Profile | | | | | | | | | | |
| SNAns | 86.82 | 76 — 96.5 | 3.94 | 86.64 | 78 — 95 | 3.66 | 86.92 | 76 — 96.5 | 4.32 | 0.25 |
| SNPr | 93.32 | 83 —104.5 | 4.0 | 92.19 | 85 — 98.5 | 3.40 | 94 | 83 —104.5 | 4.21 | 1.66 |
| SNId | 87.59 | 79.5— 95 | 3.58 | 87.16 | 80 — 94 | 3.36 | 87.84 | 79.5— 95 | 3.75 | 0.68 |
| SNPg | 82.18 | 74 — 91.5 | 3.63 | 81.88 | 77 — 91.5 | 3,56 | 82.37 | 74 — 88.5 | 3.70 | 0.48 |
| NAPg | 171.21 | 159.5—186 | 6.32 | 171.45 | 161.5—183.5 | 6.10 | 171.07 | 159.5—186 | 6.53 | 0.22 |
| Horizontal planes | | | | | | | | | | |
| Palatal plane | 7.1 | 0 — 20 | 3.19 | 6.23 | 2 — 10.5 | 2.62 | 7.61 | 0 — 20 | 3.42 | 1.58 |
| Occlusal plane | 16.06 | 7 — 26 | 4.27 | 15.78 | 7 — 23 | 4.52 | 16.52 | 7 — 26 | 3.85 | 0.62 |
| Mandibular pl. | 31.60 | 16 — 44 | 5.69 | 32.5 | 17 — 42 | 5.68 | 31.07 | 16 — 44 | 5.69 | 0.91 |
| Denture | | | | | | | | | | |
| Interincisal | 115.34 | 97 —137 | 8.36 | 117.02 | 100.5—134.5 | 7.91 | 114.32 | 97 —137 | 8.57 | 1.17 |
| 1 to Mand. pl. | 103.11 | 90 —122 | 6.11 | 101.59 | 90 —110 | 5.11 | 104.02 | 90.5—122 | 6.54 | 1.45 |
| NS6 | 56.5 | 47.5— 63 | 3.55 | 57.5 | 47.5— 63 | 3.67 | 55.8 | 48 — 63 | 3.31 | 1.73 |
| SN $\bar{1}$ | 92.4 | 82 —104.5 | 4.22 | 91.4 | 82 — 98 | 4.05 | 93 | 83.5—104.5 | 4.25 | 1.41 |
| Proportions | | | | | | | | | | |
| Horizontal | | | | | | | | | | |
| Maxilla | 73.57 | 66.1— 82.5 | 4.06 | 72.50 | 86.1— 81 | 3.50 | 74.2 | 63 — 82.5 | 4.23 | 1.34 |
| Mandibular | 110.30 | 97.1—123.5 | 6.29 | 108.69 | 97.1—123.3 | 6.75 | 111.3 | 98.3—123.5 | 6.11 | 1.34 |
| Vertical | | | | | | | | | | |
| Upper face | 43.24 | 39 — 48 | 1.91 | 42.85 | 39 — 46.5 | 1.83 | 43.82 | 41 — 48 | 1.87 | 0.72 |
| Length SN | 61.75 | 54 — 71.1 | 3.62 | 61.54 | 54 — 66.6 | 3.74 | 61.88 | 54.9— 71.1 | 3.59 | 0.33 |

*The 5% level of significance of 't' is 2.00.

43.24%, was in accord with previous observations in many racial groups.[22]

As in the case of the cranium, there was no significant difference between male and female facial measurements. However, the "saddle angle " (NSAr) approached the level of significance, the female cranial base being more obtuse than the male. This finding tended to confirm the work of Cameron[14] who has shown the cranial base of the American White female to be flatter than the male and that the same condition obtained in the American Negro.

Employing the standard deviation as an index of variability, the "joint angle", SArGo, was found most variable and the angle of the palatal plane to SN least variable. The palatal, occlusal and mandibular planes showed an increase in variability as the distance from SN increased, as has been reported in previous studies.

Variability of the facial profile angles, using the standard deviation as a criterion, was less than the variability of those facial structures which have been held to determine the profile (Table IV). This finding agreed with Pearson and Davin[32] who showed that variability of the cranium was less than that of the component parts; agreed, also, with Bjork[3] who believed the combination of variables may result in a cancelling out of the factors which lead to excessive prognathism.

Examination of the mean values for the more prognathic and less prognathic groups in each age subdivision showed that the chief factors in the production of the degree of facial prognathism were changes in the anterior cranial base length and the "saddle angle". A short anterior cranial base length and an acute "saddle angle" were associated with a more prognathic face. As in the cranium, the numbers in the subdivisions of the age groups were too small to permit calculations of correlations between facial measurements.

Since a combination of the angles of the facial structures, as well as the length of the anterior cranial base, has been shown to influence the individual degree of facial prognathism in the Swede and Bantu, it was interesting to notice that individuals in each aboriginal age group showed similar combinations of variables. In the child group the individuals chosen showed the effect of an increased length of the anterior cranial base (Table V and figure 5). In common with Bjork's findings, the "saddle angle" was more acute in the prognathic individual while the palatal, occlusal and mandibular planes were more nearly parallel to the SN plane. It was noticed that the degree of alveolar prognathism was less in the individual with greater total facial prognathism. Together with this reduction there was an increase in the interincisal angle.

Comparison of the individuals with greatest variation in the adolescent group showed the effects on the profile of a decreased jaw angle and a proportional increase in the length of the body of the mandible and maxilla (Table V and Figure 6). Although the anterior cranial base length was similar in each face, the reduction of the jaw angle and the relatively greater length of the maxilla and mandible have resulted in a more prognathic profile. Together with the increase in total face prognathism there has been a reduction in anterior facial height and the convexity of the profile.

Comparison of the mean facial polygons of the child and adolescent aboriginal groups revealed only slight differences. With the exception of the

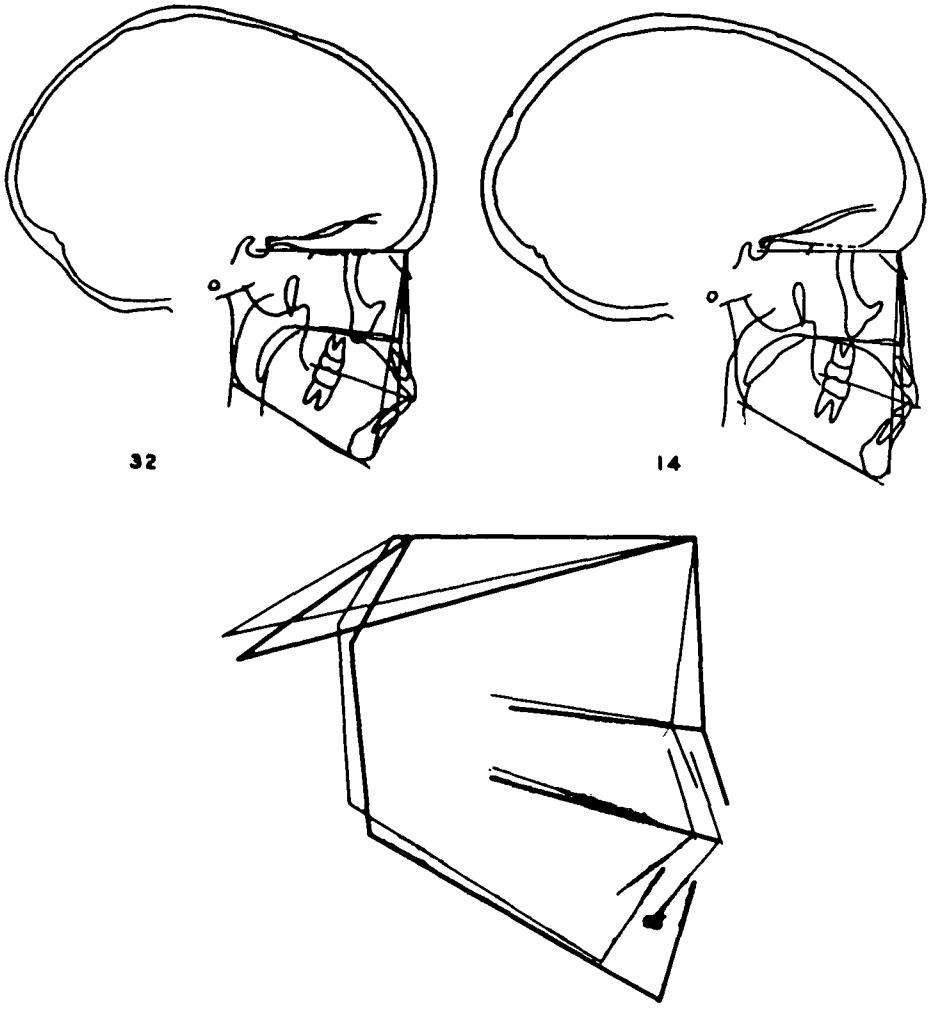


Fig. 5 Individual variation of the facial pattern in the aboriginal child.

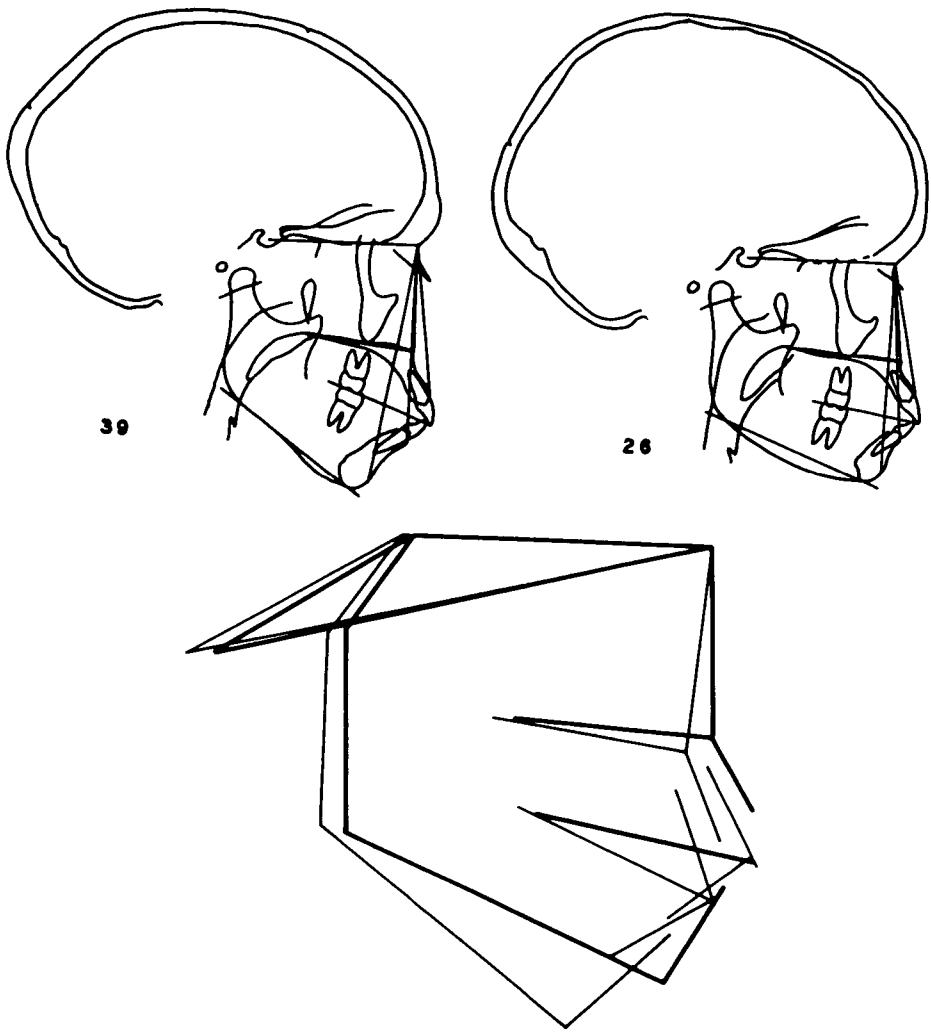


Fig. 6 Individual variation of the facial pattern in the adolescent aboriginal.

amount of maxillary alveolar prognathism, NAnsPr, there were no highly statistically significant differences (Table VI and figure 4).

Age changes were noticed in the profile, (Figure 7). Although a statistically significant difference was recorded for the increase in the degree of mandibular alveolar prognathism, this may have been of an additive nature, i.e. mandibular basal increase plus alveolar increase. As the degree of maxillary basal prognathism showed very little increase, it was not surprising to find a reduction of facial convexity with increased age. This was also seen in the decrease in proportional length of the maxilla and the increase in mandibular proportional length. These findings conform with most studies of the growing human face.

Surprisingly, the long axes of the lower incisors showed an increase in procumbency with age. Since there was a decrease in the interincisal angle, the maxillary incisors also increased in procumbency.

*Comparison with other races*

TABLE V

The Proportional and Angular Measurements of Individual Cases Exhibiting Differences of Maxillary Basal Prognathism

| | *Child* | | *Adolescent* | |
|---|---|---|---|---|
| | *No. 14 F 9 yrs.* | *No. 32 F 8 yrs.* | *No. 26 F 15 yrs.* | *No. 39 F 15 yrs.* |
| Angles | | | | |
| Bjork's polygon | | | | |
| NSAr | 119.5 | 121 | 125 | 123 |
| SArGo | 145 | 150 | 144 | 147 |
| ArGoGn | 125 | 124 | 114 | 126.5 |
| GoGnId | 77 | 91.5 | 96 | 96.5 |
| SNAns | 92.5 | 84 | 92.5 | 87 |
| NAnsPr | 167.5 | 158 | 153 | 155.5 |
| Facial profile | | | | |
| SNAns | 92.5 | 84 | 92.5 | 87 |
| SNPr | 96 | 90.5 | 101.5 | 94 |
| SNId | 90 | 83 | 94 | 87 |
| SNPg | 87 | 78 | 88 | 78 |
| NAPg | 169 | 168.5 | 170 | 165 |
| Horizontal planes | | | | |
| Palatal plane | 6 | 9 | 2.5 | 7.5 |
| Occlusal plane | 17 | 21.5 | 10 | 22 |
| Mandibular plane | 30 | 35 | 23 | 37 |
| Denture | | | | |
| Interincisal | 121 | 113 | 104 | 101 |
| 1 to Mand. pl. | 98.5 | 107 | 116 | 110 |
| $NS_{\underline{6}}$ | 56 | 57 | 54 | 57 |
| $SN_{\underline{1}}$ | 94.5 | 90 | 100 | 94 |
| Proportions | | | | |
| Horizontal | | | | |
| Maxilla | 73.8 | 70.5 | 76.4 | 71.4 |
| Mandible | 116.9 | 104.4 | 123.5 | 110 |
| Vertical | | | | |
| Upper face | 42.7 | 42.8 | 44 | 43.1 |
| Length SN (mm) | 58.5 | 61.2 | 61.2 | 63 |
| Facial angle | 91 | 89 | 100 | 90 |
| Cranial base angle, BoSN | 145 | 150 | 148 | 150 |

TABLE VI

The Proportional and Angular Readings of the Face of the Young and Adolescent Australian aboriginals.

| | *Young (27)* | | | *Adolescent (29)* | | | *'t'** |
|---|---|---|---|---|---|---|---|
| | *Mean* | *Range* | *S.D.* | *Mean* | *Range* | *S.D.* | |
| Angles | | | | | | | |
| Bjork's polygon | | | | | | | |
| NSAr | 117.51 | 101.5—130.5 | 6.07 | 119.82 | 106.5—128 | 4.67 | 1.60 |
| SArGo | 150 | 130 —168 | 8.23 | 148.33 | 133 —163.5 | 8.66 | 0.73 |
| ArGoGn | 124.81 | 111.5—137 | 5.98 | 122.08 | 104 —133 | 7.26 | 1.53 |
| GoGnId | 86.7 | 77 — 97 | 4.78 | 88.01 | 81.5— 99.5 | 5.79 | 1.55 |
| SNAns | 86.79 | 76.0— 95.0 | 3.68 | 86.84 | 78.0— 96.5 | 4.44 | 0.04 |
| NAnsPR | 162.0 | 152.0—172.0 | 6.64 | 154.60 | 141.5—165.0 | 5.61 | 4.51 |
| Facial profile | | | | | | | |
| SNAns | 86.79 | 75.0— 95.0 | 3.68 | 86.84 | 78.0— 96.5 | 4.44 | 0.04 |
| SNPr | 92.33 | 85.5— 98.5 | 3.96 | 94.24 | 85.0—104.5 | 3.86 | 1.82 |
| SNId | 86.41 | 79.5— 92.0 | 3.27 | 88.68 | 80.0— 95.0 | 3.58 | 2.47 |
| SNPg | 81.31 | 76.5— 87.5 | 3.35 | 83.0 | 77.0— 91.5 | 3.73 | 1.78 |
| NAPg | 170.35 | 169.5—180 | 5.69 | 172.24 | 162.5—186 | 6.79 | 1.13 |
| Horizontal planes | | | | | | | |
| Palatal plane | 7.2 | 2.0— 20.0 | 3.80 | 6.98 | 0.0— 12.0 | 2.57 | 0.25 |
| Occlusal plane | 17.72 | 12.0— 26.0 | 3.62 | 14.51 | 7.0— 23.0 | 4.30 | 3.00 |
| Mandibular plane | 33.13 | 25.0— 44.0 | 4.38 | 30.19 | 16.0— 42.0 | 6.42 | 1.98 |
| Denture | | | | | | | |
| Interincisal | 116.92 | 104.0—137.0 | 7.92 | 113.86 | 101.0—131.5 | 8.63 | 1.38 |
| 1 to Mand. pl. | 100.79 | 90.5—110.0 | 4.75 | 105.27 | 90.0—122.0 | 6.51 | 2.92 |
| $NS_{\underline{6}}$ | 57.7 | 52 — 63 | 2.86 | 55.22 | 48 — 60.5 | 3.67 | 2.85 |
| $SN_{\underline{1}}$ | 91.54 | 83.5— 98 | 3.61 | 93.29 | 82 —104.5 | 4.55 | 1.47 |
| Proportions | | | | | | | |
| Horizontal | | | | | | | |
| Maxilla | 74.0 | 68.1— 81.7 | 3.68 | 73.19 | 63.0— 82.5 | 4.29 | 0.67 |
| Mandibular | 108.14 | 97.1—121.7 | 6.28 | 112.32 | 102.7—123.5 | 5.79 | 2.36 |
| Vertical | | | | | | | |
| Upper face | 43.09 | 39.0— 46.0 | 1.60 | 43.80 | 41.0— 48.0 | 2.06 | 0.24 |

*The 5% level of significance of 't' is 2.00.

Mean facial measurements of the Swede[3] and Australian aboriginal are shown in Table VII and illustrated, together with Bjork's mean polygon for the Bantu,[4] in figures 8 and 9. Comparison of these figures showed inter-racial differences in the facial structures, as determined by Bjork's polygon. The Australian aboriginal showed the most acute "saddle angle", NSAr, together with the most obtuse "joint angle", SArGo. As would be expected, the "chin angle", GoGnId, was greatest in the aboriginal. The Bantu and aboriginal mandibles appeared to have a similar form, contrasting with the wider "jaw angle" of the Swede.

Despite inter-racial differences of

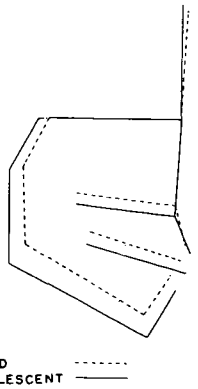


Fig. 7 The mean facial patterns of the child and adolescent aboriginal. (Superposed on the SN plane and registered at N.)

TABLE VII

Comparison of the Findings Obtained in the Swede by Bjork (1947) with the Findings Obtained in the Australian Aboriginal

| | *Child* | | | | *Adult* | | *Adolescent* | |
|---|---|---|---|---|---|---|---|---|
| | *Swede* | | *Aboriginal* | | *Swede* | | *Aboriginal* | |
| | *Mean* | *S.D.* | *Mean* | *S.D.* | *Mean* | *S.D.* | *Mean* | *S.D.* |
| Angles | | | | | | | | |
| Bjork's polygon | | | | | | | | |
| NSAr .....122.9 | 4.85 | | 117.5 | 6.07 | 123.06 | 5.33 | 119.8 | 4.67 |
| SArGO .....142.96 | 6.21 | | 150.0 | 8.23 | 143.27 | 6.91 | 148.33 | 8.66 |
| ArGoGn ....131.09 | 6.11 | | 124.81 | 5.98 | 130.85 | 7.31 | 122.08 | 7.26 |
| GoGnId .... 68.58 | 5.4 | | 86.7 | 4.78 | 64.24 | 6.43 | 88.0 | 5.79 |
| SNAns ..... 85.77 | 3.83 | | 86.79 | 3.68 | 88.16 | 4.18 | 86.84 | 4.44 |
| Facial profile | | | | | | | | |
| SNAns ..... 85.77 | 3.83 | | 86.79 | 3.68 | 88.16 | 4.18 | 86.84 | 4.44 |
| SNPr ..... 83.68 | 3.67 | | 92.33 | 3.96 | 84.83 | 4.13 | 94.24 | 3.86 |
| SNId ..... 80.01 | 3.66 | | 86.41 | 3.27 | 82.25 | 4.37 | 88.68 | 3.58 |
| SNPg ..... 78.92 | 3.63 | | 81.31 | 3.35 | 81.69 | 4.43 | 83.0 | 3.73 |
| NAPg .....173.90 | 5.27 | | 170.35 | 5.69 | 177.02 | 6.96 | 172.24 | 6.79 |
| Horizontal planes | | | | | | | | |
| Palatal plane 7.77* | | | 7.2 | 3.80 | 7.82* | | 6.98 | 2.57 |
| Occlusal pl. . 19.43* | | | 17.72 | 3.62 | 16.34* | | 14.51 | 3.00 |
| Mandib'r pl. 36.98* | | | 33.13 | 4.38 | 36.53* | | 30.19 | 6.42 |
| Denture | | | | | | | | |
| Interincisal .128.45 | 8.80 | | 116.92 | 7.92 | 137.44 | 11.76 | 113.86 | 8.63 |
| Proportions | | | | | | | | |
| Horizontal | | | | | | | | |
| Maxilla .... 75.18* | | | 74.0 | 3.68 | 77.63* | | 73.19 | 4.29 |
| Mandible ...106.2 | 5.85 | | 108.14 | 6.28 | 110.3 | 7.14 | 112.32 | 5.79 |
| Vertical | | | | | | | | |
| Upper face.. 44.26* | | | 43.09 | 1.6 | 43.22* | | 43.80 | 2.0 |
| Length SN ... 68.76mm | 2.97 | | 52.29mm | 2.79 | 73.22mm | 3.26 | 63.93mm | 2.77 |

*Calculated from Bjork's data.

the facial structures, the profiles of the three races showed similarities. The degree of alveolar prognathism was highest in the Australian aboriginal, while maxillary and mandibular basal prognathism did not differ greatly. This was especially evident in the degree of maxillary basal prognathism (SNAns) and the parallelism of the palatal planes.

Dental measurements showed the incisors to be most procumbent in the aboriginal and least procumbent in the Swede. The mean interincisal angle of the adult Swede was 137° with a range of 70°, the mean of the Bantu 120°, with a range of 55°, while the mean of the aboriginal was 113.8° with a range of only 30.5°. However, this small range may be due to the size of the sample.

Both child and adolescent or adult groups showed similar racial differences: but it was noticed that maxillary basal prognathism was slightly greater in the aboriginal child than the Swedish boy, a condition reversed in the adult.

Comparison of the selected group of Australian aboriginals with the American White, American Negro, American Chinese and Nisei,[17 18] showed the mean values for the Downs' analysis of the aboriginal facial skeleton to be within the range of variation of the American White (Table VIII). With the exception of the inclination of the occlusal

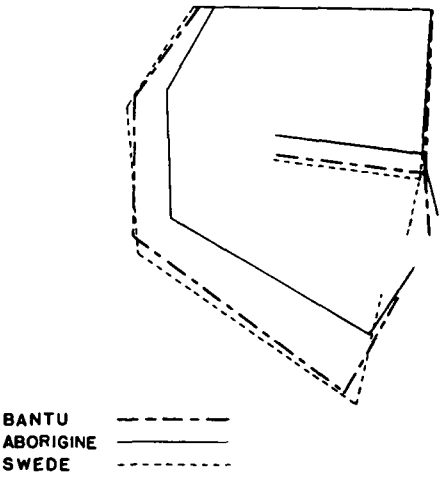


Fig. 8 Comparison of the mean facial pattern of the aboriginal child with Bjork's illustrations of the Swedish boy and twelve year old Bantu. (Superposed on the SN plane and registered at N.)

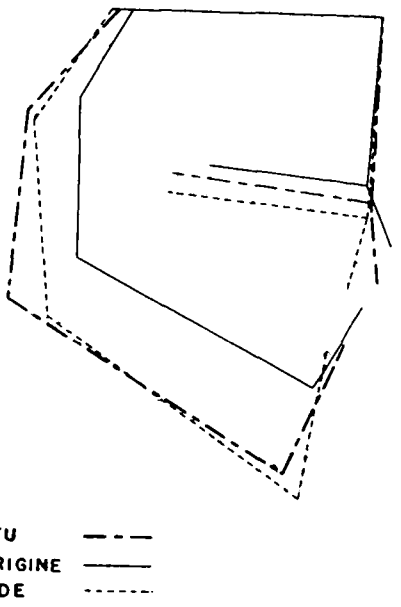


Fig. 9 Comparison of the mean facial pattern of the adolescent aboriginal with Bjork's illustrations of the adult Swede and Bantu. (Superposed on the SN plane and registered at N.)

plane to Frankfort Horizontal, the readings of the denture showed extreme dental protrusion in the aboriginal; the aboriginal facial angle was greater than

TABLE VIII

Mean Measurements and Ranges from the Downs' Analysis of the Australian Aboriginals Compared with the Findings Reported by Downs (1948), Cotton, Takano and Wong (1951).

| *Value* | *Amer. White* | *Amer. Negro* | *Nisei* | *Austr. Aboriginal* | *Amer. Chinese* |
|---|---|---|---|---|---|
| Facial angle ..... | 87.9<br>82 to 95 | 87.25<br>80 to 91 | 88.25<br>83 to 94 | 91.5<br>87 to 100 | 77.5<br>73 to 89 |
| Mandibular plane angle ..... | 21.9<br>17 to 28 | 27.25<br>17 to 35 | 24.3<br>14 to 33 | 21.9<br>9 to 31 | 32.4<br>22 to 44 |
| Y-axis ..... | 59.3<br>53 to 66 | 63.3<br>57 to 69 | 62.1<br>56 to 68 | 54.5<br>45 to 61 | 67.1<br>59 to 75 |
| Angle of Convexity ..... | 0.0<br>+10 to —8.5 | +9.6<br>+4 to +20 | 3.65<br>+12 to —1 | +8.4<br>0 to +17.5 | +7.5<br>+1.5 to +14 |
| AB plane to facial plane ..... | —4.7<br>0 to —9 | —7.7<br>—3 to —15 | —4.35<br>—1 to —7 | —2.65<br>—9 to +2 | —5.7<br>—2 to —10 |
| Cant of occlusal pl. ..... | 9.2<br>1.5 to 14 | 11.8<br>+8 to +17 | 9.65<br>2 to 19 | 7.2<br>—1 to +12.5 | 16.9<br>+8 to +25 |
| $\underline{1}$ to $\overline{1}$ ..... (interincisal) | 135.4<br>130 to 150.5 | 123.0<br>105 to 144 | 126.4<br>114 to 152 | 114.5<br>100.5 to —129.5 | 120.8<br>105 to 137 |
| $\overline{1}$ to occl. pl. .... | 14.5<br>3.5 to 20 | 22.5<br>12 to 35 | 21.5<br>8 to 31 | 29.1<br>21.5 to 40 | 22.2<br>13 to 29 |
| $\overline{1}$ to mand. pl. .. | 1.5<br>—8.5 to +7 | +6.6<br>—3.5 to +22 | +6.55<br>—6 to +13 | +14.1<br>+1.5 to +31 | 7.8<br>0 to +18 |
| $\underline{1}$ to AP pl. ..... (mm.) | 3.1<br>—1 to 5 | 8.5<br>6 to 11 | 6.6<br>2 to 10 | 10.9<br>7 to 14 | 7.6<br>3 to 12 |

any of the four ethnic groups.

When the standard deviation was taken as an indication of variability, similar variation of the angles and proportions of the face to those of the Swede[3] were found in the Australian aboriginal. As has already been pointed out, individual variation in the aboriginal was the same as that reported by Bjork in the Swede and Bantu.

It was interesting to note that in both Swede and aboriginal variability of the facial angles to the SN plane was greater than to the Frankfort Horizontal.

Growth in length of the anterior cranial bases of the Swede and aboriginal was similar (Table VII). Despite this almost equal increment, the proportional length of the maxillary base of the aboriginal decreased with age, while that of the Swede increased. This was reflected in the different measurements of maxillary basal prognathism. Although mandibular basal prognathism increased with age in both Swede and Bantu, the decrease in chin angle reported by Bjork did not occur in the aboriginals who showed an increase in this measurement.

The inclination of the palatal planes of both Swede and aboriginal remained almost the same with advancing age, but the occlusal and mandibular planes showed a tendency to become parallel to the SN plane.

Both Bjork[3] and Brodie[10] have stated that with age the basal prognathism of the jaws increases beyond alveolar prognathism. In the Australian aboriginal alveolar prognathism increased beyond basal prognathism especially in the maxilla. Accompanying the increased alveolar prognathism of the aboriginal the incisors became more procumbent. Thus, in the Swede the interincisal angle increased with age, while the aboriginal interincisal angle decreased.

## Discussion

The Frankfort Agreement of Anthropologists adopted the following classifications for length/height indices of the skull:

| | |
|---|---|
| Below 70.0 | chamae-cephalic or low headed |
| 70.1 to 75.0 | ortho-cephalic |
| above 75.1 | hypsi - cephalic or high headed. |

Thus, the Australian aboriginals in the present study are almost in the low headed group. Although this finding differs from the observations of Campbell, Gray and Hackett, who described the living Central Australian aboriginal as hypsi-cephalic, it is possible that the differences are due to the methods employed. But, if we accept Birdsell's surmise that this group is a mixture of Murrayian and Carpentarian elements, the former with a long, low and narrow cranial vault, low headedness may be readily explained.

It would appear, on the basis of the parietal curvature, that Klaatsch's[26] idea of determining racial specialization from the components of the cranial outline is not valid. However, the application of a geometric form, such as that of Wilder,[39] to radiographic cephalometry seems to hold promise, especially now that basion, or a point close to it, can be determined in some radiographs.[5] Perhaps cranial form influences the cranial base, which in turn may modify the relationships of facial structures; so that a dolico-cephalic skull is associated with a flat cranial base and the requisite compensations in mandibular form. The changes in skull outline with the variation in inclination of the forehead seem to indicate such a possibility.

Although the radiographic cranial polygon is independent of certain sexual

characteristics of the skull, e.g. the glabella, it still relies on nasion for the anterior limit of the cranial base. Since nasion is part of the face and closely associated with the supraorbital ridges, it has an independent growth relative to other cranial landmarks. Thus, some of the variation and growth changes in the inclination of the forehead can be explained on the behaviour of nasion. Bjork has observed this increased recession of the forehead with age in the Bantu and Swede.[5] It would appear that the similarity between growth of the aboriginal cranial outline and those of other primates reported by Krogman[27] is also due to the changes at nasion.

The close approximation of male and female cranial outlines may be due to the method employed and the age distribution; within the group there were greater numbers of young boys and older girls. This age distribution may also explain the almost significant difference between male and female cranial base (NSAr). In view of the work of Cameron,[14] it would appear that sex differences in the cranial base do occur. Radiographic cephalometry offers an excellent means of determining this difference, but larger groups of aboriginals would be necessary.

When the anterior cranial base was used as a reference line, the facial profiles of the aboriginal, Swede and Bantu were similar; but, when measured from the Frankfort Horizontal, marked racial differences appeared. It would seem that this plane, relying on the orbital margins for its anterior termination, must be considered as a facial plane, useful for intra and inter-racial facial typing in the adult. Krogman[28] has already pointed out that the use of the F.H. in growth studies is not valid, since porion changes position with age. However, the plane has readily accessible landmarks and, in the case of the North American White, closely approaches the normal posture of the head.[19] Whether the F.H. is also representative of head posture in other racial groups is debatable. Studies on the position of foramen magnum[5 38] suggest that there are differences.

Although the sella-nasion plane has limitations, especially the possibility of directional growth at nasion, it appears a satisfactory plane for examining the relationship of face to cranium.

The dependence of the upper face on the anterior cranial base may be a factor in determining the degree of maxillary prognathism when using nasion as a reference point. Even so, maxillary measurements in all three racial groups suggested a uniformity of the upper face which may be characteristic of Homo sapiens. This suggestion would seem to be confirmed by the observation that the proportion of upper facial height to total facial height is similar in many racial groups.[22]

Inter-racial variation was evident in the degree of mandibular basal prognathism, but none great enough to determine any characteristic racial prognathism. As Bjork has pointed out, the facial structures producing this prognathism seem to offer a means of determining variation. In this respect, the "joint angle" is significant. Bjork has described the wide "joint angle" of the Bantu as a primitive characteristic. Thus, the Australian aboriginal may be classified as primitive; but the "saddle angle", more acute than the Swede, would seem evidence for a more advanced skull form. Perhaps, racial classification cannot be based on any single measurement. Many of the differences of proportions and angles, in comparison of the adolescent aboriginal adult Swede and Bantu, may have been due to the difference in age between the three groups.

A distinguishing feature of the Aus-

tralian aboriginal was the pronounced degree of alveolar prognathism, an observation made by many investigators. There may be three possible explanations for this prognathism: firstly, the dental arch, described by Campbell as "probably larger than any other living race", cannot be accommodated within the proportionately smaller facial structures, resulting in dental and alveolar prognathism. This would also account for the greater degree of alveolar prognathism observed in the female.

Secondly, the labial musculature of the Australian aboriginal is characterized by the extension of quadratus labii superioris and quadratus labii inferioris to the vermillion borders of the lips.[13] This arrangement of the musculature may not act as a restraining influence to the forward movement of the denture described by Brodie.[8] The hypothesis may be offered that the refinement of neuro-muscular control of the labial musculature of the white race[23] has resulted in the more upright position of the incisors and alveolar processes.

Thirdly, the early loss of cusps may permit excessive mesial movement of the dental arches together with an increased procumbency of the incisors. This may be especially so in the maxilla which, by increased procumbency of the incisors, maintains an incisor relationship despite a maxillary base relatively shorter than the mandibular base.

The convexity of the face of the Swede, Bantu and Australian aboriginal, when measured from the profile angle, differed from the interpretation gained from angular readings to points on the profile. This can be explained by the variation in length of the anterior nasal spine. As has been pointed out previously, this spine is very short in the aboriginal. The use of subspinale, A, as the anterior end of the maxilla may give a more accurate indication of maxillary prognathism. When measured from point A, the American Negro has a more convex face than the aboriginal group, which may lend some support to the observation that certain African tribes exceed the Australian in upper face prognathism.

Although variation in facial structures and profile in the three racial groups may be due to the landmarks employed, the finding of similar individual variation suggests the presence of a common genetic influence. Schultz[33] has already pointed out that, "man's range of individual variations has not yet become entirely separate from corresponding ranges in other primates".

Comparison of Australian aboriginal growth with the other races studied gave the impression that the middle face of the aboriginal completed its forward growth earlier than the cranial super-structure, nasion, or the mandible. This was an exaggeration of the previous findings that the profile becomes less convex with age. The increase in maxillary alveolar prognathism, angle NAnsPr, may be due to an adaptation of the maxillary denture to a greater forward growth of the mandible and its dental arch. Bjork believed this difference in behaviour of the dental bases was responsible for the reduction of overbite of the incisors. Similar reasoning might well explain the high incidence of edge-to-edge incisor relationship reported by Turner[37] in the adult Australian aboriginal. That the entire maxillary denture moves forward during growth is suggested by the reduction of angular readings to the first permanent molar, NS6.

The forward migration of the dentition might well explain the finding that the "chin angle" of the aboriginal does not decrease with age, as occurs

in the Swede. Likewise, the decrease in interincisal angle with age may be due to the forward movement of the dentition associated with the peculiar labial musculature of the aboriginal.

## Conclusions

1. The adaptation of Wilder's analysis to radiographic cephalometry offers the possibility of understanding variations in cranial outline. In the Australian aboriginal the least variable portion of the cranial outline is the parietal region.
2. Age changes in the cranial outline occurred to a greater extent in the anterior portion and depended on the increased length of the anterior cranial base, SN.
3. Bjork's observation, that while the degree of facial prognathism is similar the nature of inter-racial facial prognathism differs, is apparent in the comparison of the Australian aboriginal with other races.
4. Inter-racial variation in the degree of middle face prognathism and the inclination of the palatal plane is less than other facial measurements.
5. The Australian aboriginal has a greater degree of alveolar prognathism than the Swede or Bantu.
6. Individual variation among the Australian aboriginals is of the same nature as that reported in the Swede and Bantu.
7. Growth changes in the Australian aboriginal facial profile are similar to those of the North American White, Swede and Bantu.
8. In contrast to the North American White, Swede and Bantu, alveolar prognathism in the Australian aboriginal increases with age.

## Summary

The availability of a series of fifty-six lateral cephalometric radiographs of Central Australian aboriginals has permitted the comparison of their facial and cranial structures with those of other living races.

Following the suggestions of Wilder, the lateral view of the cranial outline was analyzed by a geometric construction based on established craniometric landmarks. For the purpose of comparing the Australian aboriginal with the Swede and Bantu, Bjork's analysis of the face was employed.

Mean values, sexual differences and age changes were determined in both cranium and face of the aboriginal. Inter-racial variation was studied and individual variations of the face and cranium examined. Since the aboriginals were divided into two age groups, differing in mean values, the adolescent aboriginals (average age about fifteen years) were compared with the adult Swede and Bantu, while the aboriginal children (average age seven and a half years) were compared with the Swedish and Bantu boys. Thus, inter-racial variation was determined.

A characteristic geometrical form was obtained from the cranial outline in which variation of the frontal region appeared related to the length of the anterior cranial base. Age changes in the cranium showed an increased recession of the forehead. Neither cranial nor facial analyses showed significant sexual differences.

Intra-racial variation among the Australian aboriginal faces was seen to depend on the length of the anterior cranial base and differences in the facial structures. Individual variation was of the same nature as that reported in the Swede and Bantu.

Although age changes in the facial profile of the aboriginal were similar to those reported in other races, there was a significant increase in alveolar prognathism, together with a decrease in the inter-incisal angle.

When the mean facial profiles of the aboriginal, Swede and Bantu were compared by superimposition on the SN plane, there was little difference in facial prognathism. However, Downs' analysis applied to the aboriginal profile and compared with other ethnic groups showed the effects of inter-racial comparison using the Frankfort Horizontal plane. The aboriginal was the most prognathic.

Characteristic of the Australian aboriginal was the pronounced alveolar prognathism, greater than the Bantu.

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