A Cephalometric Study of the Hawaiian

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Introduction

The origin of the Hawaiian has been a subject of much discussion. Suggs[20] suggests that the Polynesian is the result of intermingling of the three main races, the Caucasoid, the Mongoloid, and the Negroid, taking place on the coastline of southern Asia in the period after the end of the last glaciation. Shapiro[14] concurs with this theory and believes that the genetic factors from the Caucasoid, Mongoloid, and Negroid elements were welded into a stable genetic unit on the mainland of Asia prior to their migrations into the Pacific. Hooton[10] states that the Caucasoid element of the Polynesian is dominant over the other two. Interracial mixtures of Polynesians with Caucasoid, Mongoloids, and Negroids help bear out this theory.

Being excellent seafarers, they evidently wandered from southeast Asia through Melanesia into what is known as Polynesia today. Buck[4] ranks them among the greatest of seafarers and navigators and suggests a similar genetic background as do Shapiro and Suggs. From folklore, Hawaii Loa, forefather of the Hawaiians, migrated to Hawaii from the south, probably the Society Islands which includes Tahiti. Boswell[3] believes the Hawaiians to be descendants of Tahitian Polynesians.

Spoehr[16] doubts the validity of the theory that the Polynesians came from the intermingling of the three main races on the grounds that there is no definite proof or evidence that there were only three races. He dates the time of entry of the Polynesians into Polynesia to at least 1000 B.C. (using radiocarbon indices in Samoa as evidence) and feels that genetic stabilization may have taken place in the Pacific instead of the mainland of Asia as previously believed. He points to strong evidence that Hawaii was first colonized in the first century by Marquesans. A second colonization by Tahitians took place at a later date. Thus, he believes there were two groups of colonizers from the south Pacific instead of one.

Marshall and Snow[12] pointed out two factors of overwhelming significance in Polynesian anthropology: over the entire area, the largest on earth, a single language was spoken; and over the entire area there was a common culture.

The Polynesian is a modern group of Homo sapiens, there being no traces of an earlier, more primitive group anywhere in Polynesia. These islands are so isolated that it would have been next to impossible for Paleolithic man such as Pithecanthropus or Solo man, with their low cultural level, to navigate there.

Suggs[20] characterized the Polynesian as tall, broad, and muscular in structure, with a tendency to corpulence. Their skin color is yellow-brown and their wavy hair is black with a reddish tinge. They range from long, narrow heads (diochocephalic) to short, broader heads (brachycephalic) with the majority being the latter. Their faces are wide with projecting cheekbones covered with some fatty padding. The nose is long, broad, and high, with a straight profile and a depression at the root. The nasal wings are full with a slight flare. The eyes are deep-set with heavy lids that sometimes have a slight Mongoloid fold. Lips are full but not Negroid. Body hair is sparse.

Sullivan[21] in his comparisons with other Polynesians found the Hawaiian the shortest in stature at a mean of

169.5 cm while the Tongan and the Samoan were the tallest by approximately an inch. He found the Hawaiian head and face relatively wide, whereas in transverse and vertical diameters the head and face were shorter than the rest of the group. The hair was straighter and more brown in color. The nose was the flattest of the group. The epicanthic fold of the eyelid, while slight, was present on twenty-two per cent of Hawaiians investigated.

Intermarriage by the Hawaiian to members of other ethnic groups, being the rule rather than the exception, has reduced pure stock Hawaiians to a rare few in less than a century. This racial mixing, started by the Hawaiians in the days of the Hawaiian monarchy, has been carried on by all racial groups and has made Hawaii the "racial melting pot of the Pacific."

The present investigation was undertaken to compare the Hawaiian, a Polynesian, with various ethnic groups using roentgenographic cephalometry. It was the original intent of this investigator to obtain living, pure-blooded Hawaiians for this study, but an inadequate sample eliminated that possibility. The study, therefore, was completed with skull material.

Review of the Literature

Among the outstanding contributions to craniofacial measurement by roentgenographic cephalometric means was Björk's study of Swedes.[1] His basic goal was the establishment of measurements of facial prognathism within the Swedish population. With these measurements he constructed cranial and facial geometric forms which we shall henceforth refer to as polygons. By comparing measurements of one polygon to another, it was possible to ascertain reasons for various types of prognathism.

Björk in 1950[2] discussed the reasons for prognathism using evolutionary changes as examples (starting with the baboon, ape, fossil apeman, to the recent homo.) By constructing polygons of 71 Bantu boys and 238 Bantu men, he was able to compare interracial differences with his previous polygon study of Swedish boys and men.

The contribution of Downs' craniofacial assessment, skeletal and dental, was the result of his study of twenty white American children, age 12 to 17, possessing excellent occlusions.[9] Employing ten measurements, five skeletal and five dental, he was able to present the profession with a definitive and descriptive appraisal, complete with means and ranges, which was of diagnostic value to the clinical orthodontist.

Borrowing from Brodie, Downs, Wylie, Thompson, Riedel, Margolis, Holdaway, Ricketts, and others, Steiner designed a simple, yet meaningful, analysis for the clinical practitioner. His role in the analysis was in the organization of the most useful measurements, both linear and angular, into a "neat, usable package." This "package" was his "chevron" type formula.[17,18,19]

Steiner's concepts are for a balanced occlusion with good facial balance. His average norm is a concept from "average measurements of normals suggested to be used for comparisons."[18] He makes it clear that "this norm is only offered for a basis of comparison and must be deviated from for individuals, particularly so for people of different ethnic groups."

Based on good facial balance, upright mandibular incisors, and a favorable growth pattern, Tweed designed his triangle which quickly describes the mandibular plane as it meets Frankfort horizontal as well as the inclination of the most medial mandibular incisor to both the mandibular plane and Frankfort horizontal.[22,23]

Describing all major cephalometric research and methods up to 1957, Krogman and Sassouni's syllabus[11] has in itself proven to be a major contribution to roentgenographic cephalometry. Their interpretation and discussion of landmarks and analyses has been a clearing house for this investigation.

Employing Downs' analysis, Cotton, Takano and Wong[7] in 1951 compared the American Negro, the American Japanese, and the American Chinese to the means and ranges compiled by Downs on the white American. Only Takano claimed the selectivity of sample of Downs. Cotton and Wong indicated that their selection was less critical and the occlusions of their samples, while possessing more or less "normal occlusion," were not necessarily excellent.

Craven[8] in 1958 conducted a cephalometric investigation of the Australian aboriginal child and young adult using Björk's Swede and Bantu polygons as a means of comparison in one part of his study, Downs' white American means and ranges,[9] and Cotton, Takano and Wong's ethnic studies[7] as other means of comparison. Craven's sample was a random one and hence similar to Björk's Swede and Bantu samples.

Miura et al.[13] published an investigation of Japanese children in 1963 using Steiner's analysis as a basis for comparison. Finding the Japanese more protrusive, they designed a new Steiner standard for the Japanese to compensate for the difference in facial pattern. Their sample consisted of ninety Japanese children with normal occlusions whose mean age was 10 years 9 months; there were forty males and fifty females.

Methods and Materials

The following steps were taken to conduct this study:

1. Skulls of pure Hawaiian origin were obtained and radiographed in the lateral aspect.
2. The radiographs were divided into male and female groups. No infant or child specimens were used.
3. Tracings were made and measurements recorded and averaged for the following cephalometric analyses: Björk, Downs, Steiner and Tweed.
4. These measurements were appraised on their own merits as well as compared with studies using similar methods on other racial groups.

Through the courtesy of the Bernice P. Bishop Museum of Honolulu and Mr. Robert N. Bowen, assistant curator, seventy-eight Hawaiian skulls were loaned to this investigator for the purpose of radiography, photography, and other studies. These specimens were carefully positioned in a cephalostat with the teeth in centric occlusion and radiographed in the lateral aspect. The distance from tube to film surface was sixty inches. To insure that the teeth were positioned in centric occlusion, the jaws were secured with elastic ligature to the base of the skull and with beeswax around the teeth where necessary. It is felt that the headfilms are accurate and that sources of errors have been minimized.

The limiting factor as to the number used in this study was the scarcity of good, usable male material. Thus in the final selection eighteen males and twenty-five females were used (Table I).

The occlusions of most specimens were well "ground in," but with no great degree of abrasion. Many of the sample exhibited ideal occlusions with little caries noted. Many of the Class II malocclusions listed above were end-to-end or not full Class II's. There was one questionable Class III malocclusion but, after careful consideration, it was considered a pseudo-Class III and classified Class I. This low incidence of

TABLE I

	Male	Female	Total
Estimated age (mean)	32.77	26.56	29.16
Class I	15	18	33
Class II	3	7	10
Mandibular Arch Discrepancy	1.61mm	0.62mm	0.95mm

Class III malocclusions concurs with Chappel[6] and Snow.[12] Class III malocclusions do, however, exist among the Hawaiians.

The selection of skulls afforded an opportunity to compare findings made by Marshall and Snow,[12] as well as a subsequent study by Snow and other associates.[15] The investigator was most fortunate to have available the consultation of Robert N. Bowen of the Bishop Museum, also an anthropologist, but more valued because he was directly responsible for the gathering of considerable material from burial sites.

The processed cephalograms were carefully studied and then traced by the writer and two assistants. Two sets of tracings were done and compared for errors.

Perhaps the greatest source of tracing and measurement error was the position of the mandibular plane. The reason for this dilemma was the presence of a number of "rocker jaws," a term used to describe the convex lower border of the mandible. This "rocker jaw" is a common occurrence among Polynesians. In these cases the investigator accepted a line parallel to GoGn.

The measurements from the four different analyses mentioned above were recorded according to sex, averaged, and then totaled for the entire sample and again averaged.

It is felt that the measurements of each analysis complement one another and serve as an excellent means of crosschecking for accuracy. More than that, since there are several cephalometric analyses in current use among orthodontists, it is the hope of this investigator that one or more of the four described will be familiar to the reader.

Analyses

Björk

The Björk analysis was by far the most complex of the four used; thirty-four of his most useful measurements were recorded for the Hawaiian; the Björk facial polygon was constructed for all samples.

Björk states that prognathism is the characteristic which determines the general shape of the facial profile.[2] Key points in the analysis of facial profile using SN registered at N, as the plane of reference, expresses prognathism in four ways. These have been outlined by Björk as follows:

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 prognathism: The angle formed by the cranial base and a profile line through nasion and pogonion.

Of considerable importance is Björk's concept of the cranial base. The cranial base has a length and also a direction or shape. The horizontal component of the cranial base is expressed by SN. The vertical component of the cranial base is expressed by SAr. It is, therefore, the saddle angle (NSAr) that gives direction or deflection to the cranial base. The line NAr is thus an expression of the length and direction of the cranial base.

Downs

The ten values of Downs are well known and there is little need for a detailed discussion. His roentgenographic assessment of the craniofacial pattern, skeletal and dental, has been routinely used by clinical orthodontists in case analysis. His statement that "there is a facial pattern that represents mean or average form for individuals possessing excellent occlusions"[9] provided a formidable challenge to Cotton, Takano and Wong[7] who, working independently, set out to investigate whether or not Downs' mean measurements and ranges applied to the Negro, Japanese, and Chinese of American ancestry. Their findings are tabulated on Table IV along with Downs' for the white American and Craven's Australian Aboriginal in comparison to findings on the Hawaiian. It might be noted that the Aboriginal and Hawaiian samples did not possess "excellent occlusions" or necessarily "normal occlusions" as did the other four ethnic groups.

Steiner

Although Steiner's analysis was basically designed as a clinical tool for the practicing orthodontist, it has been a definitive analysis as to facial profile and denture and hence has been used extensively is describing denture and facial patterns among various ethnic groups. Steiner's measurements for the white American "average norm" along with measurements of Japanese children by Miura, Inoue, and Suzuki[13] serve as a comparison for the Hawaiian.

Tweed

The Tweed triangle, basically a clinical tool, was constructed to give information about the inclination of the lower incisors, the FMA, the FMIA, and their relationships to good facial esthetics as advocated by Tweed.

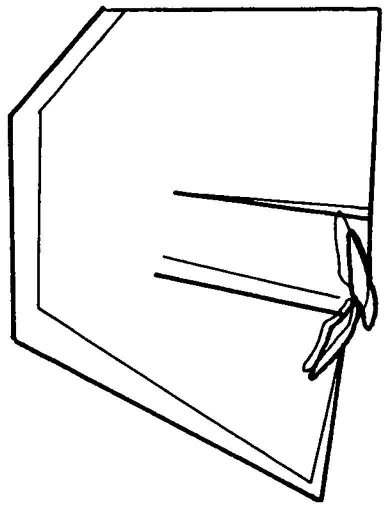

Fig. 1 Hawaiian, male, heavy line; female, light line.

Comparisons With Other Groups

The findings of this investigation will be discussed as they pertain to each of the four cephalometric analyses.

BJÖRK

Hawaiian Male with Hawaiian Female

Comparing the polygons, using Figure 1, the immediate and obvious difference is the size of each. The male is considerably larger; the length of the male cranial base is longer in all dimensions; the anterior and posterior cranial bases of the male each exceeds the female by 5 mm.

Angular differences are also noted. The saddle angle, the joint angle, and the jaw angle are all more obtuse in the female than in the male. This has a tendency to first, lengthen the cranial base; second, retract the ramus to a more posterior position; and third, move the chin point inferiorly. Thus,

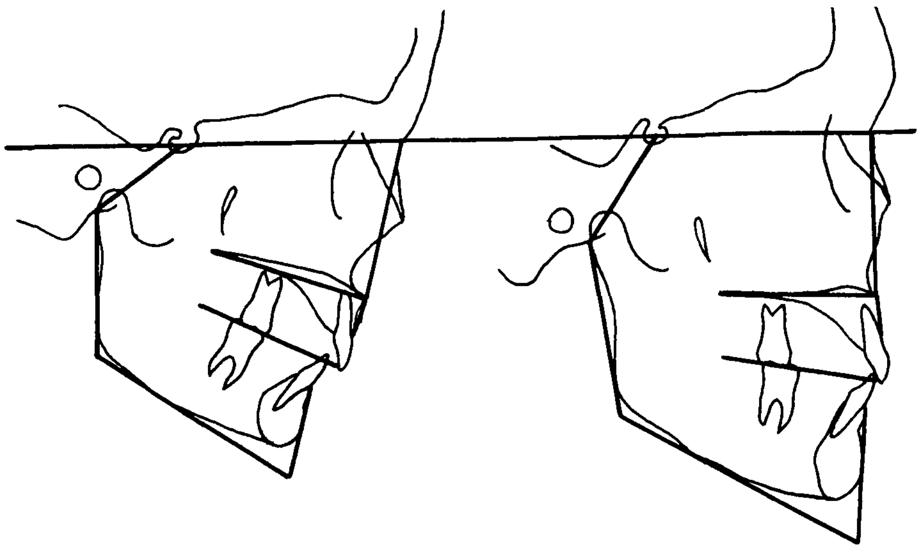

Fig. 2 Left, minimum facial prognathism; right, maximum facial prognathism.

the mandibular plane to SN is more obtuse in the female than in the male. The chin angle of the female is more acute than in the male and thus, tends to prevent undue labial positioning of the mandibular incisors.

The flatter saddle angle of the Hawaiian female corresponds with Craven's findings on the Aboriginal female, and Cameron's findings on the white American female and the American Negro female[5] when compared with the male of their respective ethnic groups. This difference can hence be regarded as a sex difference.

In degree of facial prognathism the Hawaiian male exceeded the Hawaiian female in alveolar prognathism of both jaws. The maxillary basal prognathism was basically the same for both sexes but, again, the male exhibited more mandibular basal prognathism.

Employing the standard deviation as an index of variability, the axial position of the mandibular incisors of the female and the total face height (Na-Me) of the male were found most variable. The chin angle, jaw angle, and joint angle were next most variable and fairly much in that order for both male and female. Other mandibular variations, the ramus height and corpus length, of the male showed wide variance. Least variable was overbite and overjet relation.

Intraracial variations in degree of alveolar and basal prognathism, while not as pronounced as in the Swede sample, occurred in the Hawaiian. It is felt that a larger sample might have produced more diverse variations. Figures 2 and 3 illustrate the maximum and minimum facial prognathism of this Hawaiian series.

To eliminate confusion, the Hawaiian mean shall henceforth be referred to simply as the Hawaiian mean or the Hawaiian, and the Hawaiian male to female shall be designated by sex.

Swede with Hawaiian

In order to make a fair comparison the adult Swede male was compared with the Hawaiian mean and the Hawaiian male as well. As both were adult males, the comparison is meaningful. The Hawaiian male showed up much larger in all dimensions except total face

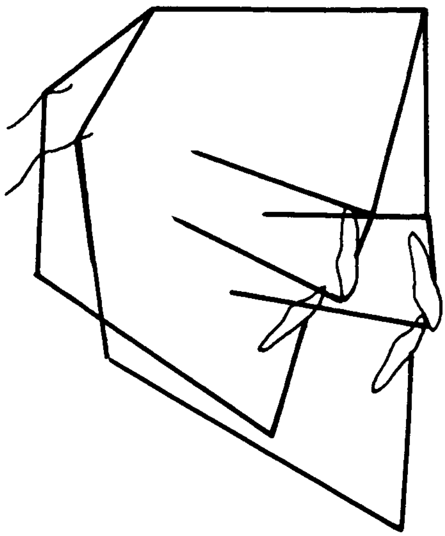

Fig. 3 Maximum and minimum facial prognathism; superimposition is on S-Na at Na.

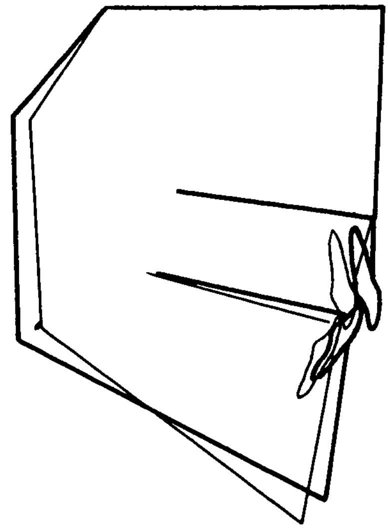

Fig. 4 Hawaiian male, heavy line; Swedish male, light line.

height. The Hawaiian male polygon was larger than all polygons compared in most dimensions (Fig. 4). The Hawaiian mean polygon was approximately the same size as the Swede polygon with differences being primarily in the saddle angle, jaw angle, and chin angle. The saddle angle and chin angle of the Swede were more acute, while the jaw angle was less acute than in the Hawaiian. The SNAns angle was almost identical in the Swede and the Hawaiian. Teeth were more recessed in the Swede. Of interest was the fact that the cranial bases of the Hawaiian mean and the Hawaiian male were longer than that of the Swede.

In the discussion of prognathism, the maxillary basal prognathism of the Hawaiian and the Swede were about the same, but in maxillary alveolar prognathism, mandibular alveolar prognathism, and mandibular basal prognathism, the Hawaiian exceeded the Swede.

Again employing the standard deviation as an index of variability, the Swedish male was found most variable in the axial position of the mandibular incisors as was the case in the Hawaiian female and the Hawaiian mean (Table II). In descending order, the Swede was next most variable in the jaw angle, the joint angle, facial height, maxillary incisor inclination, the chin angle, and the saddle angle. The overbite and overjet were the most constant, corresponding with the Hawaiian.

Bantu to Hawaiian

The adult Bantu male when compared with the adult Hawaiian male has a smaller polygon (Fig. 5). When compared with the Hawaiian mean polygon it is approximately the same size and shows similarities at the saddle angle and the mandibular plane to SNa. The SNAns angle, the joint angle, and the chin angle of the Bantu were all more obtuse than that of the Hawaiian. The jaw angle was less obtuse than in the Hawaiian.

Of interest were similarities. The lengths of the cranial bases, maxillary and mandibular corpus lengths, maxillary and mandibular dental heights, and

UNIT	DESCRIPTION OF MEASUREMENTS	LANDMARKS	HAWAIIAN ADULT (43) MEAN	HAWAIIAN ADULT (43) S.D.	SWEDE ADULT (281) MEAN	SWEDE ADULT (281) S.D.	ABORIGINAL ADOLESCENT (29) MEAN	ABORIGINAL ADOLESCENT (29) S.D.
degrees	1. Upper Jaw: Basal Prognathism	S-Na-Ans	87.02	3.66	88.16	4.18	86.84	4.44
	2. Upper Jaw: Alveolar "	S-Na-Pr	86.73	3.99	84.83	4.13	92.24	3.86
	3. Lower Jaw: Alveolar "	S-Na-Id	82.16	3.45	82.25	4.37	88.68	3.58
	4. Lower Jaw: Basal "	S-Na-Pog	81.30	3.63	81.69	4.43	83.00	3.73
	5. $\underline{1}$ Axis	$\underline{1}$ to Occl Pl	67.39	6.92	64.00	6.62		
	6. $\overline{1}$ Axis	$\overline{1}$ to Occl Pl	67.23	8.71	73.59	7.89		
	7. Saddle Angle	Na-S-Ar	131.12	5.07	123.06	5.33	119.82	4.67
	8. Joint Angle	S-Ar-Go	139.75	6.61	143.27	6.91	148.33	8.66
	9. Jaw Angle	Ar-Go-Mand Pl	120.81	6.69	130.85	7.31	122.08	7.26
	10. Chin Angle	Id-Pog-Mand Pl	70.01	7.94	64.24	6.43	88.00	5.79
mm	11. Cranial Base Length	Ar-Na	98.79	7.89	98.09	4.42		
	12. Cranial Base, Horizontal part	S-Na (SN)	69.87	4.12	73.22	3.26	63.93	2.77
	13. Cranial Base, Vertical part	Ar-S	36.59	4.13	37.02	3.32		
	14. Ramus Height	Ar-Go	54.66	6.92	53.23	5.15		
	15. Corpus Length	Go-Pog	88.41	7.87	80.66	5.16		
	16. Facial Height	Na-Me	119.72	8.41	128.28	6.66		
	17. Length of Upper Jaw	Ans-Pns	52.72	3.23	56.82	3.16		
	18. Ratio Upper Jaw to Lower Jaw	Ans-Pns/Go-Pog	.587					
degrees	19. Inclination of Occlusal Plane	Na-Ar-Occl Pl	30.56	3.83	34.82	4.44		
	20. $\underline{6}$ Angle	Na-Ar-$\underline{6}$	50.27	3.26	47.81	2.93		
	21. $\overline{6}$ Angle	Na-Ar-$\overline{6}$	51.51	3.43	49.51	3.58		
mm	22. Length of Upper Dental Arch	is to $\underline{6}$	27.43	3.23	28.02	2.94		
	23. Length of Lower Dental Arch	ii to $\overline{6}$	21.70	2.90	22.72	2.43		
degrees	24. Difference in Alveolar Prognathism	Pr-Na-Id	4.89	1.58	2.60	2.30		
	25. Difference in Basal Prognathism	Ans-Na-Pog	6.12	3.05	6.50	4.00		
	26. Maxillary Prognathism	S-Na-A (SNA)	84.94	3.66	82.00	3.60		
	27. Mandibular Prognathism	S-Na-B (SNB)	80.15	3.61	79.30	3.70		
	28. Difference Max. Mand. Prognathism	A-Na-B (ANB)	4.80	2.24	2.70	2.60		
	29. AB Plane to Occlusal Plane	Inf Post Angle	88.27	3.43	91.50	4.60		
mm	30. Overjet	is-io	3.70	1.92	3.40	2.30		
	31. Overbite	ii-io	2.16	2.27	2.10	1.90		
	32. Maxillary Jaw Height	Na-Ans	53.67	3.57				
	33. Maxillary Dental Height	Na-Pr	70.20	4.76				
	34. Mandibular Dental Height	Gn (Polygon)-Id	41.17	5.88				

Table II

ramus heights were similar in the Bantu and the Hawaiian means.

In comparison of facial prognathism, the Bantu exceeded the Hawaiian in three categories. In these the degree was markedly greater. The Hawaiian only exceeded in mandibular basal prognathism by virtue of the well-developed chin. This lack of chin in the Bantu accentuated his alveolar prognathism.

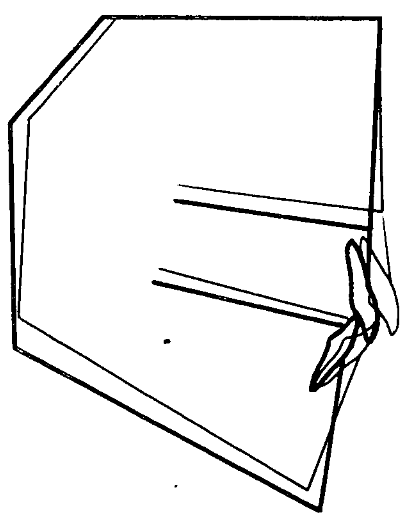

Fig. 5 Hawaiian male, heavy line; adult Bantu male, light line.

Aboriginal Adolescent to Hawaiian

While the ages of the samples of these two groups cannot be compared favorably, the angles of the polygons readily show that the Aboriginal has a short posterior cranial base and that the saddle angle is more acute than in the Hawaiian. The joint angle and the chin angle are more obtuse, while the jaw angle is less obtuse than in the Hawaiian. Of note is the obtuse degree in which the chin angle swings the alveolar process of the mandible forward, recessing the chin and accentuating the alveolar prognathism (Table II).

A few comparisons were available as to standard deviation as an index to variability. In order of variability they were the joint angle, the jaw angle, the chin angle, and the saddle angle.

Swede, Bantu, Aboriginal, and Hawaiian

While the racial differences set apart these various groups, the similarities can

Value	AMERICAN WHITES	AMERICAN NEGROES	AMERICAN CHINESE	NISEI	AUSTRALIAN ABORIGINAL	HAWAIIAN
Facial Angle (NP to FH)	87.9 82 to 95	87.25 80 to 91	77.5 73 to 89	88.25 83 to 94	91.5 87 to 100	90.69 83 to 99.5
Angle of Convexity (NA to AP)	0.0 +10 to -8.5	+9.6 +4 to +20	+7.5 +1.5 to +14	3.65 +12 to -1	+8.4 0 to 17.5	+9.15 +19 to -1.5
AB Plane to Facial Plane (AB to NP)	-4.7 0 to -9	-7.7 -3 to -15	-5.7 -2 to -10	-4.35 -1 to -7	-2.65 -9 to +2	-7.21 +1 to -12
Mandibular Plane Angle (Mand to FH)	21.9 17 to 28	27.25 17 to 35	32.4 22 to 44	24.3 14 to 33	21.9 9 to 31	18.9 10.5 to 33.5
Y Axis (SGn to FH)	59.3 53 to 66	63.3 57 to 69	67.1 59 to 75	62.1 56 to 68	54.5 45 to 61	61.26 51 to 73.5
Cant of Occlusal Plane (Occl to FH)	9.2 1.5 to 14	11.8 +8 to +17	+16.9 +8 to +25	9.65 2 to 19	7.2 -1 to +12.5	4.74 -6 to +11.5
$\underline{1}$ to $\overline{1}$ Angle (Interincisal)	135.4 130 to 150.5	123.0 105 to 144	120.8 105 to 137	126.4 114 to 152	114.5 100.5 to -129.5	133.73 106 to 166
$\overline{1}$ to Occlusal Plane	14.5 3.5 to 20	22.5 12 to 35	22.2 13 to 29	21.5 8 to 31	29.1 21.5 to 40	23.51 7 to 36
$\overline{1}$ to Mandibular Plane	1.5 -8.5 to +7	+6.6 -3.5 to +22	+7.8 0.0 to +18	+6.55 -6 to +13	+14.1 +1.5 to +31	8.96 -7.5 to +30.5
$\underline{1}$ to AP Plane (mm)	3.1 -1 to 5	8.5 6 to 11	7.6 3 to 12	6.6 2 to 10	10.9 2 to 14	5.47 -1 to +12

Table III

be pointed out as the posterior cranial base length, ramus height, corpus length of jaws, and mandibular plane to SNa (except in the Swede). The Australian Aboriginal can only be compared in angular measurements.

The Hawaiian, Bantu and Swede had similar cranial base lengths although the Swede had a more acute saddle angle. The Aboriginal had the most acute saddle angle of all measured and hence would be considered to have the shortest base in spite of the age difference.

Björk found that the saddle angle was more acute in the prognathic individual. When this happened, the palatal, occlusal, and mandibular planes became more parallel to SNa than in less prognathic individuals. This finding was confirmed by this investigator and is graphically shown in Figures 2 and 3.

Of the groups compared, the Swede was on one end of the scale of facial prognathism while the Aboriginal was on the other extreme. The Hawaiian more closely resembled the Swede than the other two.

DOWNS

White American to Hawaiian

When comparing these two groups, it is well to keep in mind that the Hawaiian did not, in this series, possess normal occlusions, much less excellent occlusions. In fact, some 23.3% were Class II malocclusions.

Using Table III, we find that all Hawaiian measurements fell within the Downs' range except for the position of the mandibular incisors in relation to the mandibular and occlusal planes, and the $\underline{1}$ to AP.

The mandibular and the occlusal planes of the Hawaiian were extremely flat, much more so than in the white American or any other ethnic group measured. This was due to the squarish jaws and increased vertical height of the ramus of the mandible.

A partial explanation as to the inclination of the mandibular incisors was that 23.3% of this series were in Class II molar relationships. With this Class II relation and extremely erect maxillary incisors, the tendency was for the mandibular incisors to incline forward to meet the opposing incisors. This type of compensation is noted in

Steiner's series[17] which shows that, when the maxillary incisors become more erect, the mandibular incisors compensate by being more inclined.

The angle of convexity was considerably greater than in the white American, but again this was explained by the fact that the Class II relation exhibits either a more prominent maxilla or a retruded mandible, thus creating a larger angle.

In general, the Hawaiian had a good facial pattern and only the presence of malocclusions prevented more of these measurements from falling within Downs' white American range.

In Table III various ethnic groups were compared to each Downs value. To facilitate description, the samples shall be described as Negro, Japanese, Chinese, White, Aboriginal, and Hawaiian.

1. The facial angle of the Hawaiian falls into the range of Downs as do those of all other ethnic groups except the Chinese; the Chinese has a much smaller angle.

2. The angle of convexity of the Hawaiian, while great, has been explained above. However (like the random sample of the Aboriginal), the Hawaiian group was not a Class I series, and hence was considered not to be convex as the Negro or the Chinese. The Aboriginal possessed a large angle also, while the Japanese, next to the White, was least convex.

3. The AB to facial plane angle is on the high range for the Hawaiian and again is explained by the Class II jaw relation. The Negro, with a Class I jaw relation, has the highest measurement while the Aboriginal has the lowest, even lower than the Japanese and the White.

4. The mandibular plane angle is very flat in the Hawaiian as explained —the flattest of the group. The largest angle is that of the Chinese, followed in order by the Negro and the Japanese. The White and Aboriginal have the same angle, both being flat.

5. The Y axis of the Hawaiian is in the middle of the group, very close to the White standard. High end of the range is the Chinese, followed by the Negro and the Japanese. The very lowest range was that of the Aboriginal.

6. The occlusal plane of the Hawaiian, as explained, is very flat, and is the flattest of the group. The Chinese is on the high end of the group, followed by the Negro, Japanese, White and Aboriginal.

7. The interincisal angle of the Hawaiian is very large and second only to the White. Exhibiting erect maxillary incisors and the greater inclination of the mandibular incisors, it easily falls within Downs' range. The White possesses the largest angle and exhibits very erect incisors. In distant third position comes the Japanese, followed by the Negro and the Chinese. At the very low end of the scale and very much in bimaxillary protrusion is the Aboriginal.

8. The $\overline{1}$ to occlusal plane angle, showing mandibular incisor inclination, finds the Aboriginal mandibular incisors much more inclined forward than the rest of the group. He is followed by the Hawaiian, Negro, Chinese, and Japanese in that order. At a considerable range away, we find the White.

9. The $\overline{1}$ to mandibular plane angle is also an index of mandibular incisor inclination and, as such, the results are much the same as the above angle except that the Chinese has traded positions with the Negro. The rest of the order remains the same.

10. The $\underline{1}$ to AP plane, measured in millimeters, finds the Hawaiian on the lower end of the group, only slightly more prominent than the White. Again, the Aboriginal is the most protrusive and is followed in order by the Negro, Chinese, and Japanese. As mentioned

above, the Hawaiian has very erect maxillary incisors.

The general impression is that the Hawaiian face is quite similar to the White face in many respects, but with significant differences. The Japanese follows the Hawaiian in degree of flatness of face. On the other extreme and apparently a bimaxillary protrusion genetically, the Aboriginal is the most protrusive. He is followed in protrusive qualities by the Negro, a distant second. The Chinese follows the Negro in this regard.

Comparative studies of the Hawaiian male and Hawaiian female with the Downs values reveals the male has a more square jaw and hence flatter occlusal and mandibular planes. The mandibular incisors of the male exhibit greater axial inclination than in the female. Other values show slight deviations.

An interesting observation of the ethnic groups was that Takano chose his sample with greater selectivity than either Cotton or Wong, and his group showed considerable flatness over the other two. This may have been a coincidence or ethnically correct, but it is felt that this type of selection will bring out unusual rather than average balance of face and denture. Therefore, comparison of relatively unselected material with selected material presents unfair, but nevertheless interesting, results. Under these conditions a carefully selected Hawaiian sample would have been of greater comparative value over a random sample such as ours.

STEINER

Comparing measurements of Steiner's norm for White Americans,[17] and the Japanese Steiner mean of Miura et al.[13] to the Hawaiian Steiner measurements, we again find the disparity of sample. As explained, 23.3% of our series were in Class II molar relationship. This will definitely increase the ANB angle. Notwithstanding, the measurements recorded are meaningful and most interesting. Using the Steiner type of "chevron" formula for easy reading and comparison, Steiner's norm, acceptable compromises of his norm, and the Japanese and Hawaiian means are listed in Table IV. The numerical tables of Steiner values are also listed.

Using the Steiner norm and acceptable compromises as standards, there is considerable similarity in incisal positions of the Hawaiian at ANB 4.8°, the mean for the Hawaiian. This Hawaiian series, in spite of the Class II cases that were included, is approximately within one mm of matching the White norm in linear incisal positions in relation to lines NA and NB. The inclinations of the incisors are within normal range when measured to NA and NB, with the maxillary incisor being more erect than in Steiner's norm. In contrast, the Japanese mean, a Class I by selection, has procumbent incisors and an imbalance in alveolar base relation to the extent of having an ANB angle of 4.5°. Using the American concept of bimaxillary protrusion, the Japanese mean may be so classed, not so with the Hawaiian.

Steiner, in recent years, has come to realize that all races and facial types cannot be treated to his White norm. Thus, he has recommended what is known as "individualizing the formula." This is often done by positioning incisors forward. If the maxillary and mandibular incisors of the Steiner's acceptable compromise for Whites at ANB 4° were relocated forward one millimeter, the Japanese would still be more protrusive than the acceptable compromise for that ANB angle. The Hawaiian would be very close to the acceptable compromise.

Comparing the Hawaiian male with the Hawaiian female in the Steiner analysis, the male has a greater ANB

			AMERICAN WHITE "Average Normal"	JAPANESE (90)	HAWAIIAN (43)
1.	SNA	(angle)	82	81.3	84.95
2.	SNB	(angle)	80	76.8	80.15
3.	ANB	(angle)	2	4.5	4.80
4.	SND	(angle)	76	73.4	76.89
5.	$\underline{1}$ to NA	(mm)	4	5.9	3.49
6.	$\underline{1}$ to NA	(angle)	22	24.1	13.55
7.	$\overline{1}$ to NB	(mm)	4	7.8	5.69
8.	$\overline{1}$ to NB	(angle)	25	31.2	28.67
9.	Pog-NB	(mm)		0.43	0.97
10.	$\underline{1}$ to $\overline{1}$	(angle)	131	120.3	133.73
11.	Occl-SN	(angle)	14	20.0	14.77
12.	GoGn-SN	(angle)	32	36.2	28.93
13.	SL	(mm)	51	41.1	52.64
14.	SE	(mm)	22	21.0	24.19

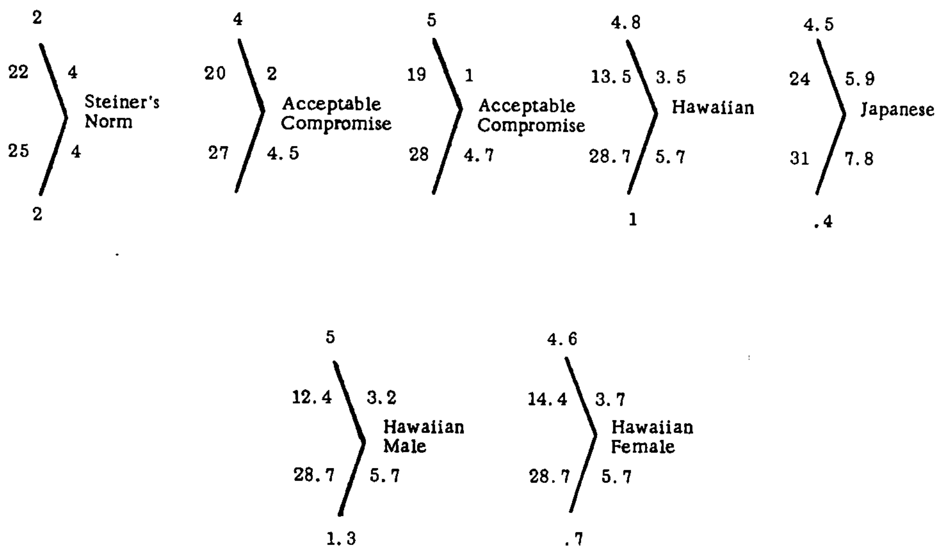

Table IV

angle. While the difference is less than a degree, it shows that the male has a greater imbalance of bony jaw bases, to one another. The incisal positions are quite similar but the development of the chinpoint of the male far exceeds the female. This may perhaps be a sex difference as there is considerable more development of the glabella in the male. There is a level of significance in the length of SL, the male being larger by 6.4 mm.

SL is on the short side for the Japanese. Of course, age must be taken into consideration, but in relation to White children of the same age, SL is short. This dimension is well developed on both sexes of the Hawaiian. Line SE is quite similar in the White and the Japanese, but is greater in the Hawaiian male, female, and the mean of them.

Because of the erect maxillary incisors, A point is far forward and gives the Hawaiian a large SNA angle which exceeds the White by three degrees and the Japanese by four. The interincisal angle of the Hawaiian exceeds Steiner's norm by three degrees and, of course, the Japanese by thirteen. This again is primarily due to the upright maxillary incisors.

The basic difference among the White, Japanese, and Hawaiian is that the Japanese have a large ANB angle. The Japanese have protrusive incisors in comparison with the White and the Hawaiian, both in angulation and linearly beyond lines NA and NB. The Hawaiian is only slightly more protrusive than the norm of Steiner. Their mandibles are square and register a low GoGn to SN angle as related to the White and the Japanese.

While no effort has been made to establish a norm for the Hawaiian, it is significant that the Hawaiian "norm" should be rather close to that of Steiner's White norm. It is most significant that, through the use of the Steiner charts and formulas, much definitive information is given as to the position of teeth, jaws, and supporting structures with relatively few measurements. It is also pertinent that the anatomical structures and planes used are more stable and easier to locate than in the other analyses used in this investigation. The two planes that are significantly used to advantage are SN and GoGn. These are contrasted to the Frankfort horizontal and mandibular planes; the latter were most difficult to locate on the Hawaiian sample.

In short, while the Steiner analysis was not designed as a research tool, its practical value cannot be overlooked, even for an investigation such as this. In the opinion of this investigator, the inherent errors in this analysis were less than in the other analyses used in this study.

TWEED

In this discussion of the Tweed Triangle,[22] the concept of Tweed must be understood. He favors a small FMA, 20° to 30°, 25° being the median, but the lesser being more favorable than the greater. If FMA exceeds 30 degrees, treatment to a good profile becomes less favorable. The IMPA should range between 85° and 95°, the median being 90°. For the FMIA, an angle of 65° is optimum, but the direction of deviation is important. Tweed favors a larger angle or toward 70° rather than toward 60°.

The following measurements were obtained from the Hawaiian sample to construct the Tweed Triangle:

Angle	*Hawaiian Male*	*Hawaiian Female*
FMA	18.72	19.23
FMIA	60.75	62.34
IMPA	100.72	98.34

While the mandibular incisor (IMPA) is about five degrees beyond Tweed's range, it is not excessive. As noted, the forward tipping is more evident on the male than on the female. This forward inclination of the mandibular incisors confirms the findings of the other analyses.

The FMA is on the low side of the range, but it is on this smaller angle or low side that Tweed prefers the deviation. The small FMA usually denotes good mandibular development, usually in ramus height.

The FMIA falls short of the 65° ideal, but not to a great extent. Note that the female has a greater FMIA than does the male. This denotes more erect mandibular incisors than in the male.

In the comparisons listed above, it is evident that the Hawaiian female has a better Tweed pattern than the Hawaiian male; the Hawaiian face almost falls within the range of acceptability of Tweed.

The concept of flat faces advocated by Tweed may hold true for the white American children of his practice, but it is doubtful that this should be the standard of all ethnic groups. The Hawaiian, the least protrusive of all nonwhite groups in this investigation, still fell outside of Tweed's ideal range.

However, the general growth pattern and development of the Hawaiian was favorable in terms of good treatment prognosis.

In recent years Tweed has favored the use of the ANB angle in his analysis. In this regard he agrees with Steiner that 2° is a good standard. The ANB angle of the Hawaiian of this study averaged 4.8°. Considering the number of Class II malocclusions included in the series, this angle is not large. This further fortifies our thoughts that the Hawaiian possesses a balanced face with good development of jaws and teeth.

Inherent errors in this method of assessment are in the location of the Frankfort horizontal and the mandibular plane. The latter was most difficult to locate because of the presence of "rocker jaws" in the series. Advantages of this analysis are in the rapidity that measurements of clinical significance can be made.

Analytical Discussion

The use of the Björk polygon as a visual study of facial form partially predicates the acceptance of Björk's cranial bases and his concepts of facial prognathism. The use of the polygon is to be commended as it concentrates on the deviations of six sides and five angles which have a direct bearing on facial form. There are many other measurements of importance among which are the measurements for alveolar prognathism, the occlusal and palatal planes, and the inclination of the incisors. In short, the Björk analysis is more of a research tool than one for clinical evaluation although he explains its application on clinical material.

The Downs' analysis is used as a clinical assessment of facial form because of its proven merit and its relative simplicity. However, the multiplicity of lines and angles, especially in the anterior areas of the jaw bases detracts from its simplicity and often creates confusion, especially in flat faces. Downs' norm, while excellent in most respects, leaves no visual image.

As means and ranges have been established for norms of white Americans as well as for other ethnic groups, the Downs' analysis serves as a useful tool for those wishing to compare sample to norms of excellent facial and occlusal balance.

The Steiner analysis is simple, yet it positively describes positions of jaws and teeth in relation to cranial base. Steiner's norm is a visual concept which is reduced to a chevron formula which describes the most significant measurements. There are various formulas for various changes in alveolar base relationships (ANB), and thus, a sample can be quickly compared with this norm or acceptable compromises of the norm.

The Tweed triangle used in this investigation served the purpose of a check for facial balance as seen through the eyes of Tweed. It is felt that the few measurements provided inadequate information as to the morphology of the face and dental pattern for a definitive survey.

The importance of measurement accuracy cannot be overstressed. Although a constant effort was made to control measurement procedures and tabulation, it is felt that the chain of events in securing these measurements left many avenues open for error.

First, the jaws were secured in centric occlusion. This was usually accurate if the occlusions were "ground in," but difficult if they were not.

Second, positioning skulls in the cephalostat provided no real problem unless the skulls were defective.

Third, taking and processing of head films, while routine, was important in producing the correct density for proper reading and measurement.

Fourth, tracing and measuring films provided the greatest sources of error. Most important were the location and interpretation of various landmarks and planes by the investigator. Two series of tracings were completed to cross-check for errors. The final tracings and measurements were completed by one individual for the entire series. Thus it was felt that the errors in planes or landmarks, if any, were repeated throughout the series and served to cancel themselves out. Linear measurements were made to the closest one-half millimeter, and angles to the closest one-half degree.

The mandibular plane was found less consistent than the GoGn plane. What and where is the mandibular plane? Locating it on a sample, especially in cases of "rocker jaws," is often difficult. Of the four analyses investigated, only Steiner used the GoGn plane, a plane drawn between two points and not tangent to any line or border.

Other measurements were less variable although point A and positions of individual teeth posed formidable challenges. To standardize tracings, a tracing template was used on all teeth. This procedure produced tracings of uniform quality and reasonable accuracy.

Conclusions

1. The Hawaiian, a Polynesian, has a craniofacial structure similar to that of the White groups of this study. Of all the non-white ethnic groups the Hawaiian was found to be least protrusive. These included the Bantu of Africa, the Australian Aboriginal, the American Negro, the American Japanese, the American Chinese, and the Japanese. The Hawaiian exhibited greater alveolar prognathism than did members of the White groups of this study.
2. The Hawaiian male has a large craniofacial structure and a long cranial base. The jaws are large and well developed with a well-defined chin. The Hawaiian female is a smaller individual with less alveolar prognathism and less chin development than the male. The chinpoint of the Hawaiian was prominent to the extent that it exceeded all groups compared by facial polygons.
3. The Hawaiian records very flat mandibular and occlusal planes, even more so than in the White groups compared in this study. This is attributed to excellent development of ramus height of the mandible.
4. The maxillary incisors of the Hawaiian are very erect while the mandibular incisors are more labially inclined. This erect maxillary incisor position exceeded that of all groups compared in this study.
5. The Hawaiian female exhibits a larger saddle angle than does the male. This tendency is also noted for females of other ethnic groups when compared to the male and is believed to be a sex difference.
6. Variations of facial prognathism of individual Hawaiians are of the same nature as reported by Björk in the Swede and Bantu.
7. Björk observed that while the degree of facial prognathism may be similar among differing ethnic groups, the nature of facial prognathism varies. This was apparent in the relation of the Hawaiian to other ethnic groups.
8. Employing the standard of deviation as an index of variability, the axial position of the mandibular incisor to the occlusal plane and the facial height of the Hawaiian were found to be most variable.

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