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VOLUME XXX, PART I

A CORRECTION FOR ARTIFICIAL DEFORMATION OF SKULLS

BY H. L. SHAPIRO

BY ORDER OF THE TRUSTEES
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CONTENTS

Introduction

An attempt to formulate a statistical correction for deformed crania needs no apology. Physical anthropologists dealing with American Indian material are fully aware of the difficulties involved in establishing racial affiliations for great groups of aborigines in areas where artificial deformation was generally practised. The modification of the shape and proportions of the cranial vault and parts of the face under artificial deformation are so radical that, with justification, most investigators dealing with deformed crania have eliminated them because of their patently distorted character. This custom of moulding the head was so nearly universal in some areas, notably Peru, that in the great cranial collections of Peruvian material all but a pitifully small and inadequate number are deformed. This condition is not confined to Peru alone but obtains for other areas equally as important. Consequently, there are vast stretches on the anthropological maps of the Americas which must be labeled unknown because of the mass of valuable material which is locked away under the caption "deformed."

We have advanced but little in our technique of dealing with deformed crania. The literature on deformation is extensive, but, as far as I am aware, there is no successful attempt at recovering the normal craniometric values. Sullivan (1922) sought to surmount the obstacle by a study of anatomical variations, but this was not wholly successful.

This paper is concerned with a method of correction for deformation. That is to say, I have attempted, by means of statistical methods, to secure formulæ which, when applied to the means of series of deformed crania, will establish the principal diameters of the hypothetical cranial vault had the crania not been deformed. However, I make no effort to go beyond correcting for maximum head length, maximum head width, and basio-bregmatic height, principally because at the moment I am more concerned with the method than its complete application.

The material which I have used consists of over ninety series of presumably normal crania from all parts of the world. The only selection is that forced upon all such investigations, namely on the basis of adequacy of numbers in the individual groups and whether certain mean values were given by the respective authors. Wherever I was aware of artificial deformation in a series, even to a very slight degree, I excluded it from the material with which I was dealing. The data are exclusively based on males. A complete list of the groups will be found in Table 17, pp. 32–35.

Distribution of Deformation

Artificial deformation is worldwide in its distribution. The maximum occurrence, however, is in America. In Peru deformation luxuriated, and most of the varieties of deformation exist there. From Peru as a center, deformation is distributed throughout the adjacent areas of northern Chile, northwestern Argentine, Ecuador, and Colombia. In Middle America deformation is pictured in the representations of the Maya, and, on the whole, it seems clear that deformation was practised by them.[1] Deformation was also in vogue among restricted Mexican groups. Southwestern United States is also an area of much artificial deformation. Apparently in the older strata of the Southwest, among the Basket Makers, deformation was unknown, but its occurrence is frequent among the Cliff Dwellers and modern Pueblo Indians. The nomadic Apache and Navajo also practise deformation. Other centers in North America are the lower Mississippi Valley, Florida, the Mound Area, and among the modern Mohave, Yuma, and Northwest Coast tribes.

Another area of deformation exists in Oceania. It occurs in New Britain, New Caledonia, and New Hebrides, with outliers in Indonesia (Celebes, Borneo, and Mindanao).

Deformation is likewise known in Asia Minor, in Trans-Caucasus, Armenia, and among the Kurd and Juruk; also in Central Africa among the Monbuttu (Mangbatu) and in India (Punjab).

In Europe deformation is found among the modern population as a remnant of an older widespread custom. Broca described it among the Toulousaines and said that it was still fairly common among the people of Haute–Garonne and Aude of the Midi in France, also in Deux-Sèvres and Seine-Inférieure. These deformations are accidental and due to coiffures which produced the type sometimes called annular constriction. Delisle mentions deformation among the people of Limousin, Normandy, and Brittany and Bolk states that it is found among the Dutch of Holland (Marken Island).

In early historic and prehistoric times deformation was rather widely spread throughout Europe. It has been described among the early Alamannen, West Germans, Burgundians (Avars), and in graves of Roman date; also in lower Austria, Hungary, and Switzerland; and in England, Italy, Crimea in Russia, and in the Caucasus (Kertsch and Samthravo).

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[1]Spinden, 1913, 23-24.
It should be noted that the skulls from the sacred cenote at Chichen Itza are mostly deformed. (Personal communication from Doctor E. A. Hooton.)

Classification

Most of the early work on deformation was concerned almost exclusively with the classification and definition of the various types of deformation. Many of the systems were extremely detailed and fine. Gosse described sixteen separate classes. The more recent tendency is to ignore the finer distinctions, which are due to differences in pressure, variations in the mechanism of deformation, and duration of the process, and to group the phenomena which are listed under artificial deformation in fewer and more inclusive divisions. This gives a truer picture from the ethnic viewpoint since it eliminates the accidental and fortuitous variations which have no part in the ethnic relationships and general methods employed. Another change in the method of classification is the greater emphasis placed upon the method and mechanism used rather than the result produced. From the above, it is obvious that this is the better method for the analysis of the spread of the various types of deformation.

The crania which are classed as artificially deformed range from those so slightly affected as to escape notice to forms which are startlingly fantastic. The methods of deformation vary similarly from simple cradleboard and bandages to elaborate machines which have all the diabolical appearance of medieval instruments of torture.

As generally accepted at the present time, the various types of deformation may be divided into the following classes:—

1. Simple occipital. This may be the result of accidental flattening caused by the pressure of the infant's head against a cradleboard. Conscious pressure, however, is frequently used to flatten the occiput. The area of flattening varies considerably from the most posterior part of the occipital bone to the area at lambda or even slightly above. Whether or not a more or less marked lambdoid flattening occurs naturally is a debated point, but there can be no doubt that in many groups its origin is artificial.

2. Fronto-occipital. In this type of deformation pressure is exerted in two planes, the frontal and occipital. Some writers speak of an "active" and "passive" pressure, but this appears to be an over refinement of terms, since it is difficult to conceive of one pressure as active and the other as passive. Here, as for occipital deformation, the range of deformation is great, but there is no doubt that all crania which are grouped in this category must be considered as the result of conscious artifice. The area of flattening varies, especially in the occiput, where it

may be rather high up covering lambda and the adjacent parietal region. These differences are difficult to evaluate since in most cases we have no information in regard to the exact method of moulding the head.

3. Annular. This type is best exemplified in the Aymara deformation. It is not strictly a simple frontal deformation, although the deformation is most obvious in this region. The occiput appears pulled upwards and backwards as the result of circular bandages which, passing over the frontal bone, are carried across the temporals and the occipital. The pressure is therefore circular. Frequently there is a marked post-coronal depression. Whether or not boards were also used is uncertain.

4. Miscellaneous forms of deformation include "Toulousaine" which is produced by a coif which leaves a transverse depression. Other variant forms are difficult to classify and may be mainly aberrant and individual variations.

The Effects of Deformation

The practice of deforming the cranium may be the result of a conscious attempt to emphasize an ethnic conception of beauty or may be merely the carrying out of a tradition. But whether intentional or unintentional the net result is the same in a definite directing and inhibiting of growth. The essence of deformation is the fact that growth is inhibited in one direction with compensatory growth in another, thus shortening or increasing the gross diameters of the cranium. Obviously the degree to which the cranium is transformed depends on the type of deformation and the pressure exerted in the process of deformation. Unfortunately, there are only a few investigations on the changes which take place as the result of deformation, and for the most part our conclusions regarding these changes are speculative, since rarely is such a comparison carried out with due comparative insight and control. Martin (1914) estimates that under simple occipital deformation the maximum cranial length is shortened by from 5 to 30 mm., the breadth increased up to 20 mm., and the height increased up to a maximum of 15 mm. Other changes in the skull are the reduction of the orbits in the sagittal plane, a narrowing of the fissuræ orbitales, superior and inferior. Especially common in occipitally and fronto-occipitally deformed skulls is the antero-posterior shortening of the meatus acusticus externus. Exostoses which frequently occur bilaterally in the auditorium meatus are quite common in such skulls. Oetteking (1924) believes that deformation affects the declination of the pars basilaris. There are other modifications of the cranium which are correlated with various types of deformation.

The facial parts of the cranium are relatively less influenced by deformation than the cranial vault. However, it seems likely that the bizygomatic, minimum frontal and orbital diameters are changed to a certain extent. The weight of the skull is said by Martin to remain unchanged. Also, it does not appear that deformation has any generally noticed effect on intelligence or the capacity of the cranium. As will appear below, the gross diameter of basion-nasion, which is a composite measurement, is apparently uninfluenced by deformation, although it is quite possible that the angle of basion-nasion with the Frankfort plane or that the angle of the pars basilaris may be modified.

It is manifest, then, that for a more complete understanding of the phenomenon of deformation we must determine more accurately the effect of deformation under the various methods used. The basis for such an investigation is afforded by the corrections developed in the following pages.

The Problem

It seems wisest to make clear at the outset the method employed and the procedure which was necessary in securing the correction formula for deformation. In order to establish a formula which might be applied universally to all deformed series, correlations which are inter- as well as intra-racial have been utilized. This universality of the correction is essential since in many cases a group of people may be represented by deformed crania only. Occasionally, however, in addition to the deformed crania there also exists a series of undeformed skulls. Under these circumstances, if the undeformed series is statistically adequate and anthropologically homogeneous with the deformed, it would be valid to derive the correction from this undeformed group. The method outlined below would in this case be applied directly to the undeformed series and the formulæ thus obtained could then be applied to the related deformed group only. To insure validity for the correction it would have been desirable to correlate not only the individuals within each series, but also to combine all the records, regardless of group, into one all-embracing correlation. Unfortunately, the various series were represented for the most part only by means, so that to group together what individual records were available would have greatly limited the total range of the correlation. To overcome this difficulty and still retain all the data available weighted group means were correlated. For the correlation between maximum cranial length and basion-nasion seventy-six group means were used, while for the other correlations over ninety were used.

TABLE 1

CORRELATIONS FOR BASION-NASION AND HEAD LENGTH

	No.	*R*
Australians	24	.57
Early PreDyn. Egyptians	36	.48
Late PreDyn. Egyptians	99	.60
6–12 Dynasty Egyptians	80	.60
Roman Period Egyptians	50	.63
Altbayerische	55	.51
Greenland	96	.43
Tennessee Stone Graves	15	.42
Egyptians (XXVI–XXX)	895	.45[1]
Western Reserve:		
White		.45[2]
Negro		.47

In all cases where deformation was suspected the mean was excluded from the series so that only normally developed crania are included in the calculations. Another restriction made imperative to maintain as large a series as possible was the necessity of using measurements which are commonly taken.

Correction for Maximum Cranial Length. The problem, in its simplest terms, of correcting the maximum cranial length consists in the determination of a structural correlation on the skull which is both inter- and intra-racial. One of the factors necessarily involved is the diameter, maximum cranial length, which is modified by artificial deformation and for which we are correcting. The other factor in the correlation must be one which is uninfluenced by the deformation. Given such a condition, correction becomes a matter of statistical formulæ. Obviously, the probability that the corrected diameter would approximate the true diameter of the hypothetically undeformed crania increases with the approach of the correlation to unity, at which point one could correct for individual crania. But since such a correlation is practically never realized in biometric phenomena, the correction can be applied only to group means.

In Table 1 are listed the coefficients of correlation between maximum cranial length and basion-nasion in various series. All these are very

[1]Pearson and Davin, 1924, 348.
[2]Cameron, 1925, 147.

Table 2

Array of Seventy-Six Group Means for Maximum Cranial Length and Basion-Nasion

Basion-Nasion	Maximum Cranial Length 173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
97				1																
98	1				1	1	2	1												
99		1	4	4	2	1	1				2		2				1			
100			1		2	2	2	3	1				1							
101			1	1	2	1	1	1		1	1	1		1						
102			1				1	1		1		2	2	1			1		1	
103											2	1	1							
104													2			1	2		1	
105												1		1	1	1			1	1
106																			1	

TABLE 3

COMPARISON OF MEANS OF DEFORMED AND UNDEFORMED GROUPS, FROM THE SITE

Site	Head Length	Head Width	Head Height	Basion-Nasion	Author
Patagonians del Rio					
Undeformed	188.31± .92	138.23± .70	142.32± .77	104.00± .52	Marelli
Deformed	176.69±1.10	142.65±1.34	144.44±1.18	105.23± .73	
Patagonians del Chubut					
Undeformed	187.28± .79	143.28±1.28	139.77±1.25	106.14± .70	Marelli
Deformed	184.69±1.09	149.57± .90	143.50±1.08	105.46± .62	
Madisonville					
Undeformed	179.57	142.93	137.18	105.62	Hooton
Deformed	176.88	147.06	136.70	105.47	
Tennessee Stone Graves					
Undeformed	170.6			100.8	Fuller
Deformed	162.57			102.7	
Pecos Total Series A					
Undeformed	175.74± .81	137.84± .62	137.19± .73	102.70± .49	Hooton
Deformed	164.28± .59	145.43± .43	140.84± .39	101.58± .29	

TABLE 4

MEANS FOR DEFORMED AND UNDEFORMED SERIES FROM PECOS

Horizon	Head Length	Head Width	Head Height	Basion-Nasion
Black and White Glaze I				
Undeformed	173.40±1.38	137.20±1.18	133.25	99.40
Deformed	166.85±1.37	147.61±1.02	140.10±1.14	101.00
Glaze II and III				
Undeformed	180.00±1.41	139.00±1.13	139.82±1.32	104.38± .69
Deformed	161.72± .90	144.61± .73	140.07± .60	100.96± .46
Glaze IV			135.43	
Undeformed	171.33±18.6	137.80±1.55		102.40
Deformed	164.29±1.03	147.15± .79	143.00± .77	101.89± .50
Glaze V and VI				
Undeformed	175.36±1.47	136.80± .92	138.70±1.25	103.22± .55
Deformed	166.64±1.30	144.00± .86	140.27± .76	102.50± .63

high and point to a real relationship between these two diameters within the group. It would, of course, have been desirable to make a similar group correlation for each series, but the correlations given, which are random ones, sufficiently indicate the fact that the high correlation for maximum cranial length and basion-nasion is characteristic intra-racially. Table 2 represents the array of seventy-six group means for maximum cranial length and basion-nasion, giving the very high coefficient of +.65. This, I believe, is ample demonstration of the inter-racial character of the correlation and permits a formula based on this calculation to be applied universally.

As mentioned above, to correct for the cranial length which has been modified, basion-nasion must be a diameter which has remained unchanged. Otherwise there would be no accurate way of measuring directly the degree to which the maximum cranial length has been deformed. In Table 3 I have compared the means of cranial length, breadth, and height and basion-nasion in deformed and undeformed series of the same group. In Table 4 the means of the deformed and undeformed are similarly compared in the sequence of archæological strata at Pecos, New Mexico. Fortunately, these crania from Pecos have been carefully studied by Doctor Hooton and he has kindly put at my disposal the data given in this table. It is clear from a consideration of these two tables that although the maximum cranial length, maximum width, and basion-bregma height are markedly modified by deformation, nevertheless, basion-nasion remains unchanged. This conclusion on the stability of basion-nasion under deformation receives additional confirmation from a consideration of the selective or non-selective nature of the different types of deformation which are represented in Tables 3 and 4. Hooton writes:—

"Assuming artificial deformation to have been caused by pressure of the occiput on a hard cradle board, it seems clear that this cause would naturally affect round-headed infants to a greater extent than long-headed infants, for if the head of the child is free to turn from side to side, the tendency for the dolichocephalic child with the protruding occiput is to rest the head on one side or the other rather than on the back. On the other hand, a brachycephalic child with an occiput more or less flat is likely to rest on the back of the head rather than on the side. Again, if the head is fixed so that it must rest on the occiput the greater convexity of the long-headed occiput presents less surface for deformation than the relatively flat occiput of the round head."[1]

[1]Hooton, 1920, 89.

TABLE 5

SERIATION OF SEVENTY-SIX GROUP MEANS, MAXIMUM CRANIAL LENGTH

173	1
174	1
175	7
176	6
177	7
178	5
179	7
180	6
181	1
182	2
183	5
184	5
185	7
186	3
187	1
188	2
189	4
190	
191	4
192	1
	75

TABLE 6

SERIATION OF SEVENTY-SIX GROUP MEANS, BASION-NASION

97	1
98	6
99	16
100	13
101	11
102	11
103	4
104	6
105	6
106	1
	75

From the above quotation it appears that artificial deformation of the unintentional cradleboard variety may exert a definite selection based on the shape of the head and the nature of the occiput. It would be natural then to expect an original difference between the crania which remain undeformed or only slightly deformed and those which are markedly influenced by this type of deformation. On the other hand, where the deformation practised was intentional and consummated by a definite technique, there was probably no selection on the basis of cranial shape, although conceivably the degree of deformation was influenced by the shape of the head. Turning back again to the groups listed in Tables 3 and 4, which have been divided into deformed and undeformed, in the case of the Patagonians del Rio and the Patagonians del Chubut, the deformation was intentional. The similarity of the basion-nasion means for both the deformed and undeformed of these two groups is entirely expected. However, the Madisonville, Tennessee, and Pecos series exhibit unintentional deformation produced by cradleboard flattening. Here we should expect a difference between the deformed and undeformed means of basion-nasion, based on selection. This selective character of unintentional deformation is well illustrated in the differences between mean basion-nasion diameters in Table 4. Further, it should be noted that the differences between the basion-nasion diameters of deformed and undeformed are not all minus or all plus, but vary in both directions: an indication of the fact that basion-nasion is unmodified by the deformation, for otherwise one would expect a constant difference between the deformed and undeformed means. It should be pointed out that there is no inconsistency between the facts that the basion-nasion diameter remains stable under deformation and that a hypothetical change occurs in the angle of the cranial base with the Frankfort plane under deformation.

We may now return to Table 2 from which the correction or regression formula for the maximum cranial length is derived. Table 5 is the seriation of the group means for maximum cranial length (x) and Table 6 the seriation for the basion-nasion means (y). If we let r represent the coefficient of correlation between these two diameters and σx the standard deviation for cranial length and σy the standard deviation for basion-nasion, the correction or regression formula is derived in the following manner:—

$$r\frac{\sigma x}{\sigma y}$$

$$.65\frac{4.41x}{1.93y}$$

$$x = 1.49y$$

Since x equals the cranial length and y the basion-nasion diameter, we may state that for every unit change in the mean maximum cranial index there is an equivalent change of 1.49 units in the mean basion-nasion diameter. The actual correction for the maximum cranial length mean is relatively simple. The difference between the mean basion-nasion diameter of the deformed series and y (or undeformed) is multiplied by 1.49 and the sum is added to or subtracted from, according to signs, the head length of x (or undeformed). This gives a mean which represents what would have been the mean cranial length if the crania had not been artificially deformed. That is to say, the corrected mean represents the true mean as contrasted with the mean of the deformed.

Fortunately, I am able to use as a check on the method the two Patagonian series studied by Marelli.[1] These crania have been divided into deformed and undeformed, and, because of the fact that there is no morphologically selective factor operating in this type of deformation, they are therefore homogeneous, and we can profitably compare the corrected means of the deformed series with the means of the undeformed.

[1] Marelli, 1915.

Table 7

Seriation of Head Length, Deformed and Undeformed, of Patagonians del Rio Negro

Class Interval	Undeformed	Deformed
165	..	2
166	..	..
167	..	2
168	..	1
169	..	2
170	..	3
171	..	1
172	..	3
173	..	5
174	..	..
175	..	3
176	2	3
177	1	5
178	..	1
179	2	..
180	4	1
181	1	1
182	1	2
183	2	2
184	2	1
185	3	1
186	5	1
187	2	1
188	2	..
189	1	..
190	3	..
191	5	2
192	1	1
193	2	..
194	2	..
195	3	..
196	1	1
197	..	..
198	3	..
199	1	..
200	1	..
201	2	..
	52	45

TABLE 8

SERIATION OF BASION-NASION, DEFORMED AND UNDEFORMED, OF PATAGONIANS DEL RIO NEGRO

Class Intervals	Undeformed	Deformed
96	1	..
97	..	2
98	1	1
99	7	5
100	2	..
101	..	..
102	3	1
103	4	1
104	3	2
105	6	9
106	9	4
107	3	4
108	3	4
109	3	..
110	..	..
111	1	3
112	..	1
113	..	..
114	..	1
115	..	..
116	..	1
	46	39

TABLE 9

SERIATION OF HEAD LENGTH, DEFORMED AND UNDEFORMED, OF PATAGONIANS DEL CHUBUT

Class Interval	Undeformed	Deformed
174	..	2
175	..	1
176	..	..
177	..	..
178	..	2
179	..	1
180	2	4
181	..	2
182	..	3
183	2	1
184	1	2
185	5	2
186	1	1
187	2	..
188	3	2
189	3	..
190	2	1
191	..	..
192	1	2
193	..	1
194	1	2
195	2	1
	25	30

TABLE 10

SERIATION OF BASION-NASION, DEFORMED AND UNDEFORMED, OF PATAGONIANS DEL CHUBUT

Class Interval	Undeformed	Deformed
98	1	1
99	..	2
100	..	..
101	1	1
102	..	1
103	2	1
104	3	3
105	1	3
106	4	2
107	2	7
108	4	4
109	..	1
110	3	1
111	..	..
112	..	2
113	1	..
	22	29

Tables 7 and 8 give the seriation of the maximum cranial length and the basion-nasion diameters of the Patagonians del Rio, and in Tables 9 and 10 the same diameters for the Patagonians del Chubut. The mean basion-nasion diameters are very close, although the mean cranial lengths differ considerably between the deformed and undeformed. The following illustrates the method of correction:—

Patagonians del Rio

1. Mean basion-nasion, deformed 105.23
   Mean basion-nasion, undeformed 104.00
   Difference +1.23
   $+1.23 \times +1.49 = +1.83$
   Mean maximum cranial length, undeformed 188.31
   1.83
   Corrected mean for deformed crania 190.14

Were, however, an undeformed series lacking, it would be possible to use basion-nasion and maximum cranial length means of the x and y series, as the following illustrates:—

2.	Mean basion-nasion, deformed	105.23
	Mean basion-nasion, y	101.06
	Difference	+4.17

+4.17×+1.49=+6.21

Mean maximum cranial length of x series	181.85
	6.21
Corrected mean for deformed crania	188.06

The corrected means obtained by both these methods are remarkably similar and when compared with the mean, 188.31 mm., for the undeformed Patagonians del Rio, they check closely.

Patagonians del Chubut

1.	Mean basion-nasion, deformed	105.46
	Mean basion-nasion, undeformed	106.14
	Difference	—.68

—.68×+1.49=—1.01

Mean maximum cranial length, undeformed	187.28
	—1.01
Corrected mean for deformed crania	186.27

Or,

2.	Mean basion-nasion, deformed	105.46
	Mean basion-nasion, y	101.06
	Difference	+4.40

+4.40×+1.49=+6.556

Mean maximum cranial length of x series	181.85
	6.56
Corrected mean for deformed crania	188.41

Here also, the corrected means obtained by both methods are very close and approximate the undeformed mean.

Correction for Maximum Cranial Width. It was necessary, in correcting for cranial width, to adopt a slightly different procedure than was used for the cranial length. Among the available measurements there was no diameter which could serve the purpose as satisfactorily as basio-nasion length in the preceding correction.

TABLE 11

COMPARISON OF THE CRANIAL MODULES OF DEFORMED AND UNDEFORMED

	Cranial Module	Basion-Nasion
Patagonians del Rio		
Undeformed	156.29	104.00
Deformed	154.59	105.23
Patagonians del Chubut		
Undeformed	156.78	106.14
Deformed	159.25	105.46
Madisonville		
Undeformed	153.23	105.62
Deformed	153.55	105.47
Pecos Total Series A		
Undeformed	150.29	102.70
Deformed	150.18	101.58
Pecos, Glaze I		
Undeformed	147.95	99.40
Deformed	151.52	101.00
Pecos, Glace II, III		
Undeformed	152.94	104.38
Deformed	148.80	100.96
Pecos, Glaze IV		
Undeformed	148.19	102.40
Deformed	151.48	101.89
Pecos, Glaze V, VI		
Undeformed	150.29	103.22
Deformed	150.30	102.50

Consequently, I have used an index which makes a suitable substitute. On the basis of Table 11, we may assume that the cranial module is not seriously affected by deformation. This is borne out by the fact that the cranial modules of deformed and undeformed are very similar when the deformation is non-selective as shown by the approximation of the basion-nasion diameters. From a consideration of the form of the cranium under deformation it seems that by compensatory growth along lines at right angles to the plane of inhibition of growth the sum total of the diameters of the skull remains substantially the same. What is lost in one diameter is made up in the increased growth of the other diameters. In order to secure an inter-racial correlation I obtained a cranial module index by dividing the cranial module by the cranial length and correlated this index with the mean cranial width. In Table 12 there is an array of ninety series which yields the coefficient of correlation for mean cranial module index and cranial width of +.71. In Tables 13 and 14 are given the seriations of the group means used in this correlation. The application of this coefficient to the correction of the

Table 12

Array of Ninety Group Means for Cranial Module Index and Cranial Width

Cranial Module Index	Cranial Width																								
	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152
79.50	1																								
80.00							1																		
80.50			1																						
81.00			1	1	1																				
81.50				1						1				1		1									
82.00		2			1	1	2	2	1	1															
82.50					1		1	1			1	2			1										
83.00						1	1	2	1	1		1	1	1	2			2							
83.50				1	1	1		2	1	1	1			1											
84.00													1	1		1									
84.50											1	2			2	1		1					1		
85.00												3		1					1		1			1	
85.50													2	2							1				
86.00													2	1	1	1	1						1		1
86.50															1				1				1		1
87.00																1	1	1				1			
87.50																		1		1					

cranial width is achieved by the same method which was used for the maximum cranial length:—

$$r\frac{\sigma x}{\sigma y}$$

$$.71\frac{5.06x}{3.61y}$$

$$x = .99y$$

TABLE 13

SERIATION OF NINETY GROUP MEANS
CRANIAL WIDTH

128	1
129	2
130	2
131	3
132	4
133	3
134	5
135	7
136	3
137	4
138	3
139	8
140	6
141	8
142	7
143	5
144	2
145	5
146	2
147	1
148	2
149	1
150	3
151	1
152	2
	—
	90

TABLE 14

SERIATION OF NINETY GROUP MEANS
CRANIAL MODULE INDEX[1]

79.50	1
80.00	1
80.50	1
81.00	3
81.50	4
82.00	10
82.50	7
83.00	13
83.50	10
84.00	3
84.50	7
85.00	7
85.50	5
86.00	8
86.50	4
87.00	4
87.50	2
	—
	90

To obtain the cranial module index for the deformed group, the corrected mean cranial length is divided into the uncorrected cranial module. The difference between the cranial module indices for deformed and unde-

[1]Index of the means.

formed is then multiplied by the correction, and the sum is added to or subtracted from, according to signs, the mean cranial width of the undeformed. As in correcting for the cranial length, the x and y series is used where there is no undeformed group for comparison.

The two Patagonian series mentioned above are used here again as illustrations of the method and as checks on the accuracy of the correction. In Tables 15 and 16 are given the seriations of cranial width, deformed and undeformed, of the Patagonians del Rio and del Chubut.

Patagonians del Rio

1. $\dfrac{\text{Cranial module, undeformed}}{\text{Cranial length, undeformed}} \quad \dfrac{156.29}{188.31} = 82.99$ Cranial module index

$\dfrac{\text{Cranial module, deformed}}{\text{Corrected cranial length, deformed}} \quad \dfrac{154.59}{190.14} = 81.30$ Cranial module index

—1.69 Difference

$-1.69 \times +.99 = -1.67$

Cranial width, undeformed	138.23
	—1.67
Corrected cranial width, deformed	136.56

Or,

2. Cranial module index, y	83.74
Cranial module index, deformed	82.20
Difference	—1.54

$-1.54 \times +.99 = 1.52$

Cranial width x	139.87
	—1.52
Corrected cranial width, deformed	138.35

TABLE 15

SERIATION OF HEAD WIDTH, DEFORMED AND UNDEFORMED, OF PATAGONIANS DEL RIO NEGRO

Class Intervals	Undeformed	Deformed
130	2	2
131	1	1
132	..	2
133	4	3
134	5	3
135	3	2
136	3	..
137	1	2
138	8	2
139	8	1
140	3	1
141	1	1
142	2	2
143	1	4
144	2	2
145	2	..
146	..	1
147	1	1
148	1	1
149	..	..
150	..	..
151	1	5
152	..	..
153	1	1
154	..	..
155	..	1
156	..	1
157	..	2
158	..	1
159	..	..
160	..	..
161	..	..
162	..	1
	50	43

Table 16

Seriation of Head Width, Deformed and Undeformed, of the Patagonians del Chubut

Class Intervals	Undeformed	Deformed
132	1	..
133	..	..
134	..	..
135	1	..
136	..	1
137	2	..
138	3	..
139	2	..
140	1	..
141	1	..
142	3	2
143	..	..
144	2	..
145	1	2
146	1	..
147	..	3
148	1	3
149	..	4
150	2	5
151	1	2
152	1	2
153	1	..
154	..	2
155	..	1
156	..	..
157	..	1
158	..	..
159	1	..
160	..	2
	25	30

Patagonians del Chubut

1. Cranial module, undeformed / Cranial length $\frac{156.78}{187.28}=83.71$ Cranial module index

Cranial module, deformed / Corrected cranial length, deformed $\frac{159.25}{186.27}=85.49$ Cranial module index

$1.78\times+.99=1.76$

Cranial width, undeformed	143.28
	+1.76
Corrected cranial width, deformed	145.04

Or,

2. Cranial module index, y	83.74
Cranial module index, deformed	84.52
Difference	+.78

$+.78\times+.99=+.77$

Cranial width x	139.87
	+.77
Corrected cranial width, deformed	140.64

Correction for Cranial Height. The correction given in this section for the cranial height is put forth with considerable hesitation and should be regarded as strictly tentative. Following the methods adopted in the previous corrections outlined above, I obtained from eighty-two group means the expectedly high correlation of —.91 between the cranial width and the breadth-height index. Although this is a spurious correlation, nevertheless, for the purpose of this correction, it may be regarded as suggestive. It should be noted, however, that a double error exists. Necessarily there is a certain error in the corrected cranial width which is given double value in this correlation since it is present in both variates of the correlation—cranial width and breadth-height index. The regression formula is obtained as in the above.

$$r\frac{\sigma x}{\sigma y}$$

$$-.91\frac{4.44x}{5.06y}$$

$$x=-.798y$$

The corrected cranial height (basion-bregma) is obtained by multiplying the corrected cranial width by the corrected breadth-height index obtained by the above formula.

However, the corrected basio-bregmatic height may be secured in another way: by subtraction of the sum of the corrected means for cranial length and width from the sum of the three uncorrected cranial diameters.

Conclusion and Summary

In order to make clear the comparisons between the undeformed, deformed, and corrected means, I append the following table. The significance of these figures is explained in the above.

	Undeformed	Deformed Corrected by x Series	Corrected by Undeformed Patagonians
Patagonians del Rio			
Head Length	188.31	188.06	190.14
Head Width	138.23	138.35	136.56
Patagonians del Chubut			
Head Length	187.28	188.41	186.27
Head Width	143.28	140.64	145.04

The method outlined above serves as an approach to the problem of deformation. Its usefulness can be determined only by its application to deformed crania. It should be pointed out again, in justice to the method, that in all biometric phenomena we expect some individual deviation, so that the investigator must determine for himself the applicability of these corrections for each series.

The following are the three correction formulæ. I include that for basio-bregmatic height with the reservations given above:—

Maximum Cranial Length	+1.49
Maximum Cranial Width	+.99
Basio-Bregmatic Height	—.80

TABLE 17

GROUP MEANS FOR NINETY SERIES

Series	Cranial Length	no.	Cranial Width	no.	Cranial Height	no.	Basion-Nasion	no.	Capacity	no.	Author
Moorfields	189.15	44	143.02	46	129.84	31	98.54	35	1473.8	22	Macdonell, 1906
Whitechapel	189.1	72	140.7	72	132.0	72	101.6	72	1477.0		Macdonell, 1904
Long Barrow	190.6	12	142.4	12	137.8	12	102.0	12			Schuster, 1905
Round Barrow	188.6	36	144.77	31	135.94	16	103.94	16			Schuster, 1905
French Soldiers	179.96	56	143.41	56	130.68	56	99.7	56	1473	56	Macdonell, 1904
Alamannen der Schweiz	183.5	147	141.8	233	132.3	119	99.3	117	1426	58	Schwerz, 1912
Daniser-Disentis	175.15	41	149.4	41	132.10	41	99.29	41	1467	46	Reicher, 1913
West Prussian	183.0	18	135.1	18	139.1	18					Asmus, 1902
Pommerian	186.2	12	138.3	12	137.6	12					Asmus, 1902
Würtemberger	179.48	97	147.88	96	130.94	93	98.6	96	1493.77	91	Macdonell, 1904
Austrian	179	36	146	36	132	36	98?				Toldt and Weisbach, 1888
Walser-Vorarlberg	176	43	150	43	131	43	99	43	1436	40	Wacker, 1912
Bavarian	180.6	100	150.5	100	133.8	100	100.3	100	1504	100	Thomson, 1915
Bohemian	185.2	60	143.4	60	141.9	60	101.7	60			Asmus, 1902
Mecklenburg	183.1	26	140.6	26	133.1	26	99.3	26	1432.5	22	Asmus, 1902
Serbo-Croat	175	80	147	80	138	80	102	80	1524.55	80	Weisbach, 1884
Slovene	175	60	146	60	134	60	99	60	1406	60	Weisbach, 1912
Rumanian	175	40	145	40	136	40	100	40	1478.87	40	Weisbach. 1870
Greek	176	95	143	95	139	95	101	95	1489.03	95	Weisbach, 1882
Turk	175	70	145	70	138	70	101	70	1461.78	70	Weisbach, 1873
Dzoungarien	179	23	140	23	143	23	102	23	1490	23	Quatrefages and Hamy, 1882
Tatar (Volga)	176	8	142	8	129	8	99	8	1435	8	Quatrefages and Hamy, 1882
Altai-Telenget	175.79	62	151.54	59	129.75	61	99.44	61	1429	45	Reicher, 1913
Buriat	179.3	31	151.6	31	131.5	15	101.4	25	1484	15	Morant, 1924
Kalmuck	182.8	65	149.6	65	129.7	50	100.6	35	1498.5	35	Morant, 1924

Table 17 (*Contd.*)

Group Means for Ninety Series

Series	*Cranial Length*	no.	*Cranial Width*	no.	*Cranial Height*	no.	*Basion-Nasion*	no.	*Capacity*	no.	*Author*
Mongol-Torgouts	179.0	13	150.75	12	125.46	13	100.15	13	1489	9	Reicher, 1913
Tibetan A	175.7	37	138.7	35	130.9	35	96.9	37	1452.4	36	Morant, 1923
Tibetan B	185.5	14	139.4	14	134.1	15	99.2	15	1537.7	14	Morant, 1923
Burmese A	173.5	44	143.7	45	136.0	43	98.5	43	1406.9	27	Tildesley, 1921
Burmese B	173.8	8	141.1	7	134.7	7	98.8	8	1415.0	4	Tildesley, 1921
Burmese C	176.7	8	140.4	8	139.1	8	100.5	7	1442.2	5	Tildesley, 1921
Hindu	175.4	33	132.3	69	131.5	10	99.2	44	(1319.9)	34	Tildesley, 1921
Nepalese	176.9	47	132.6	47	132.8	47	98.0	47	1436.2		Morant, 1924
Maravar	175.6	21	131.4	38	132.5	38	98.8	38	(1289.7)	17	Tildesley, 1921
Veddah	179.1	32	128.8	21	133.0	37	98.1	40	(1285)	50	Morant, 1924
Annamese	177.0	27	140.3	27	137.0	25	99.8	24	(1501.4)	20	Morant, 1924
Siamese	177.9	7	143.9	11	137.8	5	100.0	7	(1527.7)	7	Morant, 1924
Malayan	174.7	78	142.2	77	137.4	76	99.5	76	(1424.4)	76	Tildesley, 1921
Ainu	185.8	88	141.2	88	139.5	88	105.4	88	1462	76	Koganei, 1894
Japanese	180.3	69	141.2	77	137.8	16	101.9	27	(1503)	71	Morant, 1924
Koreans	177.1	20	143.4	20	136.3	3	100.9	15	1490.2	17	Morant, 1924
Chinese	177.1	84	139.5	102	136.9	69	99.1	66	1467.6	46	Morant, 1924
North Chinese	177.9	46	138.8	46	136.7	46	99.7	46	(1454.7)	40	Morant, 1924
North Chinese	180.1	70	140.5	70	140.5	70	100.4	70	1485.5	69	Koganei, 1902
South Chinese	177.6	102	139.4	120	137.1	89	99.5	84	(1480.9)	64	Morant, 1924
Formosa Chinese	179.9	14	139.4	14	140.5	13	99.9	13	1408.9	14	Morant, 1924
Dayak	178	11	138	11	135	11	101	11	1530	11	Quatrefages and Hamy, 1882
Boughir and Macassar	177	11	141	11	135	11	99	11	1475	11	Quatrefages and Hamy, 1882
Java	177	19	142	19	138	19	101	19	1565	19	Quatrefages and Hamy, 1882
Maori	183	16	136	16	139	16	103	15	1405	13	Weisbach, 1890

TABLE 17 (*Contd.*)

GROUP MEANS FOR NINETY SERIES

Series	*Cranial Length*	no.	*Cranial Width*	no.	*Cranial Height*	no.	*Basion-Nasion*	no.	*Capacity*	no.	*Author*
Moriori	186.86	66	141.74	65	135.75	66	(104.7)	66	1438.81	57	Thomson, 1915
Maori	185.5	43	140.1	43	137.6	43	103.9	43	1476	43	Thomson, 1915
Loyalty Island	191.3	35	130.2	35	140.1	34	104.2	30	1463	34	Sarasin, 1922
Lifou	189	18	132	18	139	18	104	18	1460	18	Quatrefages and Hamy, 1882
Kunie Island	191	7	128	7	138	7	106	7	1470	7	Quatrefages and Hamy, 1882
New Caledonia, various provinces.	188	43	131	43	140	43	104	43	1445	43	Quatrefages and Hamy, 1882
New Caledonia, Kanala	185	25	132	25	139	25	104	25	1425	25	Quatrefages and Hamy, 1882
Caledonia and Loyalty Is. Total	184.2	97	132.2	97	139.3	91	103.5	72	1420	89	Sarasin, 1922
Australian	183.56	78	130.6	78	131.13	78					Berry, Robertson, and Cross, 1910–1911
Australian coastal	186	14	130	14	135	14	101	14	1285	14	Quatrefages and Hamy, 1882
Tasmanian	183.44	54	136.69	54	132.11	54					Berry, Robertson, and Cross, 1910–1911
Berber	184	28	136	28	138	28	101	28	1585	28	Quatrefages and Hamy, 1882
Arab	185	28	135	28	135	28	103	28	1530	28	Quatrefages and Hamy, 1882
Naqada	185.13	139	134.87	139	135.21	134	99.34	109	1380.1	88	Fawcett, 1902
Egyptians, Thebes XVIII-XXI	181.94	169	136.63	169	136.05	169	100.63	160	1387.63	164	Pearson and Davin, 1924
Egyptians, XXVI-XXX	185.34	895	138.88	896	134.08	884	101.64	896	1438.86	753	Pearson and Davin, 1924
Northern Negro	182.85	39	133.15	39	135.31	39	102.96	27	1347.7		Benington, 1912
Kaffir	190.62	38	137.36	36	137.37	38	105.05				Benington, 1912
Angoni	184.34	25	134.58	25	136.98	24	102.46				Benington, 1912
Zulu	184.15	20	137.05	19	138.13	20	101.85				Benington, 1912

TABLE 17 (*Contd.*)

GROUP MEANS FOR NINETY SERIES

Series	*Cranial Length*	no.	*Cranial Width*	no.	*Cranial Height*	no.	*Basion-Nasion*	no.	*Capacity*	no.	*Author*
Gaboon 1880	182.33	18	138.22	18	136.67	18	101.89	18	1447.44	16	Benington, 1912
Gaboon 1864	179.48	50	135.48	50	135.42	50	100.29	48	1380.51	49	Benington, 1912
Congo	177.87	50	138.52	50	133.81	48	98.19	48	1343.91	47	Benington, 1912
Mozambique	186	13	136	13	136	13	102	13	1510	13	Quatrefages and Hamy, 1882
Senegambia, Sereres	192	13	134	13	136	13	105	13	1490	13	Quatrefages and Hamy, 1882
Senegambia, Mandingo	184	10	134	10	136	10	105	10	1460	10	Quatrefages and Hamy, 1882
East Sudanese	180	11	129	11	134	11	101	11	1330	11	Quatrefages and Hamy, 1882
Eskimo	188.2	148	134.1	146	140	56	104.9	39			Morant, 1923
So. New England	182.2	41	134.0	39	136.1	28	105.7	31	1404.4	17	Knight, 1915
Guarani and Carib	180	9	135	9	133	9	98	9	1410	9	Quatrefages and Hamy, 1882
Fuegian	192	34	145	34	141	34	104.5	3	(1474)		Thomson, 1915
Arapaho	178.8	10	140.2	10	132.6	10					Otis, 1880
Cheyenne	180.3	23	147.7	22	135.7	22					Otis, 1880
Hidatsa	183	15	139	14	133	9					Otis, 1880
Chippewa	181	13	144.9	13	132.6	12					Otis, 1880
Pawnee	179.6	7	142.1	7	133.5	7					Otis, 1880
Tierra del Fuego	184.1	8	140.6	8	138.6	8					Flower, 1879
East Africa	181.5	27	135.2	27	134.8	27					Flower, 1879
Sudán and Central Africa	177.9	12	132.7	12	133.3	12					Flower, 1879
W. Coast, Africa	181.1	46	134	46	137.2	46					Flower, 1879

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