Artificial Cranial Deformation: a component in the variation in Pleistocene Australian Aboriginal crania.

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The extremes of morphological variation in Australian Aboriginal crania have long fuelled debate as to the biological origins of the Australian population (Topinard 1872; Turner 1884; Keith 1925; Wood-Jones 1934; Campbell *et al.* 1936; Howells 1937; Fenner 1939; Wunderly 1943; Birdsell 1949, 1967; Abbie 1951; Macintosh 1963; Thorne 1975; Larnach 1978; Freedman and Lofgren 1979; Thorne and Wolpoff 1981). A factor central to the debate is the shape and development of the fronto facial area. It was specifically in relation to this area that Weidenreich (1946) suggested that the osteological details of some recent and prehistoric Aboriginal crania are evidence of a continuous line of evolution from the Indonesian Pithecanthropine forms.

Thorne (1975) concluded that the diagnosdc features of the Kow Swamp crania support Weidenreich's statements. In particular, he suggested that the overall form of the frontal bones of some individuals points directly to Pleistocene Southeast Asia. Thorne's comparison of the Kow Swamp crania with a 'modern' Murray Valley series demonstrated that the morphological and metrical features that distinguish the two series are concentrated on the face and forehead. Of the 15 statistically significant metrical differences between the two male groups, 12 relate to the facial and frontal areas. Compared to the Victorian comparative series the Kow Swamp male frontal bones are flattened, broader anteriorly and longer anteroposteriorly.

A contrasting interpretation of the Kow Swamp and Cohuna crania by Brothwell (1975) suggested that the frontal recession evident in the Kow Swamp material was in fact too extreme to be natural and represented artificial deformation rather than the persistance to 10,000 years BP of an archaic morphotype. Thorne's reply (1976), supported by Larnach (1978), observed that there were no structural osteological characters in the Kow Swamp crania that would support deformation. Thorne argued that given the extreme anterior recession some corresponding posterior reaction should be observable. He found none - indeed the occipital region of the Kow Swamp cranium was fully developed and expanded.

A detailed descriptive comparison between the Kow Swamp and Cohuna crania and an artificially deformed series has not previously been undertaken. Previously, given the fragmentary material available, and especially the poor preservation of the basi-occipital area in the Kow Swamp material, it was unlikely that conclusive results would have been obtained. Recently the reconstruction of 16 crania from the Coobool area, 120km north west of Kow Swamp provided an opportunity to test this issue as statistical comparisons demonstrate that the Coobool crania fall within the Kow Swamp range. In this analysis the Coobool-Kow Swamp-Cohuna crania are compared with a series of artificially deformed crania, the Arawe from southern New Britain (Blackwood and Danby 1955).

Materials

For this analysis it would have been preferable to compare deformed and undeformed crania from the same biological populations. However, the material is simply not available. The sample can be subdivided into two subsets, Australian Aboriginal and Melanesian crania. The only definitely deformed crania available were Melanesian. Due to the morphological differences between Australian and Melanesian crania a direct comparison of deformed Melanesian crania with undeformed Australian Aboriginal crania would have produced spurious results. Therefore the initial comparison was made between the artificially deformed Melanesian series (the Arawe) and an undeformed Melanesian series (Sepik River). These data were then compared with those from the three Australian Aboriginal cranial series (Kow Swamp-Cohuna, Coobool Creek, and a 'modern' Murray Valley series). Data from all crania were used for the initial analysis but only the male data are presented in detail here. This is because in the Arawe, Sepik River and Coobool material there were not enough females for statistically significant comparisons.

1. Murray Valley. A series of 100 Australian Aboriginal crania (47 males and 53 females) from the Murray River Valley, in the collection of the Anatomy Department of the University of Melbourne (Sunderland and Ray 1959), form the comparative 'modern' Australian series. No geographic, stratigraphic or archaeological information is recorded for this collection. Taken as a whole the collection appears morphologically homogeneous and is probably from the period 5000 to 150 years BP. Sex determination was made through an examination of the associated innominates (Brown 1981).

2. Coobool Creek. The Coobool crania form part of the Murray Black collection in the Anatomy Department, University of Melbourne. This material was collected in 1950 from a site near 'Doherty's Hut' at Coobool Crossing on the Wakool River between Swan Hill and Deniliquin, in southern N.S.W. by the late George Murray Black (L. J. Ray, personal communication). As with the rest of the Murray Black collection no stratigraphic or detailed locational information is available for the material. I surveyed the area during 1980 but failed to locate the site.

The only descriptive work previously undertaken on this material

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is by Brace (1980) who compared the Coobool dentitions with those from Kow Swamp. Brace remarked that in both cranial and post-cranial form the Coobool Crossing material displays a degree of robustness well beyond that of the most rugged recent Aborigines.

Most of the Coobool crania were covered with a thick layer of siliceous carbonate and the bone is heavily mineralized. Sixteen of the more complete crania (the criteria being a well preserved cranial base, face, teeth and mandible) were reconstructed. Another 8 could be analysed without complex restoration.

Sex was determined through the use of the Larnach and Freedman (1964) technique as modified for Murray Valley crania (Brown 1981). Individuals scoring greater than 13 were classed as male, those scoring less than 14 female. Sixteen male and 8 female crania were defined in this analysis.

3. Arawe. A total of 57 artificially deformed crania in the collections of the Anatomy Department of Melbourne University, the South Australian Museum and the Australian Institute of Anatomy were examined. The Arawe of southern New Britain, forming the largest (n=25) well defined unit within this collection, were chosen as the representative artificially deformed sample.

Sex was determined through a detailed examination of cranial morphology (Krogman 1962; Larnach and Freedman 1964). I would have liked to test the diagnosis by using the Giles and Elliott (1963) discriminant function technique but the degree of deformation suggests that the results would have been even less reliable than the original morphological sexing. This suggested 16 male crania and 9 female crania were present, but the subjective nature of morphological sexing does not preclude error.

Blackwood and Danby (1955) present a detailed description of both the process of head binding among the Arawe and its effect on the cranial vault. According to them the motive for head binding appears to be a purely aesthetic one - the long head was admired and considered attractive to the opposite sex.

They describe how almost immediately after birth a bandage consisting of strips of bark cloth and vine was bound around the infant's forehead and back of the cranium. The first bandage served for about 3 weeks, larger pieces being substituted as the child grew. The amount of deformation produced was left entirely to the discretion of the mother, who kept the bandage fastened tightly if she wished the child's head to be particularly long. Even at one day old deformation was quite marked. The bandage was kept on for about a year. Reasons given for discontinuing the practice were that the child's head was considered long enough, or that the child kept pulling it off.

4. Sepik River. The largest regional series, approximating a population, that could be obtained from collections in Melbourne, Adelaide and Canberra consisted of 26 crania with incised frontal bones from the Sepik River area of northern New Guinea. There are no known ethnographic records of artificial deformation being practised in the Sepik (Dingwall 1931) and the crania show no evidence of deformation.

Sex was determined though an examination of cranial morphology (Krogman 1962; Larnach and Freedman 1964), and discriminant function analyses of the crania and mandibles (Giles and Elliot 1963; Gilles 1964). Close agreement was obtained between the morphological and metric techniques. In the five instances where crania obtained intermediate discriminant function scores, greatest emphasis was placed on morphological characteristics. Fourteen male crania and 12 female crania were identified by this analysis.

Methods

All dimensions were taken to standard osteological points (Martin and Saller 1957; Comas 1960) and measured to the nearest millimetre using standardized equipment (GPM sliding, spreading and coordinate calipers). Unmodified SPSS computer programs (release 8) were used to calculate the descriptive statistics. Snedecor's variance ratio test (F value) was used to test the differences between sample variances and Student's t test differences between the sample means. Correlation matrices were generated using the convention of pairwise deletion of missing data.

Lateral radiographs were taken of eight of the Arawa and all of the Coobool crania. Heavy mineralization of the latter resulted in comparatively low resolution. These radiographs were compared with a series of radiographs of Australian Aboriginals taken as part of the long term growth study of Walbiri and Pintubi people at Yuendumu (Brown and Barrett 1971, 1973; Brown *et al,* 1979).

Results

1. Arawe and Sepik River. The statistical data for the Arawe and Sepik River male crania are presented in Table 1.

Compared to the Sepik River frontal bones the Arawe frontals are greatly elongated and flattened. Both the mean frontal chord (Nasion-Bregma) and frontal arc length of the deformed crania are significantly longer (P=.000, P= .048) than in the undeformed series.

Viewed laterally the flattening of the Arawe frontals is largely restricted to the anterior two-thirds, with the surface in some crania being slightly concave. There is little evidence of the frontal boss preserved and the point of maximum convexity (Metopion) is situated posterior to that of the Sepik series. The mean frontal curvature index of the Arawe is significantly lower than that in the undeformed series with only a slight overlap between the two ranges. There are no significant differences in supraorbital breadth.

Magitot (1885) found that artificially deformed European crania were often distinguished by a marked pre-bregmatic bulge or eminence and a series of lateral depressions bordering the midline, halfway between nasion and bregma. Marked pre-bregmatic eminences were present in 4 of the Arawe male crania, with slight bulges in 5 others. Lateral depressions bordering the midline, sometimes two on each side, were well developed in 7 of the males. These features were not present in any of the undeformed Melanesian crania examined.

With head binding the depth of the post-orbital ophrionic groove appears to be slightly increased giving a superficial impression of a frontal torus in the more robust

	Arawe Males				Sepik River Males							
	n	x̄	s	Range	n	x̄	s	Range	F	P	T	P
Bi-Parietal Breadth	14	126.4	4.57	119-133	14	132.0	5.51	120-140	1.45	.511	−2.91	.007*
Glabella-Opisthocranion	16	183.9	6.04	169-193	14	180.9	7.12	170-192	1.39	.537	1.24	.225
Basion-Bregma	16	140.6	5.55	133-151	14	134.1	4.99	123-141	1.24	.708	3.37	.002*
Basion-Nasion	16	102.9	3.79	96-110	14	100.7	3.93	95-107	1.07	.885	1.53	.138
Basion-Prosthion	11	105.8	4.29	100-113	14	102.6	3.97	96-111	1.16	.783	1.90	.071
Basion-Lambda	16	122.7	8.67	102-131	14	109.8	7.67	93-118	1.28	.666	4.33	.000*
Basion-Inion	16	67.0	10.46	41-79	14	67.1	11.46	29-77	1.20	.730	−0.04	.972
Bi-Auricular Breadth	16	122.3	5.99	113-133	14	118.1	5.01	108-124	1.44	.519	2.08	.047*
Nasion-Bregma	16	118.9	3.98	111-126	14	111.4	2.90	105-117	1.89	.257	5.96	.000*
Metopion Height	16	17.2	2.78	13-22	14	23.2	3.02	19-29	1.17	.760	−5.66	.000*
Nasion-Metopion	16	58.2	11.66	41-83	14	46.8	10.76	10-53	1.17	.781	2.78	.010*
Supra Orbital Breadth	16	106.4	4.68	98-118	14	107.0	5.88	96-116	1.58	.392	−0.29	.776
Bi-Zygion	16	135.4	6.33	125-147	14	131.0	5.56	123-143	1.29	.650	2.01	0.54
Opisthion-Lambda	16	102.7	4.29	96-113	14	93.2	3.58	90-102	1.43	.519	6.60	.000*
Basion-Staphylion	16	50.2	3.58	45-57	13	47.5	3.15	43-53	1.29	.664	2.12	.044*
Lambda-Inion	16	73.1	9.41	58-98	14	65.4	5.40	56-76	3.03	.050*	2.81	.010*
Lambda-Asterion	16	85.5	6.28	75-96	14	81.0	4.04	75-88	2.42	.117	2.36	.026*
Bregma-Lambda	16	111.1	6.18	99-120	14	115.7	7.46	105-132	1.46	.482	−1.84	.077
Subtense Height	16	31.1	3.54	22-37	14	26.4	2.93	21-31	1.46	.499	3.98	.001*
Bregma-Subtense	16	60.3	4.25	55-68	14	58.4	5.56	51-70	1.71	.321	1.03	.313
Auriculare-Opisthion	16	76.8	4.24	69-85	14	73.5	2.82	66-77	2.25	.149	2.50	.019*
Auriculare-Basion	16	67.1	3.59	60-73	14	63.7	2.84	57-67	1.59	.404	2.85	.008*
Nasion-Nasospinale	16	55.9	2.60	50-59	14	53.6	3.25	49-59	1.56	.410	2.06	.050*
Nasion-Prosthion	12	71.5	4.60	65-82	14	69.9	3.99	64-77	1.33	.621	0.96	.346
Orbital Height	16	36.7	1.66	34-39	14	34.4	2.53	29-37	2.32	.122	2.94	.008*
Bi-Ectoconchion	16	102.1	4.05	95-112	14	100.2	5.06	91-108	1.56	.407	1.13	.268
Frontal Curvature Index	16	14.5	1.84	11-18	14	20.9	2.27	17-26	1.56	.410	7.93	.000*
Parietal Curvature Index	16	28.8	3.12	22-33	14	22.9	1.73	20-27	3.18	.049*	5.69	.000*
Occipital Curvature Index	16	19.2	3.32	13-24	14	26.0	4.47	20-34	1.87	.253	4.36	.000*
Gnathic Index	13	103.9	5.17	99-116	14	101.7	2.93	97-107	3.07	.050*	1.19	.213
Foramen Magnum-Nasion Angle	16	146.2	5.61	138-158	14	155.4	4.58	148-161	1.47	.483	4.37	.000*
Frontal Arc	16	128.6	5.24	120-138	14	125.1	3.94	120-134	1.77	.308	2.07	.048*
Parietal Arc	16	132.0	7.87	112-145	14	131.6	8.97	118-151	1.30	.624	0.14	.891
Occipital Arc	16	113.5	4.56	106-123	14	109.6	5.71	99-120	1.57	.403	2.06	.050*

* Probability level of .050—.000 considered significant.

Table 1. Comparative dimensions of Arawe and Sepik River male crania (linear dimensions in mm).

males. A large glabella, relative to other Melanesian populations, is a feature of male crania from New Britain (Bonin 1936) and this persists in the deformed crania. There is no apparent change in the size of the superciliary ridges with deformation.

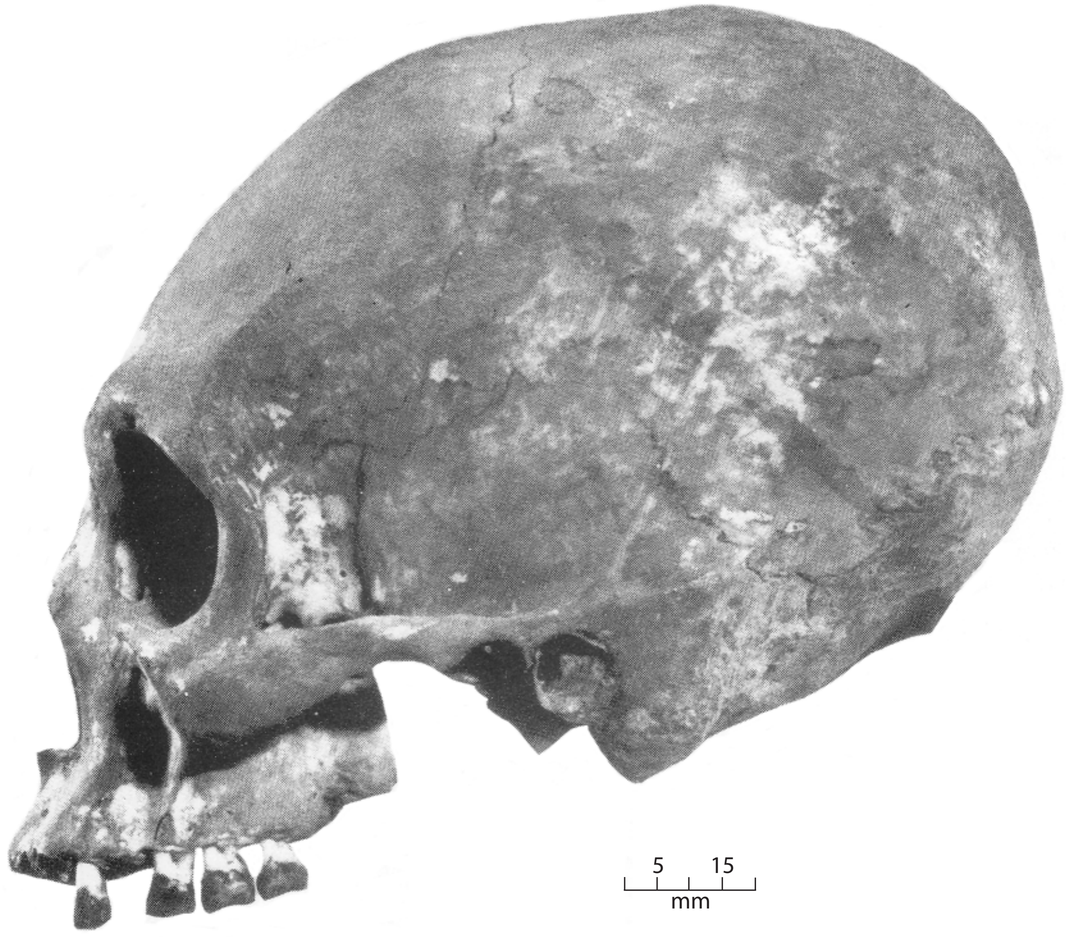
Larnach (1974) demonstrated that in artificially deformed crania pressure on the frontal resulted in an increase of curvature in the parietals. This change can be measured through the parietal curvature index. For this index the parietal chord (straight line distance from bregina to lambda) and the parietal subtense (maximum perpendicular distance from the parietal chord to the maximum projection of the parietal curvature) are taken with co-ordinate calipers. Larnach found that the mean parietal curvature index of his deformed series was significantly higher than that for the undeformed crania and there was no overlap in range. He argued that this index could therefore, be used to distinguish between deformed and undeformed crania. Although in this study the mean parietal curvature index of the Arawe is significantly higher than the Sepik males (P~.000), thus supporting Larnach's general conclusions, there is a considerable overlap in the ranges for this index. The parietal curvature index remains an excellent indicator of artificial deformation but it cannot be used as the sole discriminator.

Goldstein (1940) noted that, apparently as a result of concurrent frontal and occipital flattening, a saddle-like depression often occurred in the anterior third of the parietal bones, just behind bregma. Parietal saddles were present in 8 of the 16 Arawe male crania, with the maximum depth of the depression reaching 4mm. Parietal saddles were not present in any of the undeformed crania examined.

Pressure on the sides of the vault during head binding results in a lateral constriction of the Arawe parietals with a reduction

Figure 1. Lateral view of male Arawe cranium (A.I.A. 2846).

Figure 2. Lateral view of female Arawe cranium (A.I.A. 4280).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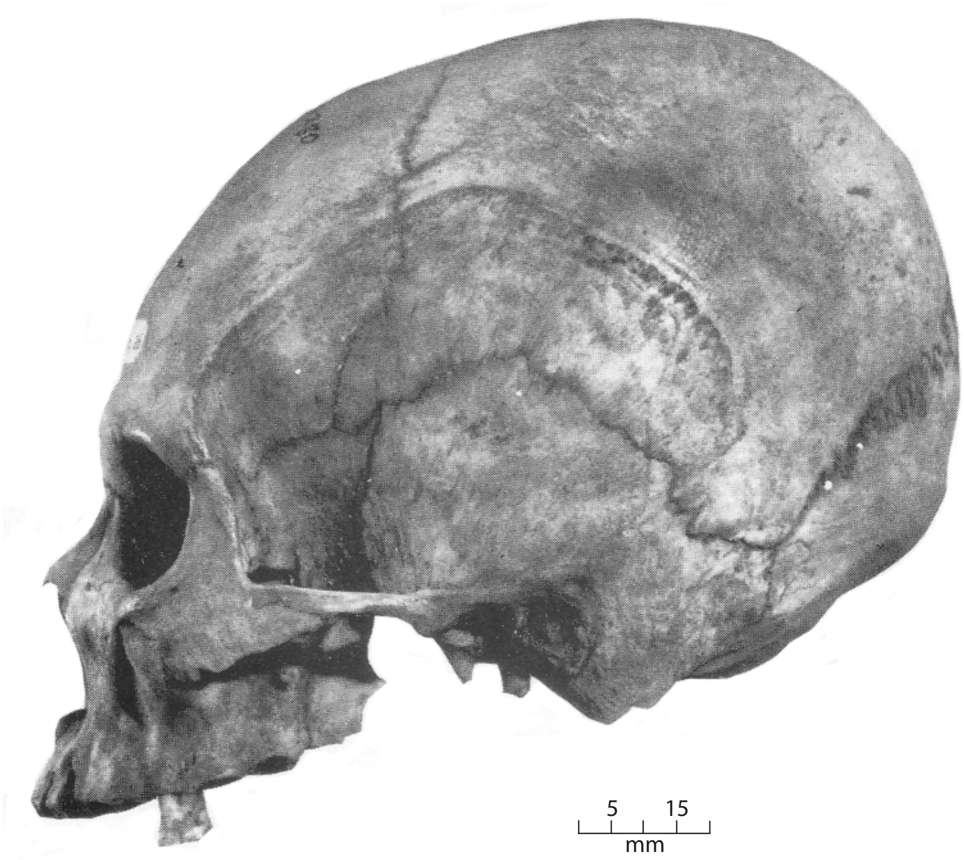
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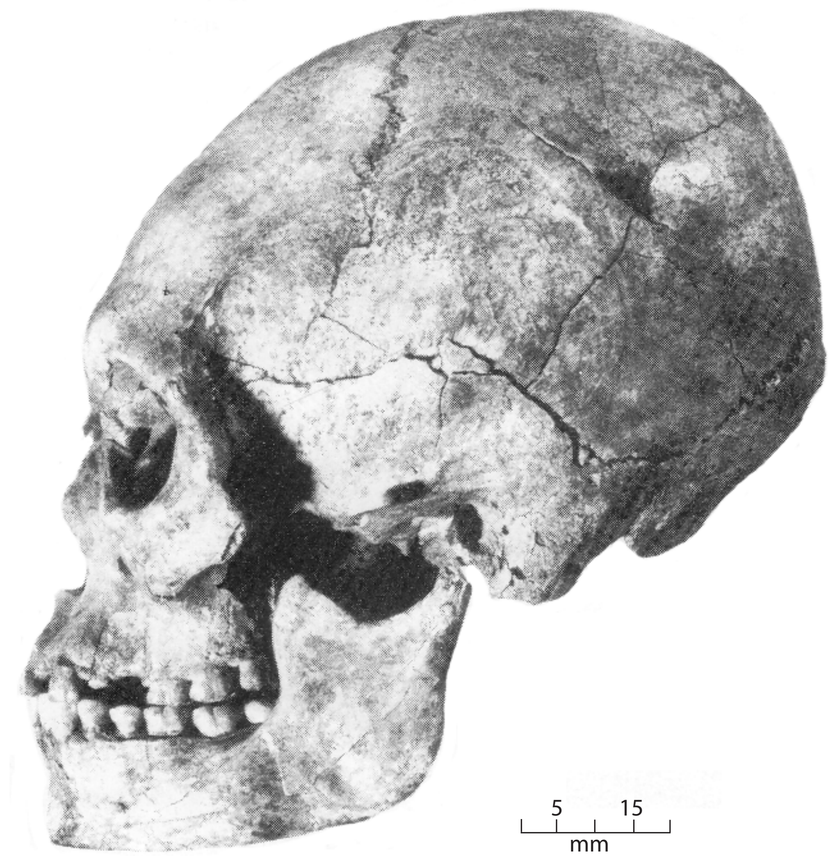
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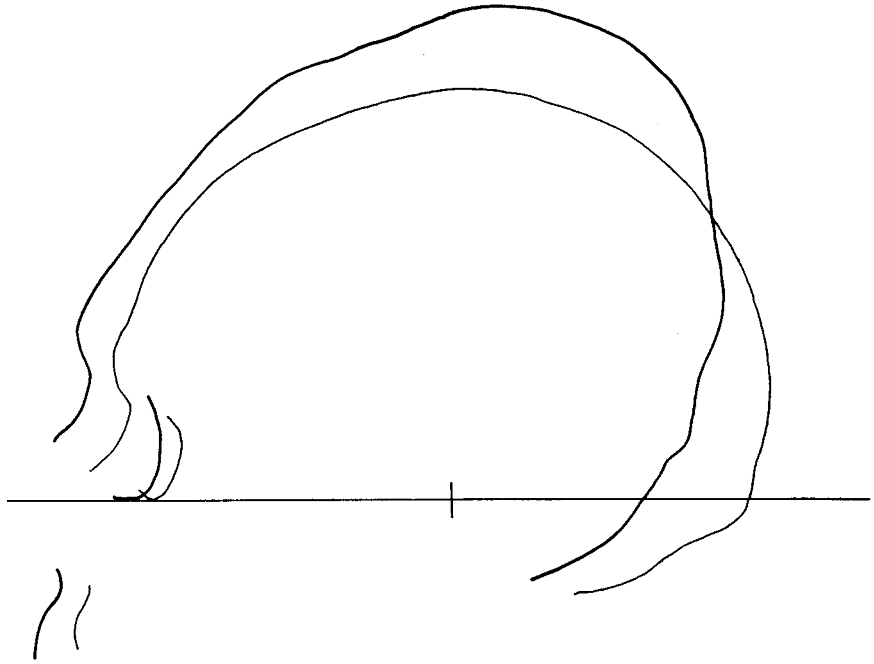

Figure 3. Midline cranial contours of an artificially deformed Arawe male (heavy line) and an undeformed male from northern New Britain.

of maximum bi-parietal breadth. In some crania the parietals narrow to a marked point at the vertex with the increase in curvature evident both antero-posteriorly and in norma occipitalis.

As with the frontals and parietals, changes in occipital morphology resulting from head binding are most evident in lateral aspect. The Arawe occipitals are significantly longer (lambda-opisthion) (P = .000) and flatter than those in the undeformed series, with little evidence of an occipital bun. The deformed occipitals give the impression of being pushed up and under the parietals and present a flatter posterior surface to the vault than in undeformed crania (Figures 1, 2 and 3).

An occipital curvature index was constructed using the chord length (lambda-opisthion) and the occipital subtense (maximum perpendicular distance from the occipital chord to the maximum projection of occipital curvature) measured by co-ordinate calipers. The occipital curvature index of the Arawe is significantly lower (P=.000) than in the undeformed crania with only a slight overlap in range. With deformation the posterior edge of the foramen magnum is drawn upwards toward lambda. The upward movement of opisthion results in a reduction of the angle linking nasion- basion-opisthion. The mean foramen magnum-nasion angle is significantly lower in the Arawe than in the Sepik crania (Table 1).

One of the major distinguishing features of artificially deformed crania is a marked increase in cranial height (Kiszely 1978). Pressure on the front and back of the cranium forces the posterior third of the frontal and much of the parietals superiorly. This results in the elevation of bregma and vertex (Figure 3). Arawe cranial height (Basion-Bregma) is significantly greater (P~.002) than that in the undeformed series.

Maximum cranial length (glabella -opisthocranion) is not significantly greater in the Arawe but there is a considerable difference in the mean location of opisthocranion. Opisthocranion, the posterior end of the maximum length line of the skull based on glabella, is usually located posterior to lambda in Melanesian and Australian Aboriginal crania, especially those with a well developed occipital bun. In the Arawe the flattening of the occipital bone coupled with the upward and backward movement of the parietals results in a relocation of opisthocranion, either at lambda or up to 20mm anterior to it.

Figure 4. Lateral view of Coobool male cranium CC 65,

Figure 5. Lateral view of Coobool female cranium CC 01.

Changes in facial morphology with head binding appear to be highly variable. Although there is no significant difference between the mean gnathic indices of the two Melanesian series (P=.213), the maximum gnathic index of the Arawe (116) exceeds both that recorded for the Sepik (107) and the maximum recorded for Australian Aboriginal crania (112). There are no significant changes of facial breadth (supra orbital or bi-ectoconchion) with deformation but there is a significant increase in upper facial height (nasion-nasospinale) and orbital height. The upper margins of the orbits were noticeably displaced posteriorly in 8 of the Arawe male crania.

Blackwood and Danby (1955) sagittally sectioned 4 Arawe crania and noted a medial thickening of the frontal bone immediately antenor to bregma. This was due to a thickening of the diploë, accompanied by a bulging of the outer table of the vault, the inner table remaining undisturbed. It is this expansion of the diploë which, in its maximum form, corresponds to the pre-bregmatic eminence. Lateral radiographs of the Arawe crania showed the variable development of this feature. An expansion of the diploë anterior to bregma is often accompanied by a marked constriction of the diploë midway between nasion and bregma. All of the Arawe crania radiographed displayed at least a slight expansion of the diploë in the posterior third of the frontal. I could not find this feature in lateral radiographs of undeformed Australian Aboriginal, Melanesian and European crania. 2. Coobool - Kow Swamp - Cohuna and Murray Valley. The statistical data for the Coobool and Murray Valley male crania are presented in Table 2, with the individual dimensions of the Kow Swamp 5, Cohuna, Coobool 65 and Coobool 49 crania in Table 3.

Compared to the Murray Valley series the Coobool crania are characterized by significantly larger mean cranial dimensions and great morphological variation. The most striking feature of the Coobool series is the marked frontal recession evident in several of the male and female crania, which in some cases is associated with a cranial height exceeding the modern Murray Valley range.

	Coobool Males				Murray Valley Males							
	n	x̄	s	Range	n	x̄	s	Range	F	P	T	P
Bi-Parietal Breadth	17	138.1	3.98	133-145	46	130.5	4.52	122-143	1.29	.595	6.45	.000*
Glabella-Opisthocranion	17	196.4	5.73	185-207	47	189.1	5.76	178-201	1.01	1.000	4.44	.000*
Basion-Bregma	17	143.4	5.22	134-153	45	133.5	4.05	126-143	1.66	.184	6.32	.000*
Basion-Nasion	17	104.5	3.68	100-111	45	102.5	3.29	95-108	1.25	.541	2.01	.055
Basion-Prosthion	14	109.6	3.99	105-120	45	106.5	4.38	95-116	1.20	.749	2.49	.020*
Basion-Lambda	17	123.8	6.69	115-142	45	114.2	2.84	108-119	5.56	.000*	5.70	.000*
Basion-Inion	17	78.6	4.73	71-92	43	81.5	4.94	69-91	1.09	.891	–2.13	.041*
Bi-Auricular Breadth	16	126.8	2.59	123-132	47	121.3	4.24	112-131	2.68	.040*	6.16	.000*
Nasion-Bregma	17	121.0	5.17	115-131	47	113.5	4.28	102-120	1.46	.315	5.37	.000*
Metopion Height	17	23.2	3.81	16-29	47	25.7	2.21	21-30	2.98	.004*	–2.47	.022*
Nasion-Metopion	17	53.7	5.36	43-61	47	51.0	3.35	43-57	2.56	.013*	1.92	.069
Supra Orbital Breadth	16	115.9	4.14	109-123	47	108.5	3.48	101-116	1.41	.364	6.44	.000*
Bi-Zygion	7	143.0	5.35	134-150	44	135.6	5.01	124-146	1.14	.709	3.44	.009*
Opisthion-Lambda	17	102.1	6.04	95-120	46	94.5	3.49	88-109	3.00	.004*	4.88	.000*
Basion-Staphylion	10	49.8	3.39	46-57	44	47.7	2.49	42-54	1.86	.171	1.82	.095
Lambda-Inion	17	68.5	7.90	60-91	47	61.1	5.25	47-73	2.26	.031*	3.55	.002*
Lambda-Asterion	17	132.2	3.99	128-143	47	82.4	3.57	74-92	2.19	.039*	3.55	.002*
Bregma-Lambda	17	121.5	5.76	107-129	46	117.0	5.04	107-134	1.30	.475	2.58	.016*
Subtense Height	17	25.3	2.78	18-29	44	23.3	1.94	20-28	2.06	.062	2.69	.013*
Bregma-Subtense	17	61.9	4.97	54-72	44	59.5	4.63	50-69	1.16	.675	1.67	.106
Auriculare-Opisthion	17	79.2	2.22	76-84	46	77.1	3.00	67-82	1.82	.190	3.08	.004*
Auriculare-Basion	17	68.8	1.56	66-72	45	66.2	3.14	57-72	4.05	.004*	4.29	.000*
Nasion-Nasospinale	14	54.5	3.06	50-59	47	49.9	2.66	44-55	1.32	.474	5.02	.000*
Nasion-Prosthion	14	75.1	2.70	70-78	47	70.6	3.91	62-78	2.09	.147	4.89	.000*
Orbital Height	15	31.4	2.72	25-35	47	32.9	2.50	23-39	1.18	.646	–1.94	.065*
Bi-Ectoconchion	13	108.6	3.64	103-114	46	104.3	3.49	97-111	1.09	.784	3.80	.001*
Frontal Curvature Index	17	19.2	3.15	12-24	47	22.6	1.57	19-26	4.18	.002*	–5.67	.000*
Parietal Curvature Index	17	20.9	1.77	17-24	44	19.8	1.14	17-23	2.50	.050*	2.87	.009*
Occipital Curvature Index	16	27.7	2.85	19-33	40	29.3	3.45	24-37	1.41	.364	–1.78	.099
Gnathic Index	13	105.6	3.57	100-112	45	103.9	3.53	97-111	1.08	.887	1.50	.115
Foramen Magnum-Nasion Angle°	14	152.4	5.86	142-167	40	156.1	5.89	149-172	1.04	.943	1.99	.060
Frontal Arc	17	135.8	5.17	128-148	46	130.3	5.59	115-140	1.17	.756	3.67	.001*
Parietal Arc	17	135.6	6.98	117-143	42	130.2	6.14	119-149	1.29	.495	2.82	.009*
Occipital Arc	17	121.2	7.25	111-142	43	113.7	4.95	105-123	2.14	.049*	3.96	.001*

* Probability level of .050—.000 considered significant.

Table 2. Comparative dimensions of Coobool Creek and Murray Valley male crania (linear dimensions in mm).

Compared to the Murray Valley frontals the Coobool frontals are greatly elongated and flattened. Both the mean frontal chord and frontal arc length of the Coobool crania are significantly longer than that in the Murray Valley males (P=.000; P=.001), with the frontal chord length of 7 of the Coobool males exceeding the Murray Valley range. The Kow Swamp and Cohuna crania are also characterized by a frontal chord which is significantly greater than the modern range (Thorne 1975).

Frontal curvature indices below the Murray Valley male series range (range 19-26) are found in 6 of the Coobool male crania (range 12.4-18.2). In the most ex treme of these (CC 65) the frontal is flat to slightly concave anteriorly with no evidence of a frontal boss (Figure 4). In this individual metopion is located more posteriorly than in any of the Murray Valley males (Tables 2 and 3). The frontals of KS 5, KS 7 and Cohuna display similar flattening in their middle thirds, with a posterior location of metopion in KS 7 and Cohuna. Variance in both the height and location of metopion is significantly greater in the Coobool crania than in the Murray Valley series (P=.004; P=.013).

The Coobool frontals are broader anteriorly than the Murray Valley series with significantly greater supra-orbital breadth (P=.000). The maximum supra-orbital breadth of the Coobool males (123mm) is exceeded only by the estimate for KS 9 (124mm) (Thorne 1975) in Australian Aboriginal crania.

A well developed pre-bregmatic eminence is present in the Coobool male cranium CC 65 with a moderate development of this feature evident in CC 29, KS 7 and Cohuna. Pre-bregmatic eminences were not present in any of the Murray Valley crania examined and are not present in the crania from Roonka, Swanport and Broadbeach I examined. Lateral depressions bordering the midline are well developed in the Coobool female CC 01 (Figure 5) and KS 5 with a slight development in CC 41.

Unlike some of the Kow Swamp and Cohuna crania, those from Coobool are not distinguished by particularly robust supra-orbital development. In general the glabellae are small for an Australian Aboriginal male series and the superciliary ridges do not gain the high degree of development evident in KS 1 and some modem Australian crania. An undivided frontal torus is not present in any of the reconstructed Coobool crania.

Viewed laterally the Coobool parietals vary in curvature with greater variance and a higher mean curvature index than the Murray Valley males. The parietal curvalure index of Coobool males CC 65 and CC 41, Coobool female CC 01 (index 24.6), Kow Swamp 5 and Cohuna are at the top of the Murray Valley range and within the lower limit for the Arawe (Tables 1, 2 and 3). Parietal curvature in the Coobool crania does not approach the extremes of the Arawe, with no evidence of either a marked pointing of the parietals towards vertex or lateral constriction (see Figures 3, 6a and 6b). However, the curvature is certainly more marked than is common in Australian Aboriginal crania (Figures 6a and 6b). Both mean bi-parietal and bi-auricular breadth in the Coobool crania are significantly greater than in the Murray Valley male series (P=.000; P-.000). There is no evidence of the lateral constriction of the vault as evident in the Arawe. Parietal saddles are not present in the Kow Swamp, Coobool or Murray Valley crania examined.

Variation on a scale similar to that in the Coobool frontals and parietals is also evident in the Coobool occipitals. The mean length of the Coobool occipitals is significantly higher than that for the Murray Valley series (P=.000), with greater variance (P=.004). There is a tendency for the occipital curvature index of the Coobool crania to be lower, with the indices of crania CC 18, CC 41, CC 65 and KS 5 being below the Murray Valley series range. In Coobool crania CC 01, CC 49, CC 65 and Kow Swamp 5 the occipitals give the impression of being pushed up and under the parietals, presenting a flatter posterior surface to the vault than is common in Murray Valley crania (Figures 6a and 6b). Poor preservation of the occipital in the Kow Swamp-Cohuna material prevents the measurement of the occipital curvature index in all crania except KS 5. Enough of the occipital is preserved in KS 1 to demonstrate a high degree of curvature for this specimen, well within the modern range.

Although there is no significant difference between the mean nasion-foramen magnum angle of the Coobool and Murray Valley crania, the angle in Coobool cranium CC 65 is well below the Murray Valley range. In this individual the posterior third of the foramen has been drawn up toward lambda presenting a similar appearance to that seen in some of the Arawe crania. Once again poor preservation pre-

	CC 65	CC 49	KS 5	Cohuna	X
Bi-Parietal Breadth	136	142	139	130	136.8
Glabella Opisthocranion	195	203	192	199	197.3
Glabella-Lambda	194	201	190	196	195.3
Basion-Bregma	149	151	(148)	(141)	147.3
Basion-Nasion	102	100	-	(104)	102.0
Basion-Nasospinale	101	99	-	(102)	100.7
Basion-Prosthion	105	108	-	(112)	108.3
Basion-Lambda	129	142	-	(127)	132.7
Basion-Inion	85	78	-	-	81.5
Bi-Auricular Breadth	127	130	118	128	125.8
Bi-Asterionic Breadth	106	114	112	107	109.8
Fronto-Sphenoid Breadth	112	112	95	96	103.8
Nasion-Bregma	129	127	(117)	125	124.5
Metopion Height	16	21	15	18	17.5
Nasion-Metopion	47	61	45	73	56.3
Supra Orbital Breadth	112	120	111	115	114.5
Post Orbital constriction	88	106	96	89	94.8
Bi-Zygion	(143)	143	(139)	(145)	142.5
Bi-Zygomaxillare	103	109	103	110	106.3
Bi-Stephanion	87	113	109	93	100.5
Bi-Stenionic	73	73	64	69	69.8
Opisthion-Inion	47	43	(39)	-	43.0
Opisthion-Lambda	102	120	(108)	-	110.0
Opisthion-Asterion	68	71	(65)	-	68.0
Opisthion-Glabella	149	142	(143)	-	144.7
Foramen Magnum Length	42	37	-	-	39.5
Foramen Magnum Breadth	36	28	-	-	32.0
Basion-Sphenobasion	24	26	-	-	25.0
Basion-Asterion	84	87	-	(81)	84.0
Basion-Mastoidale	57	55	-	-	56.0
Lambda-Bregma	121	125	(125)	116	121.8
Subtense Height	28	25	(29)	26	27.0
Bregma-Subtense	72	62	(57)	55	61.5
Lambda-Inion	60	91	76	-	75.7
Lambda-Asterion	86	100	93	88	91.8
Nasion-Nasospinale	57	55	53	54	54.8
Nasion-Prosthion	74	75	73	75	74.3
Nasal Breadth	30	29	31	30	30.0
Orbital Height	33	30	32	30	31.3
Orbital Breadth	42	44	42	44	43.0
Bi-Ectoconchion	108	111	102	110	107.8
Frontal Curvature Index	12	17	13	14	14.0
Parietal Curvature Index	23	20	23	22	22.0
Occipital Curvature Index	20	26	(20)	-	22.0
Gnathic Index	103	108	-	108	106.3
For. Magnum-Nasion Angle	142	153	-	-	147.5
Frontal Arc	141	139	(124)	140	136.0
Parietal Arc	140	138	(144)	131	138.3
Occipital Arc	111	142	(121)	-	124.7

Table 3. Comparative cranial dimensions for Coobool Creek 65, CC 49, Kow Swamp 5 and Cohuna (linear measures in mm).

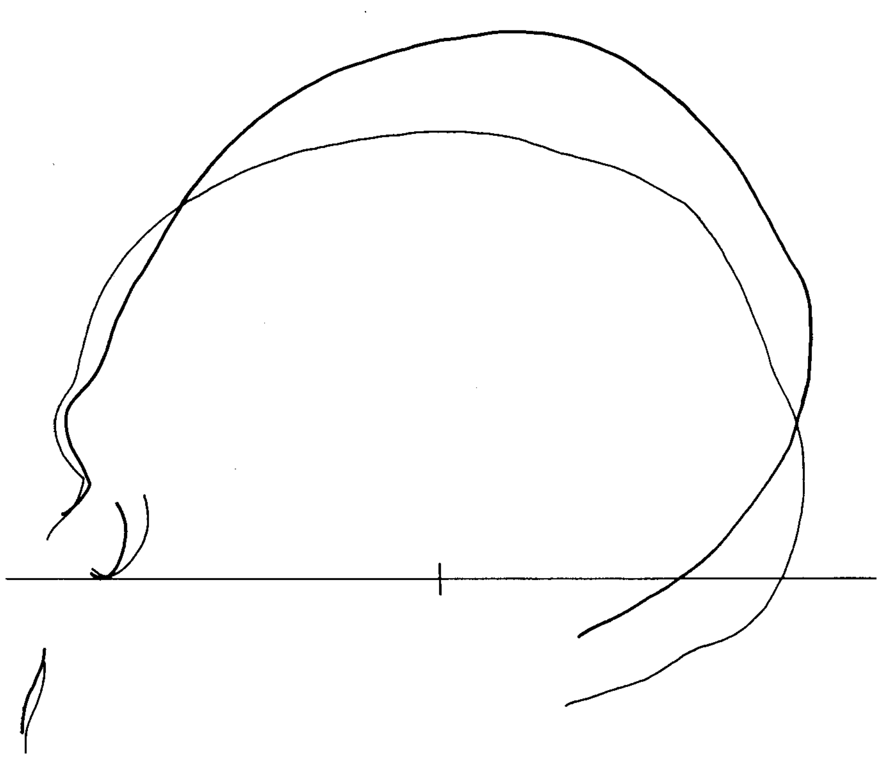

Figure 6a. Midline cranial contours of Kow Swamp 5 (heavy line) and a modern Murray Valley male.

vents the measurement of this angle in the Kow Swamp and Cohuna crania.

One of the major distinguishing features of the Coobool series is a high mean cranial height. The mean basi-bregmatic height of the Coobool male crania is significantly higher than in the Murray Valley male series, with the Murray Valley maximum of 143mm being exceeded by 6 of the Coobool male crania. The maximum basion-bregma height in the Coobool series (153mm) exceeds the maximum recorded for Australian Aboriginal crania (150mm for Broadbeach male 102, author's observation). In Australian Aboriginal crania there is normally a strong positive correlation between basion-nasion length and basion-bregma height. In the pooled Murray Valley male and female sample a strong correlation of r= .676 (n=95) was obtained, with a lower correlation in females (n= 49, r=.335) than in males (n= 46, r=.585). In the Coobool crania the correlation for the pooled male and female sample is only slight (n=23, r=.370) with an extremely low correlation of r = .080 (n=17) in the male crania (there are too few females in the Coobool female sample to provide statistically significant results). The great basi-bregmatic height of Coobool crania CC 49, CC 65, Kow Swamp 5 and Cohuna coupled with a low frontal curvature index, relatively high parietal curvature index and a low occipital curvature index give these crania a midline cranial contour similar to the Arawe mean, Figures 3, 6a and 6b.

The mean cranial length (glabella-opisthocranion) figure for the Coobool male crania is significantly higher than in the Murray Valley series (P=.000). Opisthocranion is located well below lambda in the Coobool crania with well developed occipitals. In those crania with high parietal curvature indexes and flat occipitals (CC 49, CC 65, Female CC 01) opisthocranion is located at lambda. In Kow Swamp 5 opisthocranion is located just below lambda.

Both mean upper face (nasion-nasospinale) and total face (nasion-prosthion) height are significantly greater (P=.000; P=.000) in the Coobool males than in the Murray Valley series. The Coobool faces tend to have lower rectangular orbits and great breadth in the upper face with significantly greater (P-.001) breadth across the orbits. The gnathic indices of the Coobool crania are not significantly greater than the modern mean (P=.115). The destruction of the cranial base in the Kow Swamp crania prevents the measurement of this index in these crania. Cohuna is prognathic (gnathic index 108) but within the modern range.

Lateral radiographs taken of the Coobool crania display a marked thickening of the diploë anterior to bregma in the frontals of CC 01,

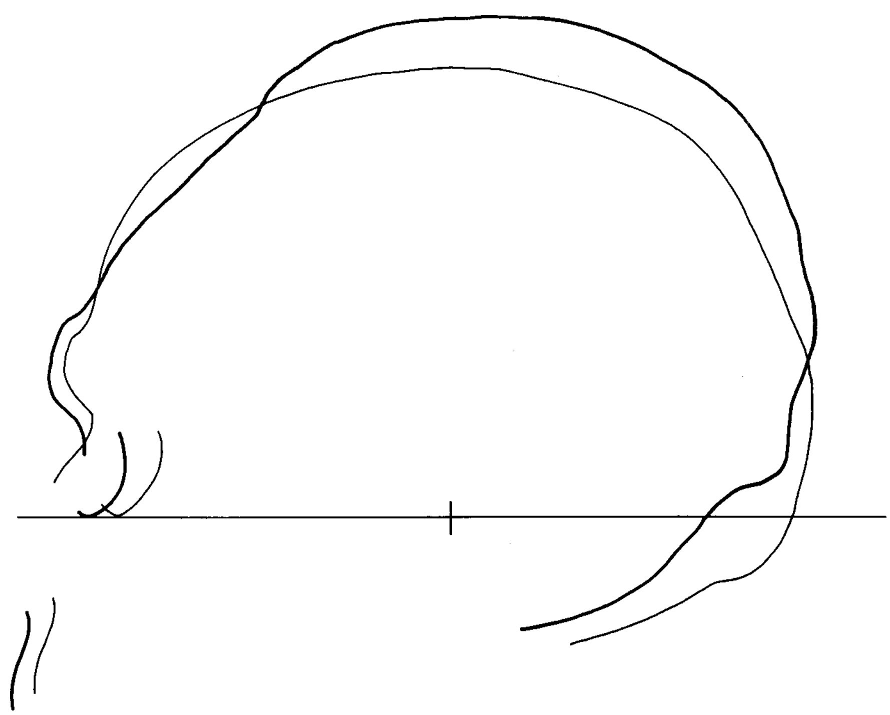

Figure 6b. Midline cranial contours of Coobool Creek 65 (heavy line) and a modern Murray Valley male.

CC 29, CC 49 and CC65. In CC 65 it is this expansion of the diploë which results in the well developed pre-bregmatic eminence. In CC 65 and CC 0 1 this posterior thickening of the frontal diploë is preceded by a constriction of the diploë in the middle third of the frontal. Although radiographs of the Kow Swamp and Cohuna crania are not available it is evident that there is a pre-bregmatic expansion of the diploë in KS 5, KS 7, and Columa. This feature was not present in lateral radiographs of Australian Aboriginals from Yuendumu.

Taking this analysis as a whole it is evident that several of the crania from Coobool, Kow Swamp and Cohuna are artificially deformed. The crania which show obvious signs of deformation are Coobool crania CC 01, CC 49, and CC 65, Kow Swamp crania KS 5 and KS 7 and Cohuna. The features which differentiate these crania and the Arawe from undeformed crania are:

1. A long and flat frontal. Flattening of the frontal is evident in the middle third with a posterior location of metopion. A pronounced thickening of the diploë anterior to bregma with a constriction of the diploë in the middle third of the frontal. Symmetrical depressions bordering the midline in the anterior two thirds of the frontal.
2. Great basion-bregma height.
3. A long and flat occipital with a low occipital curvature index, and minimal development of the occipital bun. In Coobool cranium CC 65 the posterior edge of the foramen magnum is oriented towards lambda resulting in a low nasion-foramen magnum angle.
4. A high parietal curvature index.
5. Greater variance in the parietal curvature index, frontal curvature index and in the location of lambda.

The major features which distinguish the Arawe from crania such as Kow Swamp 5 and Coobool 65 relate to the greater degree of deformation evident in the Arawe, especially in the parietals, and the well developed cranial breadth in the Australian crania. In the Arawe head binding restricts the lateral development of the parictals forcing them inward and upward. In direct contrast to this the Australian crania CC 01, CC 49, CC 65, KS 5 and Cohuna all have broad vaults with a mean bi-parietal breadth which is significantly greater than the Australian mean. This suggests that the Australian crania could not have been deformed by a fixed series of head bindings such as those employed by the Arawe.

Discussion

I can find only three ethnographic references to intentional cranial deformation among Australian Aborigines. In 1841 G. A. Robinson (Kenyon 1928:165) recorded that a few of the children of the Burrumbeet of northern Victoria had their heads artificially flattened. Robinson does not describe the method by which the crania were deformed and makes no other reference to the practice. I have examined over 1000 recent Australian Aboriginal crania from Victoria and the Murray River Valley and found no evidence of artificial deformation.

Brierly (1848-1850) and Macgillivray (1852) both present detailed descriptions of infant head pressing in Cape York. ‘Pressure is made by the mother with her hands . . . one being applied to the forehead and the other to the occiput, both of which are thereby flattened, while the skull is rendered proportionally broader and longer than it would naturally have been’ (Macgillivray 1852:12). Further north, in the islands of Torres Strait, head pressing was recorded by Miklouho-Maclay (1880) and Haddon (1912:7-9). In his report Haddon describes the head-pressed crania at Mabuiag as being ‘low in the forehead, flat at the back and not too well developed above’.

Head pressing would produce a more subtle and variable deformation of the vault than head binding and this was probably the method employed on the deformed Coobool and Kow Swamp crania. At Coobool and Kow Swamp there is a fine gradation from the crania that are obviously deformed into those which show no evidence of deformation. This creates problems of definition. Three crania at Coobool (CC 35, CC 41 and CC 66) and one at Kow Swamp (KS 1) have long flat frontal bones without possessing great basi-bregmatic height. The frontal curvature indices for each of these crania (range 14.3-15.8) are well below the modem Murray Valley range (19-26) and the length of the frontals (Nasion-Bregma range 119128) are either at the top of, or exceed, the modern range (102120). Basi-bregmatic height (range 139-142) while towards the top of the modern range (126-143) is not great given the overall size of the crania. Parietal curvature in the 3 Coobool crania (range 22-23) is at the top of the modern range (17-23), while that in KS 1 is only moderate (19). The occipital in KS 1 is well developed with a good occipital bun and torus, while the Coobool occipitals are close to the modern mean in length (Opisthion-Lambda range 96-105) and curvature (range 25-30).

Whether or not these particular 4 crania are classified as artificially deformed ultimately depends on subjective factors of weighting. It is conceivable that crania of this morphology could be produced by head pressing, with gross deformation evident only in the frontals, but a survey of the literature on artificial cranial deformation has not revealed any similar crania. The difficulty is increased through the lack of adequate reference material. The artificially deformed crania in Australian collections were collected primarily for their novelty value, with the grossly deformed crania possibly being over represented. A more complete study would look at the within population gradation from the deformed to the undeformed range. Ehtnographic accounts of artificial deformation all stress the great within-population variability in deformed crania (Dingwall 1931).

The major implications of this analysis relate to the previous interpretations of the significance of the Kow Swamp crania. Morphological and statistical comparisons have differentiated the Kew Swamp crania from ‘modern’ Australian Aboriginal crania (Thorne 1975; Pietrusewsky 1979) and a more gracile, group of Pleistocene Aboriginal crania including Mungo 1, Mungo 3 and Keilor (Thome 1977; Thorne and Wilson 1977). Recently the first detailed argument for a regional clade (a fossil sequence showing both continuity over time and differentiation from other contemporary morphological clades) containing the Indonesian *Homo erectus* crania and the Kow Swamp-

Cohuna material has been presented (Thorne and Wolpoff 1981).

In their multivariate statistical comparison of the Kow Swamp crania with a 'modern' Victorian series Thorne and Wilson (1977) found that the major distinguishing features were fronto-facial in origin. They argue that this indicates major morphological changes have occurred in the facial and frontal regions of Aboriginal crania from northern Victoria over the last 9000-10,000 years. Pietrusewsky (1979) obtained similar results. The most aberrant sample in this entire analysis was Kow Swamp, which was never found to cluster with any of his prehistoric or modern samples. Clearly, direct statistical comparisons between artificially deformed and undeformed crania would be expected to yield aberrant results. Work in progress, using the apparently undeformed Coobool crania and taking into account the effects of deformation on the remaining Coobool and Kow Swamp crania, indicates that the major distinguishing feature of the Kow Swamp and Coobool crania is size rather than morphology. Morphologically, and in the case of Keilor metrically, the Pleistocene cgracile' group (Mungo, 1, Mungo 3 and Keilor) were found to fall within the range of variation exhibited by this material.

Weidenreich (1946) was the first to draw attention to the morphological similarities between the middle Pleistocene *Homo erectus* crania from Indonesia and the late Pleistocene and Holocene Australian Aboriginal crania. Thorne and Wolpoff (1981) argue that evidence of a local morphological continuity containing these crania is found in the vault and face. Features which they find are suggestive of this clade relation are flatness of the frontal in the sagittal plane, the posterior position of minimum frontal breadth, the relatively horizontal orientation of the inferior supra-orbital borders, the presence of a distinct pre-bregmatic eminence and a low position of maximum parietal breadth. Several of these features (flatness of the frontal, a pre-bregmatic eminence and a low position of maximum bi-parietal breadth) which are present in Kow Swamp 5, Kow Swamp 7, and Cohnna. are now seen to be the result of deformation in these crania. This does not detract from the general argument for regional continuity which is supported by the size and morphology of the orofacial complex in the Coobool-Kow Swamp-Cohuna crania.

Features supportive of Thorne, and Wolpoff's argument are most apparent in the mandibles, palates and dentitions of the Coobool and Kow Swamp crania. The Coobool and Kow Swamp mandibles are large and robust with great symphyseal height (Coobool n=14, R 39.1; Kow Swamp n = 5, R 38.0; Murray Valley n- 43, X 36.2) and thickness (Coobool n=14, *R* 16.5; Kow Swamp n = 5, R 16.2; Murray Valley n=43, X 15.8). The mandibular rami are tall relative to mandibular length with broad robust condyles and high arched coronoid processes. Posteriorly the mandibles are distinguished by marked gonial eversion, deep masseteric fossae and great bigonial breadth (Coobool n=9, *R* 110.5; Kow Swamp n=2, R 121.0 Murray Valley n=38, *R* 98.6). Anteriorly the chin region is typically high and negative with little incurvature. The lateral prominence is in most cases extremely pronounced relative to the Australian Aboriginal mandibles from Roonka, Broadbeach, Chowilla, Swanport and the Murray Valley I examined. The Coobool dentitions are the largest in any Australian Aboriginal series and the palates are extremely broad and high. The maximum alveolar breadth in the Coobool series (83.Omm) exceeds the recorded Australian range and the mean (n = 14, R 73.2) is significantly higher (P-.000) than the modern Murray Valley mean (n= 47, *R* 69.3).

Conclusion

Artificial deformation is a component in the variation in Pleistocene Aboriginal crania from the Murray River Valley. The probable method of deformation was repetitive pressure by the mother's hands on the front and back of the infant's cranium. This results in a pronounced flattening of the frontal and occipital and an increase in cranial height. Crania which this analysis suggests are deformed are Kow Swamp 5 and 7, Cohuna, Coobool 01, 49 and 65. The radiocarbon date of 13,000-±:280 (ANU 1236) on shell associated with the grave of KS 5 (Thorne 1975) appears to be the oldest positively dated record of this practice.

Arguments as to the affinities between the Indonesian *Homo erectus* and Kow Swamp crania (Thorne and Wolpoff 1981) are modified but not negated by this analysis. The regional clade described by Thorne and Wolpoff is supported by the size and morphology of the orofacial complex in the Coobool crania.

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