Bull. Natn. Sci. Mus., Tokyo, Ser. D, **18**, December 22, 1992

Poor Swelling of the Parietal Tuber Associated with the Strong Occlusal Wear of the Maxillary First Molar

By

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Abstract In order to elucidate the formation mechanism of the parietal tuber, the correlations of the bregma-asterion arc with other cranial measurements were examined by means of the principal component analysis, taking account of the sex differences, the position of euryon and the degree of occlusal wear of the maxillary first molar. In result, it was found that the factor loadings of the principal component (PC) highly correlated with the b-ast arc had a significant rank correlation with those of the PC on dental wear differences. The PC on the positions of euryon also had a significant rank correlation with the same PC on dental wear differences in their factor loading variation patterns. From these findings, it was inferred that some factors causing dental wear such as biomechanical stress and/or aging were associated with the undeveloped or decreased swelling of the parietal tuber.

It is well known that the parietal tuber is more strongly developed in children and females than in adult males. In fact, KANAZAWA (1979), investigating the shape of the parietal bones by the method of moiré contourography, quantitatively demonstrated the presence of sex difference in the relative heights of landmarks scattered on the lateral regions of the parietal bones. On the other hand, it has been said that cranial shape is, ontogenetically, determined by the shape of the brain (SULLIVAN, 1978). If the cranial shape is really determined mainly by the brain shape, it should be considered that the brain shape is different between children and adults or between males and females. In addition to the brain shape, however, there may be many factors which affect the cranial shape and are associated with age or sex differences, *e.g.*, body size, the amount of muscles, the kind and amount of foodstuffs, *etc.*

In the present study, an attempt was made to search for some of such factors, especially affecting the formation of the parietal tuber, through the analysis of correlations between various cranial measurements, sex, euryon position and dental wear.

Materials

The skulls of 158 males and 27 females of the Edo period (1603–1867 A.D.) from Fukagawa Unkoin Temple in Tokyo were measured by the present author for an investigation of the parietal tuber. This sample was collected by Emeritus Prof. Hisashi SUZUKI of the University of Tokyo, and is now housed in the Department of

Anthropology and Prehistory, University Museum, the University of Tokyo.

Methods

The cranial measurements dealt with here are shown in Table 1, 3, or others. All of them but the bregma-asterion arc and chord were measured after MARTIN and SALLER (1957). In the present study, the bregma-asterion arc and inter-parietal-tuber breadth, especially the former, were used as measures for the development of the parietal tubera.

In addition, sex, the position of euryon and the degree of occlusal wear of the maxillary first molar were recorded. Positions of euryon were classified according to MARTIN and SALLER (1957) as follows.

p. t. = Maximum breadth on the parietal tubera
p. m. = Maximum breadth in the middle of the parietal bones between the parietal tuber and the lower margin
p. i. = Maximum breadth on the lowest portions of the parietal bones
s. s. = Maximum breadth on or near the squamosal sutures
t. s. = Maximum breadth on the upper margins of the temporal squamae
t. p. = Maximum breadth on the posterior portions of the temporal squamae

The degree of dental wear was observed after BROCA's grading system (MARTIN and SALLER, 1957).

In order to examine the influences of sex, the position of euryon and dental wear on cranial measurements, the skulls were divided into several groups, that is, first, into male and female groups; and, then, into three groups according to the three positions of euryon, p.t., p.m. and s.s., in each sex; or, similarly, into two groups according to the two wear grades, 1 and 2, in each sex. The rest of the above grades were not used in either case of the position of euryon and the degree of dental wear for the following analyses because the sample sizes for them were too small.

The significance of differences in means and variances was assessed using the STUDENT's *t*-test or COCHRAN's approximate significance test (SNEDECOR and COCHRAN, 1967) and the *F*-test, respectively. The homogeneity or independence test for non-metric characters was carried out using the chi-square test.

To grasp overall interrelationships among cranial measurements, the principal component analysis (LAWLEY and MAXWELL, 1963; OKUNO *et al.*, 1971, 1976; TAKEUCHI and YANAI, 1972) was used. The matrices analyzed are the correlation matrix for the whole sample of each sex as well as the standardized within- and between-group covariance matrices for the subsamples classified on the basis of the position of euryon, the degree of dental wear, or sex. The decomposition of a correlation matrix into such standardized within- and between-group covariance matrices was done by TAKEUCHI and YANAI's (1972) dummy variable method.

Finally, the SPEARMAN and KENDALL rank correlation coefficients (SIEGEL, 1956) were employed to evaluate the resemblance between two sets of between-subsample differences in the Q-mode variation patterns of the between-subsample differences standardized in R-mode or the resemblance between two principal components in the factor loading variation patterns.

The calculations were performed with the mainframe, HITAC M-880 (VOS3) System, of the Computer Centre, the University of Tokyo. The programs used are STSTBT, X2TST, PCAFPP and RKCNCT, which were written by the present author in FORTRAN for the significance tests of differences in means and variances, chi-square tests, principal component analyses, and rank correlation coefficients, respectively.

Results

The means, standard deviations and coefficients of variation for the cranial measurements dealt with here are listed in Table 1. The between-sex differences in means for most cranial measurements including bregma-asterion arc were found to be significant at the 5% level, but it is noteworthy that those for both inter-parietal-tuber and inter-frontal-tuber breadths were not.

The chi-square test showed that there was no sex difference in the distribution of the positions of eurya (Table 2). In the case of the occlusal wear of the maxillary first molar, however, it was found that the tooth was significantly more worn in males than in females (Table 2), though the sample size for females was very small.

Table 3 shows the differences in cranial measurements between male subgroups classified according to the position of euryon. Similar comparisons for females were not made because of the small sample size. It is clear from Table 3 and Fig. 1 that the inter-parietal-tuber breadth and bregma-asterion arc consistently show significant between-subgroup differences in means, suggesting a significant association between the euryon position and these two cranial measurements or, probably, the parietal tuber. It should be noted here, however, that there are no significant between-subgroup differences in the maximum cranial breadth (Table 3 and Fig. 1).

Although the degree of dental wear for the maxillary first molar (UM1) was recorded to grasp the relative age of each individual in the beginning, the grouping based on the degree of dental wear showed a surprising result. As shown in Table 4 and Fig. 1, the individuals who have the more worn UM1 have significantly smaller inter-parietal-tuber breadth, smaller basibregmatic height and greater bizygomatic breadth.

As both euryon position and dental wear were suggested to be associated with the development of the parietal tuber in the above analyses, the significance for the direct association between the former two was tested using the chi-square test (Table 5). But no significant association was found by this test. Then, for the same purpose, Q-mode rank correlation coefficients were estimated between the standardized between-subgroup differences on euryon position, dental wear and sex in cranial measurements (Table 6 and Fig. 1). In this case, significant rank correlation coefficients

Table 1. Basic statistics for the cranial measurements of the early modern Edo people in Japan and between-sex differences in the means and variances.

Variable[1)]			Male				Female				Sex diff.	
			n	Mean	S.D.	C.V.	*n*	Mean	S.D.	C.V.	t[2)]	F[3)]
1	Cranial length		153	182.1	6.1	3.4	26	173.8	7.7	4.4	6.13***	1.56
5	Cranial base ln.		131	101.7	4.1	4.0	24	97.0	4.1	4.3	5.28***	1.03
8	Cranial breadth		158	140.0	5.3	3.8	27	135.4	3.9	2.9	4.34***	1.78
8 (1)	Int.-p.-t. br.[4)]		156	126.9	7.4	5.8	27	124.0	6.4	5.1	1.91	1.35
9	Min. front. br.		152	93.9	4.5	4.7	25	90.6	4.7	5.1	3.41***	1.09
9 (2)	Int.-f.-t. br.[5)]		155	51.5	5.5	10.7	25	49.5	4.0	8.2	1.72	1.84
12	Biasterionic br.		154	109.5	4.5	4.1	26	104.9	3.9	3.7	4.88***	1.32
14	Min. cranial br.		124	76.7	5.9	7.7	22	71.3	4.5	6.4	4.09***	1.71
17	Basibregmatic ht.		134	137.0	5.0	3.7	25	133.0	4.6	3.5	3.68***	1.18
25	Med. sagit. arc		143	374.0	12.3	3.3	24	359.7	14.4	4.0	5.14***	1.37
26	Frontal arc		149	127.0	6.3	5.0	26	121.8	4.7	3.9	4.05***	1.79
27	Parietal arc		156	126.6	7.3	5.8	27	123.2	8.1	6.6	2.23*	1.22
27 (1)	T.-p. arc,[6)]	L	132	106.0	4.6	4.4	24	100.3	4.1	4.1	5.70***	1.30
		R	132	106.5	5.1	4.8	25	100.3	3.8	3.8	5.79***	1.78
27 (2)	F.-p. arc,[7)]	L	138	111.0	5.1	4.6	24	107.0	5.2	4.9	3.55***	1.08
		R	141	112.3	5.7	5.1	25	105.6	4.9	4.7	5.53***	1.37
27 (3)	O.-p. arc,[8)]	L	153	93.0	5.7	6.2	27	89.1	4.9	5.5	3.37***	1.38
		R	155	92.1	5.7	6.2	26	90.3	5.4	6.0	1.46	1.10
BAA	b-ast arc,[9)]	L	155	163.0	7.7	4.7	27	157.4	6.8	4.3	3.51***	1.26
		R	154	165.4	8.0	4.8	26	159.3	6.2	3.9	3.68***	1.68
28	Occipital arc		151	119.1	7.7	6.5	25	112.4	7.6	6.8	4.02***	1.02
28 (1)	Up. sq. arc[10)]		156	79.6	7.3	9.2	27	74.4	8.0	10.8	3.36***	1.20
29	Frontal chord		149	111.2	4.6	4.1	26	106.7	3.7	3.5	4.77***	1.50
30	Parietal chord		157	113.7	5.7	5.0	27	110.8	6.5	5.9	2.39*	1.30
30 (1)	T.-p. chd.,[11)]	L	135	101.0	4.2	4.2	24	95.5	4.0	4.2	5.85***	1.15
		R	139	101.2	4.4	4.3	25	95.2	3.9	4.1	6.47***	1.28
30 (2)	F.-p. chd.,[12)]	L	139	97.1	4.0	4.1	24	93.5	4.4	4.7	4.02***	1.17
		R	141	97.0	4.4	4.6	25	91.9	3.5	3.8	5.39***	1.62
30 (3)	O.-p. chd.,[13)]	L	154	85.1	4.8	5.6	27	81.4	4.4	5.4	3.76***	1.18
		R	155	85.0	4.8	5.6	26	82.7	4.7	5.6	2.25*	1.06
BAC	b-ast chd.,[14)]	L	155	135.8	4.4	3.2	27	129.1	5.2	4.0	7.08***	1.41
		R	155	136.5	4.8	3.5	26	130.6	5.3	4.1	5.77***	1.23
31	Occipital chord		151	98.7	4.7	4.8	25	96.4	5.3	5.5	2.29*	1.26
31 (1)	Up. sq. chd.[15)]		156	72.3	6.2	8.6	27	68.0	7.3	10.8	3.25***	1.40
45	Bizygomatic br.		95	135.2	4.9	3.6	15	123.9	4.0	3.3	8.43***	1.48
48	Upper facial ht.		107	71.9	3.8	5.2	20	67.8	3.0	4.5	4.69***	1.55

[1)] Variable number according to MARTIN and SALLER (1957); [2)] Two-tailed t-test; [3)] Two-tailed F-test; [4)] Inter-parietal-tuber breadth; [5)] Inter-frontal-tuber breadth; [6)] Tempero-parietal arc; [7)] Fronto-parietal arc; [8)] Occipito-parietal arc; [9)] The shortest arc from bregma to asterion on the surface of the parietal; [10)] Upper squamous arc of the occipital; [11)] Tempero-parietal chord; [12)] Fronto-parietal chord; [13)] Occipito-parietal chord; [14)] The linear distance between bregma and asterion; [15)] Upper squamous chord of the occipital.

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

Table 2. The distribution of the positions of eurya and the degree of occlusal wear of the maxillary first molar.

	n	Score (%)				Sex difference	
		0	1	2	3	d.f.	χ^2
Position of euryon[1]:							
Male	158		8.86	19.62	71.52		
Female	27		11.11	18.52	70.37	2	0.15
Wear of UM1[2]:							
Male	75	0.00	33.33	66.67	—		
Female	11	0.00	72.73	27.27	—	1	4.74*

[1] The classification for the position of euryon according to MARTIN and SALLER (1957): "1" designates "p.t."; "2," "p.m."; and "3," "s.s." In the present sample, only one male had eurya at the position of "t.p.," but was excluded from the analyses.

[2] The grades for the occlusal wear are according to BROCA (MARTIN and SALLER, 1957). In the present sample, only one male showed the grade of "3," but was excluded from the analyses.

* $P<0.05$.

were found between the differences on euryon position and dental wear at the 1% level, as expected, but not between those on euryon position and sex.

Tables 7 and 8 show the results of the principal component analyses (PCA) for the correlation matrices on cranial measurements from the male and female samples, respectively. According to the results from the male sample which is larger in number than the female one, the principal component having the highest correlation with the bregma-asterion arc (PC V in Table 7) also have high correlations with the inter-parietal-tuber breadth and basibregmatic height, but not with the maximum cranial breadth (Fig. 2). This is consistent with the results of univariate analyses on the position of euryon (Table 3 and Fig. 1).

Tables 9, 10 and 11 reveal the results of the principal component analyses for the standardized within- and between-group covariance matrices on cranial measurements from the subgroups classified on the basis of euryon position, dental wear and sex, respectively. From each of these principal component analyses, the principal components (PCs) which had the highest rank correlations with the PC V relating to the parietal tuber (Table 7) and with the between-group PC I on euryon position (Table 9) were selected and are shown in Table 12 and Fig. 2. In result, the between-group PC I on dental wear (Table 10) was found to have significant rank correlations both with the PC V on the parietal tuber (Table 7) and with the between-group PC I on euryon position (Table 9). And the between-group PC I on sex (Table 11) also have a significant rank correlation with the between-group PC I on euryon position (Table 9).

From comparisons with the within-group PCs (Table 12), the above associations may further be confirmed. That is to say, the PC V on the parietal tuber (Table 7) has the lowest rank correlation in absolute value with the within-group PC V on dental wear (Table 10) of the within-group PCs on sex, euryon position and

Table 3. Differences in cranial measurements between the male

Variable[1]		1 (p.t.)			2 (p.m.)		
		n	Mean	Var.	*n*	Mean	Var.
1	Cranial length	14	185.4	63.79	31	180.1	43.05
5	Cranial base ln.	11	103.2	27.36	30	99.9	15.54
8	Cranial breadth	14	141.7	21.76	31	141.0	40.10
8 (1)	Int.-p.-t. br.	14	137.0	29.85	31	129.9	48.96
9	Min. front. br.	13	94.9	21.24	31	93.5	21.46
9 (2)	Int.-f.-t. br.	13	53.4	47.42	31	51.8	22.76
12	Biasterionic br.	14	107.6	19.94	31	108.9	20.73
14	Min. cranial br.	13	75.5	20.27	24	76.7	17.88
17	Basibregmatic ht.	11	139.8	33.36	30	136.8	9.66
25	Med. sagit. arc	13	380.5	157.89	29	373.8	98.74
26	Frontal arc	14	128.6	39.34	30	128.4	31.43
27	Parietal arc	14	128.0	27.38	31	125.6	76.71
27 (1)	T.-p. arc, L	13	107.3	38.40	27	105.6	21.55
	R	12	105.8	38.33	27	106.0	14.69
27 (2)	F.-p. arc, L	13	112.2	16.19	28	113.3	28.64
	R	12	112.4	37.90	29	114.4	22.39
27 (3)	O.-p. arc, L	14	95.4	47.65	31	92.9	32.72
	R	14	93.8	34.80	31	92.0	33.67
BAA	b-ast arc, L	14	169.1	11.98	31	165.1	38.80
	R	14	170.2	24.80	31	167.6	26.30
28	Occipital arc	13	122.7	77.73	29	118.6	64.54
28 (1)	Up. sq. arc	14	83.4	51.32	31	79.9	51.98
29	Frontal chord	14	112.6	25.79	30	112.0	16.10
30	Parietal chord	14	115.3	22.68	31	112.7	48.33
30 (1)	T.-p. chd., L	13	102.5	32.27	29	100.4	17.83
	R	12	101.7	25.88	29	100.7	14.31
30 (2)	F.-p. chd., L	13	96.8	13.31	29	98.1	20.19
	R	12	96.3	15.66	29	98.0	17.07
30 (3)	O.-p. chd., L	14	86.6	29.48	31	84.9	21.62
	R	14	85.6	22.09	31	85.0	22.43
BAC	b-ast chd., L	14	137.7	16.37	31	135.9	18.36
	R	14	137.4	19.48	31	136.7	17.46
31	Occipital chord	13	101.2	29.64	29	98.2	20.24
31 (1)	Up. sq. chd.	14	75.5	57.81	31	72.2	33.74
45	Bizygomatic br.	10	133.1	16.77	17	133.6	16.62
48	Upper facial ht.	10	74.2	16.18	24	71.8	18.78

1) Variable number according to MARTIN and SALLER (1957).
2) Two-tailed *t'*-test, *i.e.*, COCHRAN's approximate significance test for the difference between two
3) Two-tailed *F*-test.
$*P<0.05$; $**P<0.01$; $***P<0.001$.

subgroups classified on the basis of the positions of eurya.

3 (s.s.)			Between-subgroup difference					
			1 vs. 2		2 vs. 3		1 vs. 3	
n	Mean	Var.	t'[2]	F[3]	t'	F	t'	F
108	182.2	31.32	2.14*	1.48	−1.59	1.38	1.44	2.04*
90	102.2	14.46	1.89	1.76	−2.77**	1.08	0.62	1.89
113	139.5	24.77	0.40	1.84	1.22	1.62	1.64	1.14
111	124.8	40.44	3.68***	1.64	3.65***	1.21	7.71***	1.36
108	93.9	19.38	0.96	1.01	−0.48	1.11	0.76	1.10
111	51.1	30.06	0.75	2.08	0.68	1.32	1.14	1.58
109	109.9	19.94	−0.89	1.04	−1.05	1.04	−1.79	1.00
87	76.9	42.18	−0.74	1.13	−0.19	2.36*	−0.93	2.08
93	136.7	28.69	1.63	3.45**	0.12	2.97**	1.68	1.16
101	373.2	161.93	1.71	1.60	0.27	1.64	1.98	1.03
105	126.4	42.25	0.07	1.25	1.65	1.34	1.19	1.07
111	126.8	50.84	1.13	2.80	−0.67	1.51	0.79	1.86
92	105.9	19.42	0.87	1.78	−0.30	1.11	0.77	1.98
93	106.7	28.01	−0.09	2.61*	−0.77	1.91	−0.47	1.37
97	110.2	24.05	−0.68	1.77	2.68**	1.19	1.64	1.49
100	111.8	34.43	−0.99	1.69	2.49*	1.54	0.36	1.10
108	92.8	30.66	1.21	1.46	0.10	1.07	1.40	1.55
110	91.9	32.01	0.94	1.03	0.08	1.05	1.13	1.09
110	161.6	62.54	2.81**	3.24*	2.58*	1.61	6.34***	5.22**
109	164.2	74.62	1.59	1.06	2.81**	2.84**	3.86***	3.01*
109	118.8	55.39	1.45	1.20	−0.14	1.17	1.53	1.40
111	79.1	53.34	1.51	1.01	0.54	1.03	2.10	1.04
105	110.8	21.53	0.44	1.60	1.33	1.34	1.28	1.20
112	113.8	29.96	1.43	2.13	−0.79	1.61	1.07	1.32
93	101.0	16.26	1.14	1.81	−0.57	1.10	0.92	1.99
98	101.3	20.01	0.62	1.81	−0.79	1.40	0.23	1.29
97	96.8	15.26	−0.99	1.52	1.40	1.32	0.00	1.15
100	96.7	20.68	−1.27	1.09	1.42	1.21	−0.39	1.32
109	84.9	22.28	1.04	1.36	−0.01	1.03	1.14	1.32
110	84.9	23.56	0.45	1.02	0.03	1.05	0.53	1.07
110	135.5	19.19	1.36	1.12	0.49	1.05	1.93	1.17
110	136.3	24.79	0.44	1.11	0.48	1.42	0.82	1.27
109	98.6	21.23	1.71	1.46	−0.38	1.05	1.64	1.40
111	71.9	36.98	1.46	1.71	0.20	1.10	1.69	1.56
68	135.9	25.99	−0.34	1.01	−1.94	1.56	−1.96	1.55
73	71.7	12.03	1.55	1.16	0.12	1.56	1.89	1.35

means with different variances (SNEDECOR and COCHRAN, 1967).

Table 4. Differences in cranial measurements between the male subgroups classified on the basis of the degree of occlusal wear for the maxillary first molar.

Variable[1)]		Score 1			Score 2			Difference	
		n	Mean	Var.	n	Mean	Var.	t'[2)]	F[3)]
1	Cranial length	25	181.4	45.50	49	183.2	36.62	−1.13	1.24
5	Cranial base ln.	23	101.2	16.24	47	101.7	13.16	−0.55	1.23
8	Cranial breadth	25	140.4	33.67	50	139.0	17.88	1.07	1.88
8 (1)	Int.-p.-t. br.	25	128.8	40.69	49	124.7	46.25	2.52*	1.14
9	Min. front. br.	25	93.0	16.12	50	94.6	17.51	−1.58	1.09
9 (2)	Int.-f.-t. br.	25	50.1	12.99	50	52.1	37.22	−1.83	2.87**
12	Biasterionic br.	25	109.1	27.36	49	110.0	19.41	−0.75	1.41
14	Min. cranial br.	24	75.4	19.56	48	77.0	64.00	−1.11	3.27**
17	Basibregmatic ht.	23	139.3	17.15	47	136.5	21.91	2.58*	1.28
25	Med. sagit. arc	25	378.0	173.99	49	375.3	124.10	0.90	1.40
26	Frontal arc	25	129.9	42.66	50	127.5	33.72	1.56	1.27
27	Parietal arc	25	127.3	60.13	50	125.9	56.71	0.71	1.06
27 (1)	T.-p. arc, L	24	106.6	15.64	47	105.9	20.81	0.72	1.33
	R	25	107.9	16.83	45	105.9	32.48	1.74	1.93
27 (2)	F.-p. arc, L	25	112.3	44.06	48	110.8	15.94	1.04	2.76**
	R	25	113.8	29.22	45	111.6	21.02	1.75	1.39
27 (3)	O.-p. arc, L	25	92.6	42.99	48	94.6	28.71	−1.29	1.50
	R	25	91.2	49.50	49	93.7	29.25	−1.57	1.69
BAA	b-ast arc, L	25	164.8	46.44	49	161.9	100.45	1.45	2.16*
	R	25	167.7	34.48	48	164.4	111.05	1.72	3.22**
28	Occipital arc	25	119.9	83.08	49	120.8	65.81	−0.42	1.26
28 (1)	Up. sq. arc	25	80.0	52.12	49	80.8	62.71	−0.41	1.20
29	Frontal chord	25	113.3	24.31	50	111.6	19.80	1.51	1.23
30	Parietal chord	25	113.8	31.50	50	113.3	37.32	0.34	1.19
30 (1)	T.-p. chd., L	25	101.3	13.31	47	101.1	18.41	0.27	1.38
	R	25	102.2	13.64	45	101.1	27.53	0.95	2.02
30 (2)	F.-p. chd., L	25	98.0	28.12	48	97.2	10.44	0.70	2.70**
	R	25	98.4	21.99	45	96.4	13.75	1.76	1.60
30 (3)	O.-p. chd., L	25	85.4	35.74	49	86.1	18.84	−0.55	1.90
	R	25	84.3	39.81	49	86.4	19.50	−1.50	2.04*
BAC	b-ast chd., L	25	136.7	16.96	49	136.2	20.33	0.49	1.20
	R	25	137.6	22.83	49	137.0	18.58	0.53	1.23
31	Occipital chord	25	99.8	31.27	49	99.1	22.55	0.50	1.39
31 (1)	Up. sq. chd.	25	72.8	32.17	49	72.5	49.09	0.19	1.53
45	Bizygomatic br.	21	133.6	22.16	40	136.3	22.56	−2.13*	1.02
48	Upper facial ht.	25	72.1	16.53	49	72.3	11.89	−0.22	1.39

[1)], [2)] and [3)] See the footnote to Table 3.
$*P<0.05$; $**P<0.01$; $***P<0.001$.

Table 5. Significance tests for the independence of the position of euryon and the degree of occlusal wear of the maxillary first molar in males.

Wear of UM1[2]	Position of euryon[1]			Total	χ^2-test		
	1	2	3		d.f.	χ^2	Prob.
1	4 (16.0%)	7 (28.0%)	14 (56.0%)	25			
2	4 (8.0%)	12 (24.0%)	34 (68.0%)	50	2	1.48	0.48

[1] and [2] See the footnote to Table 2.

Table 6. Rank correlations between the t- or t'-values for the euryon position differences and those for the dental wear differences and sex differences in cranial measurements.

	No. of pairs	SPEARMAN rank correlation		KENDALL rank correlation	
		rho	Prob.	tau	Prob.
eu[1]—Wear[2]	36	0.5458	<0.001	0.3835	<0.01
eu[1]—Sex[3]	36	−0.2615	0.10<, <0.20	−0.1783	0.10<, <0.20

[1] t'-values for the subgroups 2 and 3 classified on the basis of the position of euryon (Table 3).
[2] t'-values for the subgroups 1 and 2 classified on the basis of the degree of wear of the maxillary first molar (Table 4).
[3] t-values for the sex differences (Table 1).

dental wear, implying that the dental wear is most highly associated with the parietal tuber among the three factors.

Similarly, the between-group PC I on euryon position (Table 9) has a lower rank correlation in absolute value with the within-group PC IV on dental wear (Table 10) than with the within-group PC IV on sex (Table 11).

Discussion

In the present study, factors affecting the formation of the parietal tuber were sought by applying the principal component analysis (PCA) to the correlation matrices on various cranial measurements, sex, euryon position and dental wear. The principal component (PC) which had higher correlations with inter-parietal-tuber breadth and bregma-asterion arc was found further to have a relatively high correlation with basibregmatic height and, at the same time, an inverse correlation with bizygomatic breadth (Table 7 and Fig. 2). In the following, some consideration is presented mainly to the interrelationships between this principal component on the parietal tuber and other PCs from different PCAs.

Sex and the parietal tuber

In spite of the significant sex differences in means for most cranial measurements, the sex differences for both inter-parietal-tuber breadth and inter-frontal-tuber breadth

Table 7. Principal component analysis of the correlation matrix on cranial measurements of males.[1]

	Variable[2]		Factor loadings									Total variance (%)
			PC I	II	III	IV	V	VI	VII	VIII	IX	
1	Cranial length		.62*	.17	−.12	.48*	−.33*	.09	−.03	−.13	−.23	84.2
5	Cranial base ln.		.24	−.25	−.26	.45*	−.09	−.54*	.14	−.32*	−.08	81.3
8	Cranial breadth		.62*	−.21	.08	−.30*	−.00	−.36*	−.33*	.14	.03	78.8
8 (1)	Int.-p.-t. br.		.50*	−.12	.06	−.35*	.37*	−.23	−.29	.01	−.10	67.7
9	Min front. br.		.42*	.10	−.34*	.00	−.42*	−.25	.26	.22	−.15	67.9
9 (2)	Int.-f.-t. br.		.08	.18	−.32*	−.18	−.16	−.08	.27	.38*	−.62*	80.3
12	Biasterionic br.		.57*	.25	.03	.09	−.39*	−.19	−.24	.09	.37*	79.2
14	Min. cranial br.		.32*	−.22	.04	.19	−.12	−.49*	.32*	.06	.18	57.9
17	Basibregmatic ht.		.45*	−.18	−.28	−.18	.30	−.23	.28	−.47*	.11	80.2
25	Med. sagit. arc		.82*	.15	−.25	.06	−.05	.33*	.04	−.20	−.08	92.4
26	Frontal arc		.60*	−.42*	.07	−.23	−.24	.33*	−.04	−.19	−.25	85.5
27	Parietal arc		.15	.09	−.87*	.21	−.01	.20	−.04	−.06	.14	90.7
27 (1)	T.-p. arc,	L	.51*	−.49*	.34*	.40*	.22	.12	−.01	.14	.10	86.1
		R	.50*	−.49*	.27	.47*	.08	.05	−.05	.18	−.08	82.5
27 (2)	F.-p. arc,	L	.46*	−.40*	−.10	−.52*	−.06	−.00	.13	.18	.15	73.0
		R	.57*	−.48*	−.06	−.35*	−.23	.08	.11	−.00	.01	74.7
27 (3)	O.-p. arc,	L	.66*	.53*	.05	−.12	−.20	−.13	−.16	−.00	−.08	81.7
		R	.64*	.59*	.07	−.00	−.09	.10	−.21	.08	.03	82.2
BAA	b-ast arc,	L	.47*	−.05	−.36*	−.09	.60*	−.21	−.10	.19	−.12	83.6
		R	.52*	−.11	−.36*	−.01	.49*	−.18	−.21	.09	−.19	78.0
28	Occipital arc		.65*	.47*	.40*	.06	.11	.09	.17	−.10	−.06	86.7
28 (1)	Up. sq. arc		.60*	.46*	.39*	−.06	.21	.05	.30	−.02	−.04	86.9
29	Frontal chord		.65*	−.45*	.05	−.21	−.19	.24	−.09	−.27	−.13	86.8
30	Parietal chord		.26	.14	−.80*	.30	−.06	.21	−.01	−.03	.12	88.1
30 (1)	T.-p. chd.,	L	.57*	−.42*	.29	.47*	.17	.18	.01	.12	.06	88.0
		R	.57*	−.41*	.27	.50*	.07	.13	−.06	.17	−.12	88.5
30 (2)	F.-p. chd.,	L	.56*	−.43*	−.00	−.50*	−.14	.02	.12	.10	.24	84.4
		R	.63*	−.49*	.00	−.30	−.28	.13	.09	.04	.03	83.3
30 (3)	O.-p. chd.,	L	.72*	.47*	.04	−.14	−.18	−.12	−.17	.01	.02	83.6
		R	.71*	.50*	.05	−.03	−.12	.07	−.21	.09	.10	84.4
BAC	b-ast chd.,	L	.72*	.07	−.42*	.08	.22	.04	.15	.07	.16	81.2
		R	.75*	.03	−.38*	.19	.19	.12	.01	.08	.13	82.0
31	Occipital chord		.62*	.40*	.39*	−.10	.19	.01	.25	−.16	.04	83.1
31 (1)	Up. sq. chd.		.62*	.44*	.35*	−.06	.29	.01	.28	−.01	.02	86.5
45	Bizygomatic br.		.32*	−.08	.25	.41*	−.42*	−.39*	.00	.00	.00	67.1
48	Upper facial ht.		.26	−.17	.11	−.02	.02	−.21	−.30*	−.49*	−.20	52.6
Total contrib. (%)			30.5	12.0	9.7	7.9	6.1	4.7	3.4	3.3	2.9	80.6
Cumulative prop. (%)			30.5	42.6	52.3	60.1	66.2	70.9	74.3	77.7	80.6	80.6

[1] The sample sizes for the correlation coefficients vary from 84 to 157.

[2] Variable number according to MARTIN and SALLER (1957).

* Greater than 0.30 in absolute value.

Table 8. Principal component analysis of the correlation matrix on cranial measurements of females.[1]

Variable[2]			Factor loadings PC I	II	III	IV	V	VI	Total variance (%)
1	Cranial length		.75*	−.15	−.50*	.27	.12	.18	95.1
5	Cranial base ln.		.53*	−.33*	−.51*	.27	−.07	−.25	79.0
8	Cranial breadth		.56*	.10	.05	−.56*	−.10	.27	71.9
8 (1)	Int.-p.-t. br.		.56*	.25	.19	−.35*	−.27	.10	62.3
9	Min. front. br.		.61*	−.07	−.04	−.01	−.50*	.34*	74.5
9 (2)	Int.-f.-t. br.		−.07	.26	−.21	.53*	−.56*	−.19	75.7
12	Biasterionic br.		.55*	.12	−.56*	−.21	−.34*	−.02	79.6
14	Min. cranial br.		.57*	−.02	−.00	−.35*	−.22	−.29	58.1
17	Basibregmatic ht.		.76*	−.14	.14	.08	−.08	.04	63.0
25	Med. sagit. arc		.94*	−.04	.06	.21	.13	.25	100.0
26	Frontal arc		.73*	−.25	.19	−.19	.36*	.03	80.4
27	Parietal arc		.56*	−.39*	.31*	.54*	−.21	.27	96.4
27 (1)	T.-p. arc,	L	.63*	−.48*	−.31*	.00	.27	−.13	81.7
		R	.58*	−.55*	−.33*	−.01	.17	−.19	81.9
27 (2)	F.-p. arc,	L	.74*	−.10	.46*	−.24	−.26	.06	88.8
		R	.45*	.03	.42*	−.03	−.21	−.69*	90.3
27 (3)	O.-p. arc,	L	.75*	.42*	−.38*	.07	.05	.07	88.5
		R	.77*	.47*	−.21	.01	.11	−.01	87.8
BAA	b-ast arc,	L	.82*	−.09	.33*	.12	−.06	.06	80.8
		R	.82*	.01	.37*	−.02	−.01	.02	82.0
28	Occipital arc		.76*	.56*	−.22	.05	.14	.03	96.1
28 (1)	Up. sq. arc		.75*	.48*	.01	.19	.11	.00	84.9
29	Frontal chord		.73*	−.19	.07	−.38*	.33*	.08	82.9
30	Parietal chord		.60*	−.38*	.21	.53*	−.19	.27	94.3
30 (1)	T.-p. chd.,	L	.73*	−.47*	−.21	.05	.15	−.21	86.4
		R	.72*	−.49*	−.23	.06	.14	−.23	88.8
30 (2)	F.-p. chd.,	L	.80*	−.14	.31*	−.31*	−.15	.06	87.2
		R	.59*	−.06	.39*	−.24	−.04	−.45*	76.0
30(3)	O.-p. chd.,	L	.81*	.39*	−.31*	−.02	.02	−.01	90.5
		R	.81*	.46*	−.19	−.06	.06	−.12	93.2
BAC	b-ast chd.,	L	.85*	−.18	.13	.27	−.13	−.01	86.7
		R	.88*	−.05	.22	.25	−.02	−.11	90.5
31	Occipital chord		.75*	.58*	−.05	−.06	.06	−.03	91.4
31 (1)	Up. sq. chd.		.75*	.49*	.13	.12	.05	.03	84.0
45	Bizygomatic br.		.40*	−.49*	−.30	−.58*	−.05	.34*	94.9
48	Upper facial ht.		−.14	−.27	−.51*	−.31*	−.68*	−.09	92.2
Total contribution (%)			47.2	11.0	8.6	7.5	5.5	4.5	84.4
Cumulative prop. (%)			47.2	58.2	66.8	74.3	79.9	84.4	84.4

1) Although the sample sizes for the correlation coefficents, in fact, vary from 14 to 27, the principal component analysis was carried out on the premise that the sample sizes were large enough.

2) Variable number according to MARTIN and SALLER (1957).

* Greater than 0.30 in absolute value.

Table 9. Principal component analyses of the standardized within-male subgroups classified on the

Variable[3]			Within-group							
			Factor loadings[2]							
			PC I	II	III	IV	V	VI	VII	VIII
1	Cranial length		.62*	-.20	.05	.46*	.44*	-.16	-.08	.01
5	Cranial base ln.		.15	10	.33*	.32*	.24	.52*	.04	-.29
8	Cranial breadth		.61*	.25	-.01	-.27	.09	.41*	-.14	.19
8 (1)	Int.-p.-t. br.		.52*	.11	-.08	-.25	-.14	.34*	-.14	.09
9	Min. front. br.		.41*	-.04	.22	-.11	.52*	.06	.25	.11
9 (2)	Int.-f.-t. br.		-.04	-.40*	.12	-.30*	.14	.13	.09	.48*
12	Biasterionic br.		.69*	-.21	.08	.11	.32*	.03	-.19	-.04
14	Min. cranial br.		.39*	.05	.05	-.09	.42*	.36*	.50*	.02
17	Basibregmatic ht.		.47*	.06	.35*	-.18	-.23	.24	.32*	-.54*
25	Med. sagit. arc		.82*	-.16	.25	.12	.03	-.31*	.07	-.07
26	Frontal arc		.60*	.50*	.09	-.13	.16	-.37*	-.00	-.16
27	Parietal arc		.11	-.29	.86*	.24	-.04	-.05	-.04	.07
27 (1)	T.-p. arc,	L	.36*	.59*	-.26	.50*	-.16	.14	.09	.12
		R	.52*	.54*	-.33*	.39*	-.11	.05	-.08	.09
27 (2)	F.-p. arc,	L	.47*	.47*	.24	-.37*	-.14	.05	.00	.32*
		R	.57*	.50*	.20	-.36*	.04	-.20	-.05	-.02
27 (3)	O.p. arc,	L	.70*	-.42*	-.18	-.12	.19	-.02	-.21	-.11
		R	.62*	-.60*	-.19	.07	.01	-.11	-.19	.07
BAA	b-ast arc,	L	.59*	-.10	.35*	.06	-.34*	.29	.04	.10
		R	.71*	-.14	.32*	.04	-.22	.13	-.13	.05
28	Occipital arc		.70*	-.36*	-.46*	.06	-.03	-.15	.15	-.03
28 (1)	Up. sq. arc		.60*	-.40*	-.54*	-.08	-.16	.04	.21	.02
29	Frontal chord		.60*	.54*	.09	-.18	.15	-.34*	-.06	-.20
30	Parietal chord		.19	-.35*	.76*	.29	.00	-.12	-.01	.10
30 (1)	T.-p. chd.,	L	.46*	.52*	-.23	.55*	-.12	.05	.04	.04
		R	.56*	.45*	-.32*	.50*	-.08	.03	-.12	.10
30 (2)	F.-p. chd.,	L	.59*	.49*	.19	-.41*	-.06	-.05	.06	.19
		R	.66*	.51*	.12	-.32*	.05	-.25	-.03	.02
30 (3)	O.-p. chd.,	L	.75*	-.37*	-.12	-.18	.08	.02	-.21	-.09
		R	.71*	-.52*	-.14	.01	.00	-.08	-.19	.08
BAC	b-ast chd.,	L	.68*	-.13	.44*	.14	-.27	.01	.17	-.07
		R	.73*	-.17	.36*	.24	-.30*	-.02	-.02	.07
31	Occipital chord		.68*	-.24	-.43*	-.21	-.18	-.07	.21	-.14
31 (1)	Up. sq. chd.		.63*	-.36*	-.49*	-.17	-.21	.11	.18	-.02
45	Bizygomatic br.		.34*	.12	-.23	.23	.57*	.08	.19	.12
48	Upper facial ht.		.15	.14	-.07	-.21	.16	.46*	-.58*	-.25
Total variance			11.38	4.73	3.82	2.62	1.87	1.66	1.28	1.08
Total contribution (%)			32.8	13.6	11.0	7.6	5.4	4.8	3.7	3.1
Cumulative prop. (%)			32.8	46.4	57.4	65.0	70.4	75.1	78.8	81.9

1) The sample consists of two subgroups. The sample size is 17 for the subgroup with the euryon

2) Covariances between the decomposed variables and the standardized principal components.

3) Variable number according to Martin and Saller (1957).

* Greater than 0.30 in absolute value.

and between-group covariance matrices on cranial measurements for the basis of the positions of eurya.[1]

		Between-group		
Contribution of 8 PCs (%)	Total variance	Factor loadings[2] PC I	Contribution of PC I (%)	Total variance
88.1	.99	−.10	100.0	.01
75.6	.87	−.36*	100.0	.13
85.2	.87	.35*	100.0	.13
65.2	.79	.46*	100.0	.21
57.8	.99	.07	100.0	.01
56.3	.97	.19	100.0	.03
68.2	.99	.08	100.0	.01
71.9	1.00	−.02	100.0	.00
88.3	1.00	.01	100.0	.00
89.1	.99	.08	100.0	.01
85.1	.97	.18	100.0	.03
90.5	1.00	−.06	100.0	.00
86.0	1.00	.01	100.0	.00
84.3	1.00	−.01	100.0	.00
83.3	.91	.31*	100.0	.09
81.5	.96	.19	100.0	.04
83.6	.95	.22	100.0	.05
85.5	.99	.08	100.0	.01
81.9	.85	.39*	100.0	.15
79.3	.91	.30*	100.0	.09
87.8	1.00	.05	100 0	.00
90.2	.99	.07	100.0	.01
89.3	.97	.17	100.0	.03
84.7	1.00	−.06	100.0	.00
87.0	1.00	−.02	100.0	.00
90.1	1.00	−.05	100.0	.00
88.6	.94	.25	100.0	.06
90.1	.98	.16	100.0	.02
84.9	.95	.23	100.0	.05
85.3	.99	.07	100.0	.01
83.0	.96	.21	100.0	.04
85.2	.99	.11	100.0	.01
85.0	1.00	.03	100.0	.00
89.2	.99	.09	100.0	.01
65.5	.95	−.22	100.0	.05
72.6	1.00	−.00	100.0	.00
81.9	34.71	1.29	100.0	1.29
81.9	100.0	100.0	100.0	100.0
81.9	100.0	100.0	100 0	100.0

position 2 and 46 for the subgroup with the position 3.

Table 10. Principal component analyses of the standardized within- and between-
on the basis of the degree of occlusal

	Variable[3]	Within-group							
		Factor loadings[2]							
		PC I	II	III	IV	V	VI	VII	VIII
1	Cranial length	.71*	−.13	−.05	.47*	−.22	.17	−.10	−.08
5	Cranial base ln.	.15	.09	.08	.63*	−.09	.03	.61*	.04
8	Cranial breadth	.64*	.38*	−.03	−.22	.24	.35*	.21	.18
8 (1)	Int.-p.-t. br.	.49*	.09	.13	−.35*	.41*	.32*	.12	−.16
9	Min. front. br.	.51*	.31*	.20	.08	−.14	−.20	.18	−.04
9 (2)	Int.-f.-t. br.	.00	.13	.33*	−.10	.05	−.04	.05	.62*
12	Biasterionic br.	.66*	.02	.09	.24	−.31*	.25	−.14	.26
14	Min. cranial br.	.49*	.08	.06	.21	−.43*	−.18	.32*	.23
17	Basibregmatic ht.	.35*	.18	.24	−.13	−.13	−.36*	.60*	−.11
25	Med. sagit. arc	.83*	.02	.18	.14	−.22	−.09	−.26	−.28
26	Frontal arc	.54*	.49*	−.37*	−.12	−.22	−.02	−.06	−.25
27	Parietal arc	.09	.26	.76*	.48*	.00	.02	−.22	−.06
27 (1)	T.-p. arc, L	.51*	−.11	−.54*	.31*	.44*	−.11	.08	.14
	R	.51*	−.12	−.56*	.43*	.20	.05	−.10	.10
27 (2)	F.-p. arc, L	.35*	.69*	−.08	−.19	.26	−.10	−.16	.09
	R	.43*	.67*	−.16	−.20	−.13	−.06	−.04	.09
27 (3)	O.-p. arc, L	.75*	−.17	.09	−.24	−.19	.29	.07	.09
	R	.71*	−.38*	.21	−.20	−.03	.19	−.14	.14
BAA	b-ast arc, L	.58*	.05	.44*	−.02	.50*	−.14	.11	−.13
	R	.70*	.11	.39*	−.07	.32*	.11	.08	.05
28	Occipital arc	.73*	−.52*	−.14	−.13	−.16	−.15	−.14	−.14
28 (1)	Up. sq. arc	.64*	−.59*	−.05	−.31*	−.02	−.18	.03	−.04
29	Frontal chord	.55*	.52*	−.38*	−.12	−.18	.02	−.03	−.29
30	Parietal chord	.24	.15	.71*	.49*	−.05	.02	−.30	−.07
30 (1)	T.-p. chd., L	.58*	−.20	−.50*	.40*	.33*	−.10	.05	.04
	R	.58*	−.19	−.54*	.42*	.24	.03	−.10	.02
30 (2)	F.-p. chd., L	.49*	.70*	−.17	−.17	.07	−.14	−.14	.05
	R	.54*	.62*	−.27	−.19	−.11	−.07	−.11	.09
30 (3)	O.-p. chd., L	.81*	−.10	.15	−.24	−.14	.26	.05	.10
	R	.76*	−.29	.22	−.21	−.06	.19	−.13	.15
BAC	b-ast chd., L	.68*	.01	.42*	.15	.19	−.38*	.00	−.15
	R	.75*	−.02	.32*	.18	.24	−.18	−.11	.02
31	Occipital chord	.68*	−.40*	−.13	−.35*	−.18	−.21	.06	−.05
31 (1)	Up. sq. chd.	.65*	−.57*	.03	−.29	.01	−.18	.08	−.04
45	Bizygomatic br.	.46*	.05	−.29	.36*	−.36*	.03	.03	.12
48	Upper facial ht.	.17	.07	.01	.14	.04	.67*	.31*	−.38*
Total variance		11.83	4.23	3.80	2.92	1.92	1.60	1.45	1.16
Total contribution (%)		33.9	12.1	10.9	8.4	5.5	4.6	4.1	3.3
Cumulative prop. (%)		33.9	46.0	56.9	65.3	70.8	75.4	79.5	82.8

[1] The sample consists of two subgroups. The sample size is 18 for the subgroup with the wear
[2] Covariances between the decomposed variables and the standardized principal components.
[3] Variable number according to MARTIN and SALLER (1957).
* Greater than 0.30 in absolute value.

group covariance matrices on cranial measurements for the male subgroups classified wear of the maxillary first molar.[1)]

		Between-group		
Contribution of 8 PCs (%)	Total variance	Factor loadings[2)] PC I	Contribution of PC I (%)	Total variance
89.2	.94	−.24	100.0	.06
83.4	.98	−.13	100.0	.02
87.9	.97	.18	100.0	.03
75.6	.92	.28	100.0	.08
51.3	.97	−.18	100.0	.03
58.8	.90	−.32*	100.0	.10
75.1	1.00	−.04	100.0	.00
67.3	.98	−.13	100.0	.02
82.1	.91	.31*	100.0	.09
94.0	.99	.09	100.0	.01
81.1	.98	.13	100.0	.02
94.2	.99	.08	100.0	.01
89.1	1.00	.03	100.0	.00
85.8	.97	.17	100.0	.03
79.4	.94	.24	100.0	.06
78.9	.92	.29	100.0	.08
81.3	.97	−.17	100.0	.03
84.2	.95	−.23	100.0	.05
85.4	.98	.15	100.0	.02
80.6	.97	.17	100.0	.03
92.7	1.00	−.04	100.0	.00
89.9	1.00	−.02	100.0	.00
88.1	.97	.17	100.0	.03
91.9	1.00	.03	100.0	.00
91.1	1.00	.01	100.0	.00
91.8	1.00	.05	100.0	.00
87.6	.95	.23	100.0	.05
87.9	.94	.25	100.0	.06
84.7	1.00	−.07	100.0	.00
85.7	.96	−.19	100.0	.04
88.4	.98	.13	100.0	.02
80.4	.99	.09	100.0	.01
85.2	.99	.10	100.0	.01
87.3	1.00	.04	100.0	.00
63.4	.91	−.30	100.0	.09
75.7	.99	−.10	100.0	.01
82.8	34.90	1.10	100.0	1.10
82.8	100.0	100.0	100.0	100.0
82.8	100.0	100.0	100.0	100.0

score 1 and 33 for the subgroup with the score 2.

Table 11. Principal component analyses of the standardized within- and

Variable[3]			Within-sex							
			Factor loadings[2]							
			PC I	II	III	IV	V	VI	VII	VIII
1	Cranial length		.57*	−.18	.19	.47*	.23	.02	−.09	−.10
5	Cranial base ln.		.23	.07	.37*	.36*	.04	.32*	.27	.37*
8	Cranial breadth		.62*	.29	−.24	−.31*	−.01	.40*	−.13	−.10
8 (1)	Int.-p.-t. br.		.56*	.16	−.26	−.35*	−.36*	.31*	−.20	−.22
9	Min. front. br.		.43*	−.04	.16	−.08	.38*	.24	.35*	−.30
9 (2)	Int.-f.-t. br.		.01	−.37*	.09	−.35*	.21	.24	−.03	.25
12	Biasterionic br.		.58*	−.19	.07	.13	.41*	.12	−.18	.09
14	Min. cranial br.		.37*	.15	−.06	.11	.23	.35*	.36*	−.14
17	Basibregmatic ht.		.45*	.08	.27	−.22	−.19	−.03	.51*	.29
25	Med. sagit. arc		.76*	−.09	.26	.08	.03	−.22	−.02	−.19
26	Frontal arc		.60*	.51*	−.03	−.00	.20	−.31*	−.01	−.02
27	Parietal arc		.20	−.14	.92*	−.05	−.03	−.01	−.11	−.15
27 (1)	T.-p. arc,	L	.38*	.38*	−.10	.50*	−.26	.09	−.03	.05
		R	.46*	.35*	−.13	.50*	−.12	.02	−.11	.05
27 (2)	F.-p. arc,	L	.48*	.55*	−.00	−.40*	−.03	.03	−.06	−.11
		R	.48*	.52*	−.05	−.26	.18	−.19	.03	.22
27 (3)	O.-p. arc,	L	.66*	−.45*	−.16	−.10	.22	−.00	−.09	.15
		R	.63*	−.58*	−.11	.04	.10	−.07	−.19	.08
BAA	b-ast arc,	L	.64*	−.03	.27	−.26	−.44*	.13	−.01	−.06
		R	.71*	−.02	.25	−.23	−.24	.05	−.10	.13
28	Occipital arc		.62*	−.41*	−.31*	.17	−.07	−.13	.07	−.15
28 (1)	Up. sq. arc		.57*	−.44*	−.40*	.04	−.20	−.08	.15	−.12
29	Frontal chord		.60*	.54*	−.05	−.00	.19	−.25	−.03	−.01
30	Parietal chord		.30*	−.21	.84*	.07	.02	−.02	−.10	−.23
30 (1)	T.-p. chd.,	L	.45*	.32*	−.03	.52*	−.23	.05	−.02	.08
		R	.50*	.28	−.09	.53*	−.13	.01	−.12	.06
30 (2)	F.-p. chd.,	L	.58*	.55*	−.05	−.30	.12	−.03	.03	−.12
		R	.58*	.53*	−.09	−.18	.22	−.22	.02	.10
30 (3)	O.-p. chd.,	L	.72*	−.38*	−.14	−.15	.18	.01	−.09	.15
		R	.69*	−.49*	−.11	−.02	.14	−.06	−.17	.11
BAC	b-ast chd.,	L	.63*	−.08	.37*	−.06	−.20	−.06	.12	.03
		R	.67*	−.09	.37*	.01	−.17	−.10	−.04	.15
31	Occipital chord		.62*	−.35*	−.39*	−.03	−.11	−.15	.23	.00
31 (1)	Up. sq. chd.		.57*	−.43*	−.38*	−.02	−.24	−.03	.18	−.11
45	Bizygomatic br.		.23	.06	−.09	.36*	.28	.18	.10	−.22
48	Upper facial ht.		.21	.15	−.12	−.02	.04	.54*	−.20	.16
Total variance			10.41	4.21	3.14	2.51	1.59	1.32	1.01	.90
Total contribution (%)			33.9	13.7	10.2	8.2	5.2	4.3	3.3	2.9
Cumulative prop. (%)			33.9	47.7	57.9	66.1	71.2	75.5	78.8	81.8

1) The sample size is 70 for males and 13 for females.
2) Covariances between the decomposed variables and the standardized principal components.
3) Variable number according to MARTIN and SALLER (1957).
* Greater than 0.30 in absolute value.

between-sex covariance matrices on cranial measurements.[1]

		Between-sex		
Contribution of 8 PCs (%)	Total variance	Factor loadings[2] PC I	Contribution of PC I (%)	Total variance
88.2	.78	.47*	100.0	.22
83.9	.76	.49*	100.0	.24
86.2	.93	.26	100.0	.07
84.0	.99	.10	100.0	.01
67.6	.92	.28	100.0	.08
44.8	.96	.19	100.0	.04
72.6	.85	.39*	100.0	.15
64.9	.77	.48*	100.0	.23
84.1	.84	.40*	100.0	.16
92.2	.81	.44*	100.0	.19
81.9	.92	.29	100.0	.08
94.0	.99	.08	100.0	.01
83.2	.75	.50*	100.0	.25
79.8	.79	.46*	100.0	.21
77.8	.91	.29	100.0	.09
81.6	.84	.40*	100.0	.16
84.2	.89	.32*	100.0	.11
85.5	.95	.23	100.0	.05
85.6	.89	.33*	100.0	.11
83.3	.86	.37*	100.0	.14
89.8	.81	.43*	100.0	.19
89.5	.86	.38*	100.0	.14
84.2	.90	.31*	100.0	.10
92.4	.99	.11	100.0	.01
87.7	.73	.52*	100.0	.27
88.4	.73	.52*	100.0	.27
85.3	.89	.33*	100.0	.11
89.5	.87	.37*	100.0	.13
86.1	.88	.34*	100.0	.12
85.7	.92	.29	100.0	.08
82.6	.74	.51*	100.0	.26
84.8	.77	.48*	100.0	.23
84.2	.89	.34*	100.0	.11
87.3	.87	.36*	100.0	.13
64.4	.57	.65*	100.0	.43
52.4	.82	.42*	100.0	.18
81.8	30.67	5.33	100.0	5.33
81.8	100.0	100.0	100.0	100.0
81.8	100.0	100.0	100.0	100.0

Table 12. Rank correlations between the factor loadings of the principal components relating to the development of the parietal tuber, the position of euryon, sex and dental wear.

	No. of pairs	SPEARMAN rank corr.		KENDALL rank corr.	
		rho	Prob.	tau	Prob.
PC V (Male)[1] vs.					
PC III (Female)[2]	36	0.2393	0.10<, <0.20	0.1958	0.05<, <0.10
PC V (Male)[1] vs.					
W.G. PC V (Sex)[3]	36	−0.9627	<0.001	−0.8452	<0.001
B.G. PC I (Sex)[4]	36	0.1252	0.40<, <0.50	0.0627	0.50<, <0.60
W.G. PC V (eu)[5]	36	−0.8710	<0.001	−0.7008	<0.001
B.G. PC I (eu)[6]	36	0.1266	0.40<, <0.50	0.1286	0.20<, <0.30
W.G. PC V (Wear)[7]	36	0.6773	<0.001	0.5157	<0.001
B.G. PC I (Wear)[8]	36	0.3889	<0.05	0.2921	<0.05
B.G. PC I (eu)[6] vs.					
W.G. PC IV (Sex)[3]	36	−0.7839	<0.001	−0.6011	<0.001
B.G. PC I (Sex)[4]	36	−0.4609	<0.01	−0.3723	<0.01
W.G. PC IV (eu)[5]	36	−0.6415	<0.001	−0.4344	<0.001
W.G. PC IV (Wear)[7]	36	−0.6545	<0.001	−0.4747	<0.001
B.G. PC I (Wear)[8]	36	0.4746	<0.01	0.3349	<0.01

1) From the PCA of the correlation matrix for males (Table 7).
2) From the PCA of the correlation matrix for females (Table 8).
3) From the PCA of the standardized within-sex covariance matrix (Table 11).
4) From the PCA of the standardized between-sex covariance matrix (Table 11).
5) From the PCA of the standardized within-group covariance matrix on euryon position (Table 9).
6) From the PCA of the standardized between-group covariance matrix on euryon position (Table 9).
7) From the PCA of the standardized within-group covariance matrix on dental wear (Table 10).
8) From the PCA of the standardized between-group covariance matrix on dental wear (Table 10).

were not significant at the 5% level (Table 1). These findings suggest that the parietal and frontal tubera are proportionally more developed in females than in males as against the other measurements. In fact, as mentioned previously, KANAZAWA (1979) found that the relative height of the lateral areas of the parietals from the horizontal plane passing through bregma and lambda was larger in females than in males, and considered that this was associated with the stronger development of the parietal eminence in females. The present multivariate analyses, however, failed to show that the PC relating to the parietal tuber (Table 7 and Fig. 2) has a significant rank correlation with the between-group PC on sex (Table 12).

Euryon position and the parietal tuber

From univariate comparisons (Table 3 and Fig. 1), the development of the parietal tuber, which was assumed to be represented by inter-parietal-tuber breadth and bregma-asterion arc, was suggested to have a significant association with euryon position. But the comparison of the relevant PCs failed to bear out this suggestion (Table

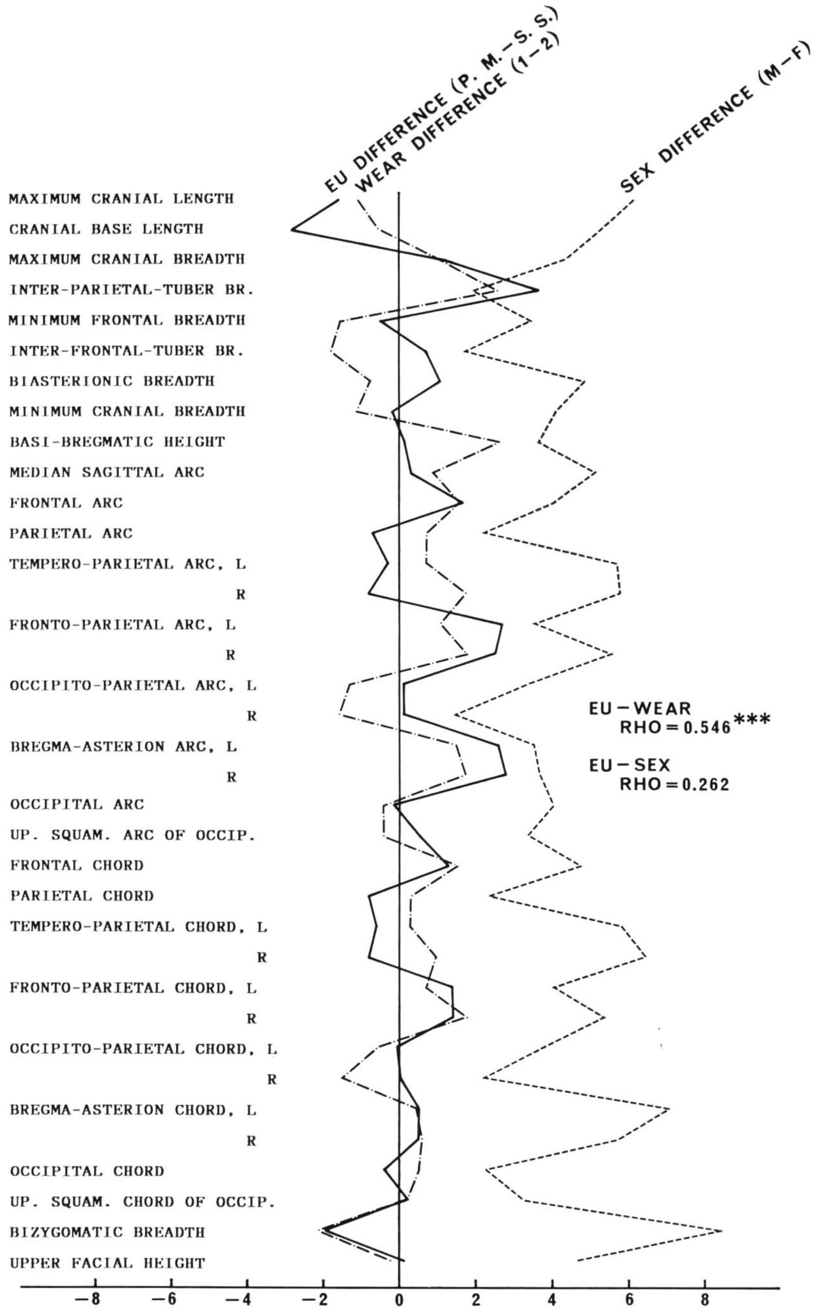

Fig. 1. Standardized differences in cranial measurements relating to euryon position, dental wear and sex (***$P<0.001$).

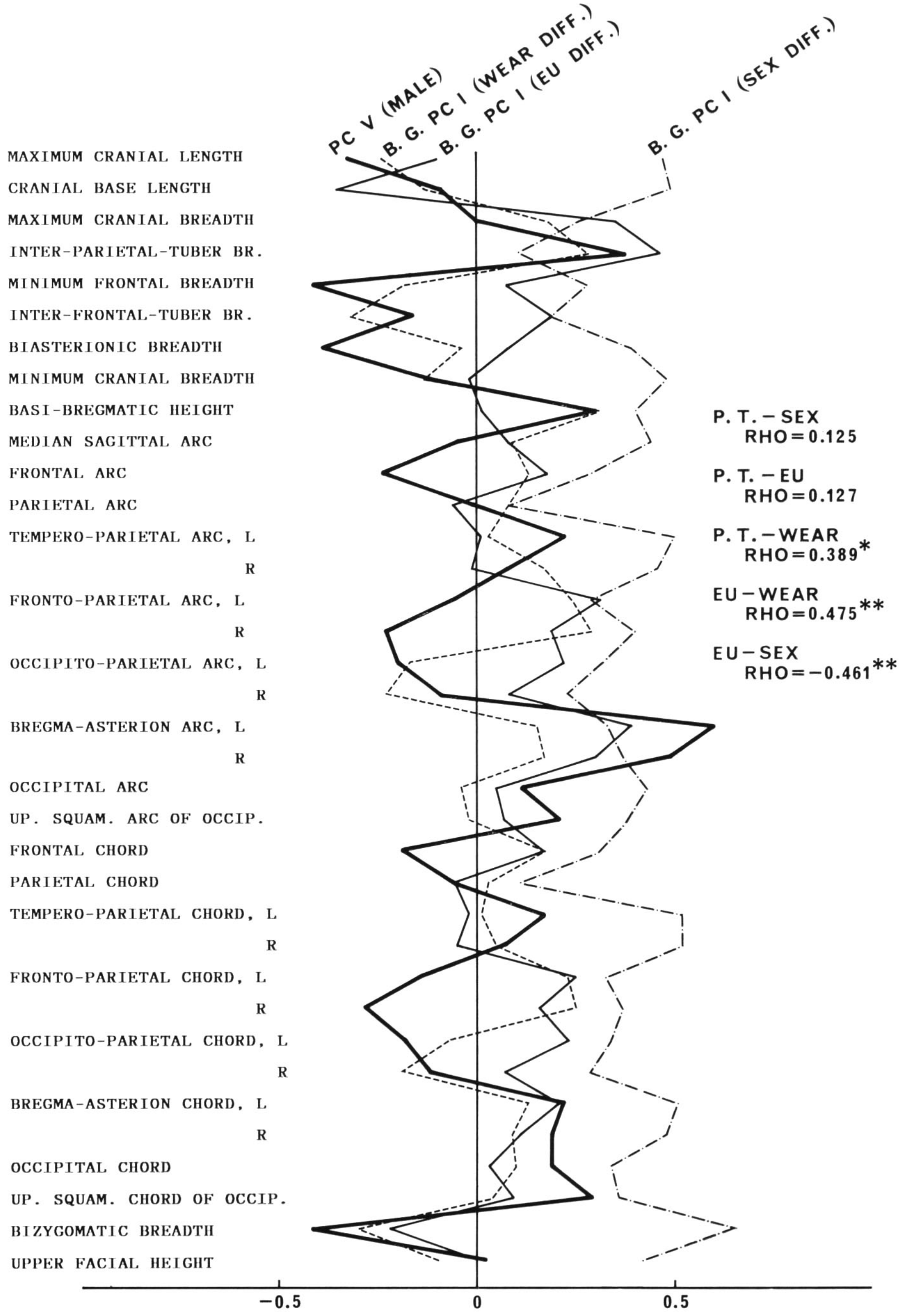

Fig. 2. Factor loadings of the principal component on the parietal tuber (PC V from males) as well as those of the between-group principal components (PC I's) on euryon position, dental wear and sex (*$P<0.05$; **$P<0.01$).

12 and Fig. 2).

As regards the relationship between euryon position and sex, the rank correlation between PCs was shown to be significant (Table 12 and Fig. 2). This supports the observation by TERADA and KANAZAWA (1974) based on the moiré contourographs of Indian skulls that the height of euryon from the Frankfort horizontal plane and the lateral protrusion of euryon from the sagittal plane passing through auriculare were larger in females than in males. Furthermore, these are consistent with KANAZAWA's (1980) findings from the PCA on the pooled sample of male and female Japanese skulls that one of two PCs showing significant sex differences is relatively highly correlated with the height of euryon from the Frankfort horizontal plane.

Dental wear and the parietal tuber

It is most interesting in the present study that individuals with the more worn UM1 have significantly smaller inter-parietal-tuber breadth, smaller basibregmatic height and greater bizygomatic breadth (Table 4 and Fig. 1). In addition, a significant association was suggested by rank correlation coefficients between dental wear and euryon position (Table 6 and Fig. 1). Moreover, from the comparisons of the rank correlations between factor loadings (Table 12 and Fig. 2), it was strongly suggested that the dental wear of the maxillary first molar was associated both with the degree of swelling of the parietal tuber and with the position of euryon.

For the present, it seems difficult to specify causal factors for the variation of dental wear in the present sample. An observed difference in dental wear may be due to a generation difference, a change toward senility during the adulthood, a difference in masticatory stress, or some combination of these and other factors. By now, however, there have been some reports on the short-term increase or decrease of cranial/head measurements. For example, GOLDSTEIN (1936) compared the head and face dimensions between young and old males from the American Jewish population and reported that all dimensions of the head except minimum frontal diminished somewhat in older people; all face lengths, except nose, decreased appreciably; all face widths were slightly greater; depths of face diminished somewhat, except auriculo-nasion and auriculo-menton. ANGEL (1982), using the cranial series from two different generations of American White and Black males and females, showed that basion-bregma height significantly had increased for about 50 years in all the groups but Black males. Further, SINGAL and SIDHU (1986), based on the cross-sectional data of Indian females ranging in age from 20 to 80 years from Punjab, stated that most of the measurements of the head and face, including head circumference and bizygomatic breadth, tended to increase up to the fifth or sixth decade. Of course, it is unknown whether these results from cross-sectional data are due to senile changes in the adulthood or to between-generation gaps. But, anyway, the Jewish older males had the lower head and wider face, the American older people had lower skulls, and the Indian older females showed a tendency toward the wider face.

On the other hand, FRIEDLAENDER *et al.* (1977) showed, on the basis of the longitudinal data from 1813 white males of below 30 to above 70 years of age, that while stature and sitting height significantly decreased with age, head length, breadth and circumference as well as face breadth significantly increased with age, though slightly. If so, it may be said that at least the greater size of bizygomatic or face breadth is partly the effect of senility.

If variation in dental wear is caused mainly by factors relating to age, it can be said from the present analysis (Table 4) that older people with heavier dental wear have smaller inter-parietal-tuber breadth, smaller basibregmatic height and greater bizygomatic breadth. But it still remains indeterminable whether such characteristics in cranial dimensions are mainly those of a certain generation or the effect of senility. On the other hand, if the variation in dental wear is chiefly due to the variation of masticatory or some other mechanical stress, it is likely that those people who use their teeth more intensively have smaller inter-parietal-tuber breadth, smaller basibregmatic height and larger bizygomatic breadth.

After all, it is out of doubt that individuals with heavier dental wear on the first molars have the less developed parietal tubera. The direct causes for such poor parietal tubera are unkown for the present.

Further consideration on previous investigations

Besides the above investigations, OLIVIER (1975) suggested, based on the pooled sample of French male and female skulls, that occipital curvature had a negative correlation with parietal curvature and a dubious correlation with the parietal protuberance. This appears to be confirmed by a principal component extracted from one of the present analyses (PC III in Table 7).

Further, CHEVERUD *et al.* (1979), using the data of American Indians, demonstrated some significant relationships between cranial metric and nonmetric characters, in which the relations of bregma-asterion arc with the lambdoid ossicle, mylohyoid arch, accessory infra-orbital foramina, foramen ovale incomplete and obelionic foramen were included. Although these relationships between metric and nonmetric cranial traits also suggest a mechanism for coordinating various parts of the cranial structure, the problem of what coordinating mechanism is acting yet remains to be solved in the future.

Conclusions

Factors affecting the formation of the parietal tuber were sought in the correlation matrices on various cranial measurements, sex, euryon position and dental wear. Although univariate comparisons suggested that the parietal tuber was proportionally more developed in females than in males, the principal component analyses of the correlation matrices failed to show such a trend. Similarly, while univariate comparisons suggested that the parietal tuber had a significant association with euryon position, the comparison of the principal components did not. However, a rank correlation coefficient between principal components indicated a significant relationship between euryon position and sex. Finally, it was strongly suggested by both univariate and multivariate analyses that the heavier dental wear of the maxillary first molar was associated with the poorer swelling of the parietal tuber and with the lower position of euryon.

Acknowledgments

I would like to thank Dr. Bin YAMAGUCHI, Director of the Department of Anthropology, National Science Museum, Tokyo, for his invaluable comments on this paper. I am also very grateful to Emeritus Prof. Hisashi SUZUKI of the University of Tokyo and Prof. Kazuro HANIHARA of International Research Center for Japanese Studies, Kyoto, for permitting me to observe the skulls used here. Finally, my appreciation is expressed to Miss Akiko NAKATSUKA for her technical assistance.

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