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Dental Affinities among Polynesian and Circum-Polynesian Populations

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Metric and non-metric dental variations were studied in a number of skeletal and cast samples that originated from Polynesia and circum-Polynesia. Within the Polynesian populations, the Tonga sample aligns with a sample from Marquesas. Several Hawaiian samples form a relatively tight cluster. The sample from the Society Islands shows a dispersed arrangement. Extending the comparisons to include Polynesian, Micronesian, Melanesian, Southeast Asian, and East Asian samples re-affirms the existence of a relatively homogeneous Polynesian morphological pattern, and the distinctiveness of the Polynesian-Micronesian population complex. Among the Polynesian samples, Tonga shows closer affinity to Southeast Asians than the other Polynesians. This finding supports the orthodox view for the initial settlement of ancestral Polynesians in Tonga and Samoa. The dental traits of Southeast Asians with lesser admixture with East Asian invaders from the north have something in common with those of the prehistoric Jomonese and their lineages in Japan, Polynesians, and Micronesians. It is likely that the Polynesians, Micronesians, and Jomonese share ancestral ties with the indigenous inhabitants of Southeast Asia.

Keywords: Polynesians, Southeast Asians, Jomonese, Dental morphology, Physical anthropology.

INTRODUCTION

Oceania comprises the three geographical areas of Melanesia, Micronesia, and Polynesia. Polynesia, with its 287 islands, is the largest geographic subdivision of Oceania. In Polynesia, two major cultural areas termed western Polynesia and central-marginal Polynesia were defined by E.G. Burrows in 1938 (Bellwood, 1979). Western Polynesia comprises Tonga, Samoa, Tuvalu, and adjacent small islands, together with all the Polynesian outliers. Central Polynesia includes the Hawaiian, Society, southern Cook, and Austral Islands, as well as Rapa. Marginal Polynesia includes the Marquesas, Mangareva, Easter Island, and New Zealand. Today, archaeologists refer to the central and marginal groups as "eastern Polynesia". Recent works on the fairly homogeneous languages of Polynesia suggest formation of a proto-Polynesian language in the Tonga-Samoa area. Subsequent Polynesian linguistic splits are fairy well established (Green, 1966; Bellwood, 1979; Pawley and Green, 1986).

The origin and migration of peoples within the great Polynesian triangle have long been matters for speculation. Physical anthropologists and related scientists have tried and are still trying to get at the facts, but even now a number of matters remain unexplained (Marshall, 1956; Bellwood, 1975, 1978, 1979; Pietrusewsky, 1971, 1984; Heyerdahl, 1978; Kirch, 1982; Kirch *et al.*, 1989). The earliest known settlements in the islands of eastern Melanesia, from the southeastern Solomons through to Tonga are closely associated with the spread and development of the Lapita Culture. The Lapita Culture as represented in Tonga from ca. 3,000-3,600 years B.P. is regarded as being early Polynesian, with the initial Lapita settlement of Samoa also taking place by 3,000 years B.P. (Groube, 1971; Bellwood, 1975, 1978, 1979).

It is now widely accepted that the eastern Melanesians and the Polynesians, who together form a linguistic and to a lesser extent a cultural continuum, are physically very different (Howells, 1970, 1979; Pietrusewsky, 1971, 1984; Kirch *et al.*, 1989). Although no sufficient analyses of Lapita skeletal materials are available, Pietrusewsky (1985) and Kirch *et al.* (1989) readily guess that the people carrying Lapita Cultural Complex would be close to the Polynesian phenotype, and to the island Southeast Asians based on the mandibular and dental features, respectively. In the past few decades, there has been great progress in our understanding of the Polynesian islands, their history, the mode of their settlement, and the relationships between them. Physical anthropological findings based on dental and cranial morphology, as well as human genetics, have made it possible to say with some certainty that the first settlements were made by migrants from Southeast Asia (Riesenfeld, 1956; Coon, 1962; Simmons, 1962; Howells, 1973, 1979; Brues, 1977; Turner and Scott, 1977; Pietrusewsky, 1984, 1985, 1990a, b; Serjeantson, 1984; Kirch, 1986; Turner, 1987, 1989; Kirch *et al.*, 1989).

Meanwhile, Howells (1973) and Pietrusewsky (1990b) note a marked separation between western Micronesia (the Marianas, Palau, and Yap), and eastern as well as central Micronesia, the so-called nuclear Micronesia, e.g. Truk, Ponape, Kosrae, Marshalls, and Gilberts. Archaeological records and linguistic evidence substantiate the east-west division (Bender, 1971; Bellwood, 1975, 1978, 1979; Craib, 1983). Western Micronesia had been settled about 3,000 years B.P. by populations with linguistic and cultural affinities with people of the Philippines or northeastern Indonesia (Bellwood, 1975, 1978, 1979; Serjeantson, 1984). Turner's findings suggest that the Guamanians originated in the southern islands of Southeast Asia, most likely in Borneo, by a Polynesian-derived colonization of Micronesia (Turner, 1990b). On the other hand, attempts have been made to classify the nuclear Micronesian languages with the eastern Oceanic subgroup, and Bellwood (1979) described that the region was first settled around 3,300 years B.P. from the northern New Hebrides. He further suggested that the nuclear Micronesians may be close cousins to the Polynesians (Bellwood, 1979), while Pietrusewsky (1990a, b) confirms the Ponapeans-Eastern Melanesian association.

In my previous studies, it has been pointed out that the aboriginal populations in Southeast Asia, with lesser admixture with Chinese, shared common dental and craniofacial morphology and probably a common gene pool with not only modern Southeast Asians but also the Pacific populations (Western Micronesians and Polynesians), the Neolithic Jomon people and the successors in Japan (Hanihara, 1990a, b, 1991a, b, c, 1992a, b, c, d). Based on such findings, the present study is focused on the dental variation of several Polynesian and circum-Polynesian populations and the assessment of the dental relationships between Polynesians, Micronesians, Melanesians, and East as well as Southeast Asians.

MATERIALS AND METHODS

This paper is based on observations and measurements made chiefly in 1988 and 1989 on the permanent dentition of a number of skeletal collections at Bernice P. Bishop Museum in Honolulu, Hawaii. Those to be discussed here include several cranial and cast series housed at Universities and Museums in Japan and the United States. Table 1 indicates the number of individuals investigated, the locations where the materials are curated, and the provenience of each sample. Complete or substantially complete adult specimens were selected for recording metric and non-metric data. The metric data were recorded on male specimens. Mesiodistal crown diameters were measured on all the teeth, except for the maxillary and mandibular third molars. Buccolingual diameters were omitted, because these are less free from post-natal environmental influence than mesiodistal ones (Sofaer *et al.*, 1971; Townsend and Brown, 1978; Kolakowski and Bailit, 1981; Matsumura 1989). The non-metric characters were recorded on both male and female specimens, because sexual dimorphism was insignificant in most of the samples observed. As regards the criteria for classification of non-metric traits, the detailed information is given elsewhere (Hanihara, 1990b, 1991a,c, 1992b, c). Both metric and non-metric data were based on right side observation. When a right tooth was missing or badly damaged, the corresponding left tooth was measured or observed.

Table 1. Materials used (N: numbers of male samples)

Population label	N	Provenience
Polynesia [B.P. Bishop Museum]		
Tonga	7	Skeletal remains from the Tonga Islands including a few specimens from the Samoa Islands (pre-historic)
Marquesas	21	Prehistoric Marquesans, Hane Dune site (MUH-1), Uahuka, 2,000-1,700 years B.P.
Society	15	Skeletal remains from the Society Islands, including small numbers of specimens from Gambier and Tuamotu Islands (pre-historic)
Hawaii	83	Skeletal remains from the Hawaii Island excavated from South Point, including small numbers of materials from Maui, Lanai, and Molokai Islands (pre-historic)
Oahu (Mokapu)	84	Pre-historic Hawaiians excavated from Mokapu site, Oahu Island, 600-500 years B.P.

Kauai	25	Skeletal remains from Kauai Island (pre-historic)
Comparative populations		
East Asia		
Japanese	483*	Recent main-island Japanese [Univ. of Tokyo]
Chinese	97*	Manchurian, Liaoning and Kirin Prefecture, 19 A.D. [Univ. of Tokyo, Kyoto Univ.]
Korean	36*	Recent Koreans [Univ. of Tokyo, Kyoto Univ.]
Jomonese	106	Middle, Late and the Latest Jomon periods (ca. 5,300-2,300 years B.P.), excavated from many sites in Honshu, Japan [Univ. of Tokyo, National Science Museum, Tokyo]
Hirota	21	Skeletal remains excavated from Hirota site, Tanegashima island, Nansei island chain (2,300-1,700 years B.P.) [Kyushu Univ.]
Sakishima Islands	39	Recent Sakishima Islanders, Miyako, Ishigaki, Hateruma, and Yonaguni-Island [Univ. of Tokyo, Kyoto Univ.]
Ainu	108	Recent Hokkaido Ainu [Univ. of Tokyo, Sapporo Med. College]
Southeast Asia		
Negrito	21	Recent Aeta tribe, Bataan Peninsula, Luzon [Univ. of Tokyo]
Filipino	14	Recent Filipinos, Marcos village, Luzon [Univ. of Tokyo]
Dajak	12	Recent Iban tribe, Pontianak, Kapuas River, Borneo [Univ. of Tokyo, Kyoto Univ.]
Early Thailand	37	Early Metal age of Thailand (ca. 3,000-6,000 years B.P.), Ban Chiang site, Nong Han district of Udon Thani province in Northeast Thailand [Univ. of Hawaii-Manoa]
Micronesia		
Guam	52	Chamorros from Guam Island, pre-historic (pre-Spanish epoch), 15 A.D. [B.P. Bishop Museum]
Tinian	13	Pre-contact people from Tinian Island including a specimens from Saipan Island [B.P. Bishop Museum]
Ponape	14	Recent populations from Ponape Island including a few materials from the Truk Islands. [Univ. of Tokyo]
Melanesia		
Fiji	8	Recent Fiji Island, excavated at early 20th century, probably intermarriaged with Tongans, including a few specimens from New Hebrides and New Guinea [B.P. Bishop Museum, Univ. of Tokyo]

*: Male and female samples are combined, since these populations were used in analyses based on the discrete crown traits.

With a computer program coded by K. Hanihara, distance analysis based on Q-mode correlation coefficients between every pair of samples were applied to two sets of measurements of different combinations of samples. For non-metric traits, Balakrishnan and Sanghvi's B-squared distance was computed (Balakrishnan and Sanghvi, 1968; Constandse-Westermann, 1972). Cluster analysis, the multidimensional scaling method, and the neighbor joining method developed by Saitou and Nei (1987) were applied to the distance matrices obtained.

POPULATION HISTORY OF JAPANESE

Concerning the affinities of modern Japanese, the points to be considered in combination are 1) that the Jomon tradition although highly modified, is still maintained in part of Japan's local area, for example, Hokkaido, the Nansei Island chain, etc.; 2) that the close affinities between Northeast Asians and Japanese is abundantly evident after the start of the Yayoi age (2,300-1,700 years B.P.); 3) that part of the Aeneolithic Yayoi populations, as represented by specimens excavated from the Doigahama site in the western-end of Honshu, Kanenokuma site in northern Kyushu, etc., were likely immigrants from Northeast Asia via the Korean Peninsula showing close similarity with modern main-island Japanese and Northeast Asians; 4) Jomonese (12,000-2,300 years B.P.), present-day Ainu, Nansei Islanders and some other geographically isolated populations are closely related to each other and to people in Southeast Asia, but they differ largely from a majority of the modern main-island Japanese (Turner, 1976, 1979, 1987, 1989, 1990a; Hanihara, K., 1985, 1987, 1991; Hanihara, 1989a, b, c, 1990a, b, c, 1991a, b, c, 1992a, b, c, d; Dodo and Ishida, 1990; Kozintsev, 1990). Based on such facts, the populations from geographically isolated Japan are distinguished from main-island Japanese and are referred to as Jomonese lineages.

RESULTS

Analysis based on discrete crown traits

The first analysis is based on the discrete tooth crown characters. The frequencies of nine non-metric crown traits for Polynesian samples are given in Table 2. Based on the frequencies, B-squared distance analysis was applied. Table 3 shows the distance coefficients between every pair of samples obtained. The dendrogram, resulting from the group average clustering technique applied to the distance matrix of Table 3, is shown in Figure 1.

Table 2. Fequency distributions of non-metric crown traits in each sample (in %, parenthesis; number of teeth)

Sample	Shovel (UI1)*			Carabelli (UM1)		Hypocone (UM2)		6th cusp (LM1)		7th cusp (LM1)		Deflecting wrinkle (LM1)	
	++	+	−	+	−	+	−	+	−	+	−	+	−
Marquesas-Society	16.7	58.3	25.0 (24)	13.3	86.7 (45)	95.1	4.9 (41)	38.9	61.1 (36)	2.4	97.6 (41)	28.6	71.4 (35)
Hawaii	5.5	50.9	43.6 (55)	13.2	86.8 (121)	85.3	14.7 (102)	45.5	54.5 (101)	3.5	96.5 (113)	33.3	66.7 (90)
Oahu (Mokapu)	16.5	68.5	15.0 (127)	18.4	81.6 (179)	90.8	9.2 (152)	43.2	56.8 (132)	6.9	93.1 (144)	37.3	62.7 (118)

Dist. trig. crest (LM1)		Protostylid (LM1)		4 cusp pattern (LM2)	
+	−	+	−	+	−
5.1	94.9 (39)	5.4	94.6 (37)	33.3	66.7 (36)
13.0	87.0 (100)	5.0	95.0 (101)	46.0	54.0 (113)
13.7	86.3 (131)	7.3	92.7 (138)	45.8	54.2 (142)

*Shovel: ++ > 1.0mm; 1.0mm > + > 0.5mm; − < 0.5mm in depth.

Table 3. B-square distance coefficients between every pair of samples based on discrete crown characters

Sample name	1	2	3	4	5	6	7
1 Japanese	—						
2 Korean	0.6494	—					
3 Chinese	0.7494	1.1784	—				
4 Jomonese	1.2307	1.3173	2.9368	—			
5 Hirota	2.1596	2.4192	4.2769	0.7488	—		
6 Sakishima Isl.	1.1011	1.3776	2.4773	0.5621	0.7540	—	
7 Ainu	1.8299	2.1888	3.4555	0.5874	0.7577	0.5972	—
8 Negrito	1.8131	1.9171	2.7700	1.1315	0.7624	1.2535	0.7749
9 Early Thailand	2.3596	2.0894	3.8551	1.2317	1.0047	0.9614	1.0648
10 Oahu (Mokapu)	1.3839	1.6134	2.6989	0.8603	1.0545	0.8691	1.0433
11 Hawaii	1.6086	1.9245	3.2124	0.4835	0.7146	0.6024	1.1392
12 Marquesas-Soc.	0.9560	1.1332	2.5364	0.6211	0.5606	0.4618	1.0463
13 Guam	1.2766	0.9879	2.2752	0.6683	1.2818	0.6541	1.4028

Sample name	8	9	10	11	12	13
8 Negrito	—					
9 Early Thailand	1.0068	—				
10 Oahu (Mokapu)	0.5224	1.2970	—			
11 Hawaii	0.5377	0.3020	0.9070	—		
12 Marquesas-Soc.	0.6592	0.3297	0.3507	1.1271	—	
13 Guam	0.9230	0.5379	0.6254	0.4893	1.4134	—

The dendrogram indicates a major distinction between three East Asian samples, or main-island Japanese, Koreans, and Chinese, and other samples. The two major clusters correspond to the sinodont dental group and the sundadont dental group (Turner, 1987, 1989). In this figure, the Polynesian samples form a tight cluster, which links with the Guam sample. The Polynesian-Guam group aligns with the sample of early Thailand. This cluster is then found to link to the cluster containing Jomonese, Sakishima Island, Ainu, and Hirota samples. The Negrito sample attaches to these two major sundadont subdivisions.

Figure 2 shows a clustering of relationships based on the neighbor joining method which results from the application of the distance coefficients given in Table 3. Again a major distinction is indicated between the three East Asian sam-

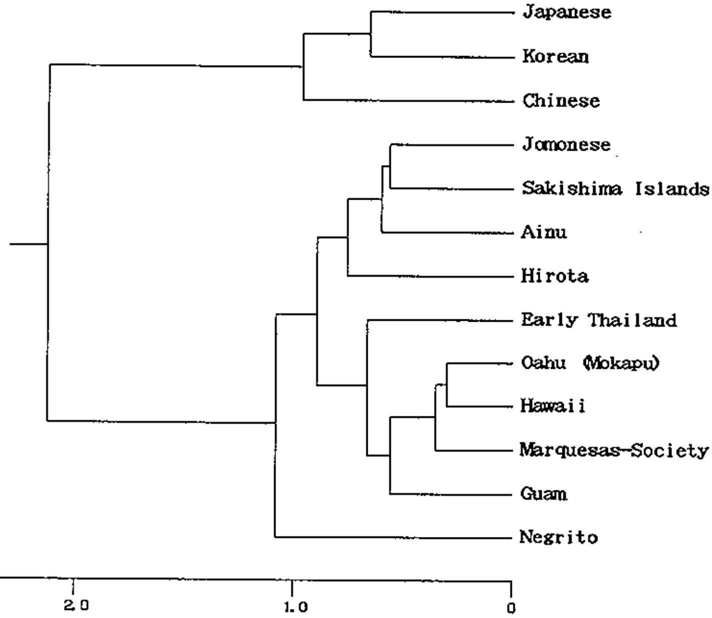

Fig. 1. Group average cluster analysis applied to B-square distance based on 9 discrete crown characters in Table 3.

ples and the others. The internal structure of the Polynesian-Guam cluster and its inclusion with the early Thailand sample is identical to the relationship found in the previous result. The sample of Negritos is loosely attached to those of the Jomonese and their lineages in Japan.

The consistent absence of any close association between the Polynesian samples and the sinodont East Asians emphasizes that the comparative framework should be focused on the sundadont populations.

Analyses based on dental measurements

Table 4 gives the basic statistical information of dental measurements for 6 Polynesian samples. Distance measures based on Q-mode correlation coefficients were applied to the dental measurements (Table 5). Using the distance matrix shown in Table 5, a dendrogram and a two dimensional scattergram were made with the group average clustering technique and the multidimensional scaling method, respectively (Figures 3 & 4). Using the first two dimensions, 99.3% of the total variance is expressed in Figure 4.

A close relationship is found between Tonga and Marquesas. Smaller subgroupings within this cluster reveal a tie between Oahu and Kauai. The Society Islands and Hawaii construct a second large cluster. In Figure 4, the Society sample is the most isolated of all groups included in this comparison.

The same statistical procedures were applied to dental measurements of 18 samples from Polynesia, Micronesia, Melanesia, Southeast Asia, and the Japanese

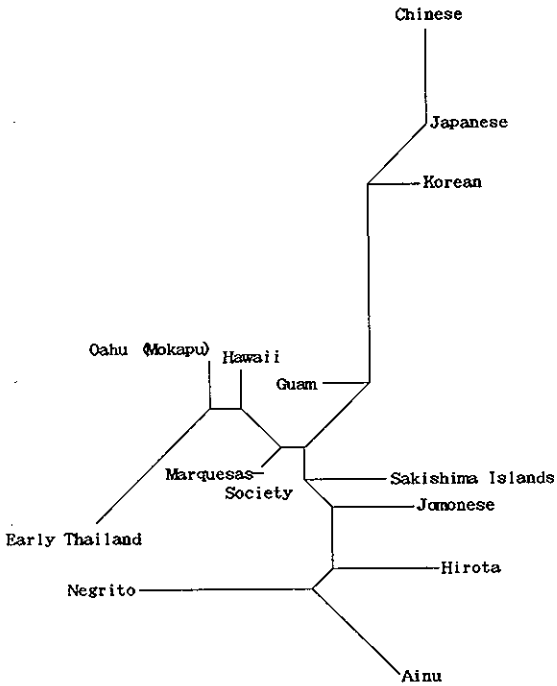

Fig. 2. Intergroup relationships drawn by the neighbor joining method based on the B-square distance coefficients on Table 3.

Table 4. Basic statistics of mesiodistal crown diameters in the permanent dentition (male)

Population	Upper 1st incisor				Upper 2nd incisor				Upper canine			
	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
Tonga	4	8.78	.436	.050	4	7.14	.218	.031	5	8.01	.779	.097
Marquesas	13	8.42	.495	.059	15	6.82	.598	.088	16	7.72	.421	.054
Society	4	8.15	.059	.002	4	7.20	.116	.016	4	8.30	.028	.033
Hawaii	25	8.30	.514	.062	32	6.89	.542	.079	47	7.89	.443	.056
Oahu (Mokapu)	47	8.46	.601	.071	63	6.87	.510	.074	69	7.87	.355	.045
Kauai	5	8.48	.661	.078	8	6.91	.653	.094	10	7.76	.046	.060

Population	Upper 3rd premolar				Upper 4th premolar				Upper 1st molar			
	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
Tonga	6	7.69	.679	.088	6	7.22	.496	.069	6	11.33	.719	.064
Marquesas	18	7.11	.315	.044	17	6.73	.467	.069	20	10.39	.418	.040
Society	7	7.72	.345	.045	6	7.22	.463	.064	8	10.91	.721	.066
Hawaii	48	7.15	.422	.059	50	6.66	.480	.072	52	10.49	.582	.056
Oahu (Mokapu)	73	7.20	.362	.050	75	6.63	.428	.065	72	10.43	.483	.046
Kauai	11	6.98	.556	.080	13	6.45	.478	.074	14	10.36	.528	.051

Population	Upper 2nd molar				Lower 1st incisor				Lower 2nd incisor			
	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
Tonga	5	10.79	.599	.055	5	5.69	.316	.056	5	6.38	.099	.015
Marquesas	20	9.88	.389	.039	11	5.27	.301	.057	13	5.87	.344	.059
Society	6	10.30	.403	.039	5	5.59	.078	.014	6	5.92	.186	.032
Hawaii	44	10.10	.545	.054	17	5.30	.240	.045	25	5.88	.294	.050
Oahu (Mokapu)	72	10.01	.677	.068	39	5.32	.299	.056	48	6.07	.367	.060
Kauai	15	10.25	.855	.083	8	5.24	.235	.045	10	5.93	.323	.055

Population	Lower canine				Lower 3rd premolar				Lower 4th premolar			
	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
Tonga	5	7.46	.163	.022	6	7.88	.544	.069	6	8.07	.436	.054
Marquesas	14	6.85	.431	.063	16	7.18	.418	.058	16	7.28	.454	.062
Society	5	7.12	.055	.008	6	7.12	.439	.062	8	7.57	.465	.061
Hawaii	38	6.94	.393	.057	46	7.04	.469	.067	49	7.12	.517	.073
Oahu (Mokapu)	59	6.95	.390	.056	65	7.16	.436	.061	67	7.13	.473	.066
Kauai	14	6.79	.334	.049	13	7.07	.556	.079	14	6.98	.557	.080

Population	Lower 1st molar				Lower 2nd molar			
	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
Tonga	6	12.46	.404	.032	6	12.11	.4956	.041
Marquesas	15	11.48	.405	.035	15	11.10	.5682	.051
Society	10	11.84	.646	.055	10	11.58	.8960	.077
Hawaii	46	11.27	.476	.042	49	10.91	.6449	.059
Oahu (Mokapu)	57	11.45	.490	.043	61	10.91	.6759	.062
Kauai	17	11.22	.520	.046	16	10.82	.7320	.068

Table 5. Distance matrix based on Q-mode correlation coefficients applied to mesiodistal crown diameters

Sample name	1	2	3	4	5	6
1 Tonga	—					
2 Marquesas	0.5718	—				
3 Society	1.7238	1.4887	—			
4 Hawaii	1.6037	1.6652	0.4934	—		
5 Oahu (Mokapu)	0.8560	0.8273	1.6187	1.2057	—	
6 Kauai	0.7884	1.1298	1.6436	1.0973	0.6619	—

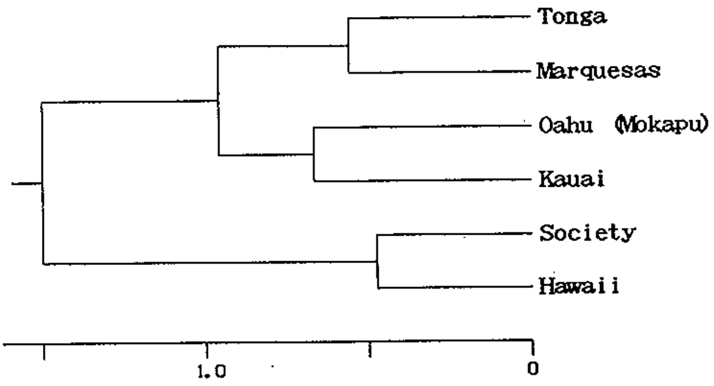

Fig. 3. Cluster analysis applied to the distance matrix transformed from Q-mode correlation coefficients in Table 5.

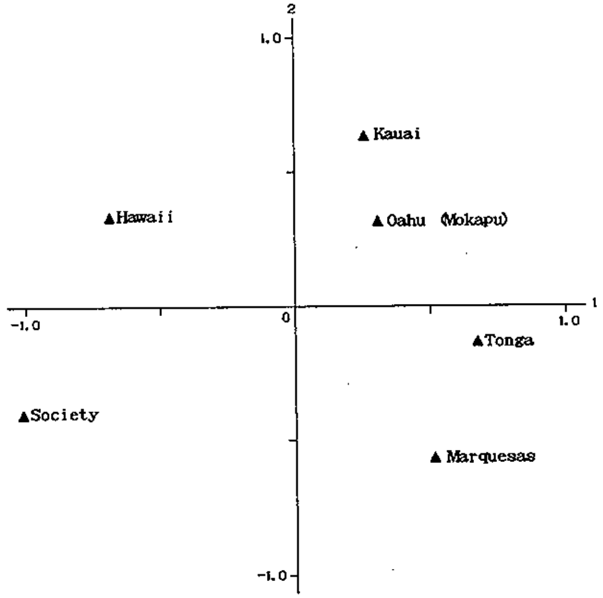

Fig. 4. Two dimensional expression of the multidimensional scaling method (MDS) applied to the same distance matrix used in Figure 3, accounting for 99.3% of total variance.

Archipelago. The distance matrix obtained is given in Table 6. Figure 5 is a dendrogram of the relationship obtained from the group average cluster analysis of the distance matrix in this Table.

A basic division occurs between the Polynesian-Micronesian constellation, including the recent Southeast Asian samples, and the one that contains the Jomonese and their lineages, the Fijian, and early Thailand samples. Within the former cluster, a further distinction is made between Polynesian and Micronesian samples. The Ponape sample falls within the Polynesian sub-branch, while the

Table 6. Distance matrix based on Q-mode correlation coefficients between every pair of samples applied to mesiodistal crown diameters

Sample name	1	2	3	4	5	6	7
1 Tonga	—						
2 Marquesas	0.2353	—					
3 Society	0.9143	0.9339	—				
4 Hawaii	0.6322	0.6278	0.5069	—			
5 Oahu (Mokapu)	0.4934	0.5700	1.2181	0.4901	—		
6 Kauai	0.7885	0.7429	1.3403	0.4824	0.3905	—	
7 Negrito	0.9880	1.1827	1.0931	1.3378	0.8856	1.3393	—
8 Filipino	0.7768	1.1484	1.0578	0.9621	0.7868	0.9495	0.5721
9 Dajak	1.3496	1.2884	1.2538	1.1671	0.7485	1.0941	0.7084
10 Early Thailand	0.9060	0.9452	1.1695	1.1580	1.3283	1.0276	1.4397
11 Fiji	1.4808	1.1755	1.2364	1.2938	1.5529	1.1303	1.4533
12 Sakishima Isl.	1.6703	1.6428	1.1126	1.3047	1.5481	0.8648	1.1028
13 Hirota	1.2069	1.1214	1.1144	1.4188	1.3641	0.9743	0.8834
14 Jomonese	1.1242	1.1414	1.4923	1.7050	1.3510	1.0335	1.0820
15 Ainu	1.3711	1.6010	1.1505	1.2896	1.0790	1.2671	0.9070
16 Guam	0.6023	0.6153	0.8809	1.0907	0.7851	1.4650	0.6928
17 Tinian	0.9007	0.7364	0.4759	0.8455	1.1950	1.4197	1.2146
18 Ponape	0.3413	0.3374	0.9660	0.3941	0.4867	0.6094	1.0444

Sample name	8	9	10	11	12	13	14
8 Filipino	—						
9 Dajak	1.0354	—					
10 Early Thailand	1.5052	1.1218	—				
11 Fiji	1.3726	0.9527	0.7146	—			
12 Sakishima Isl.	1.0175	1.1924	0.9382	0.6684	—		
13 Hirota	0.8983	1.4769	1.0005	1.0507	0.3545	—	
14 Jomonese	1.0504	1.3742	0.7386	0.7915	0.5280	0.2508	—
15 Ainu	0.8920	0.9711	0.9895	1.1888	0.8177	0.8509	0.7167
16 Guam	0.9133	0.8083	1.3235	1.2225	1.7860	1.5045	1.2915
17 Tinian	1.6120	1.1144	0.7769	1.0880	1.4152	1.3071	1.2693
18 Ponape	0.8513	1.2454	1.1130	1.1460	1.5637	1.4646	1.4845

Sample name	15	16	17	18
15 Ainu	—			
16 Guam	1.0966	—		
17 Tinian	0.5497	0.9894	—	
18 Ponape	0.6692	0.9773	1.5124	—

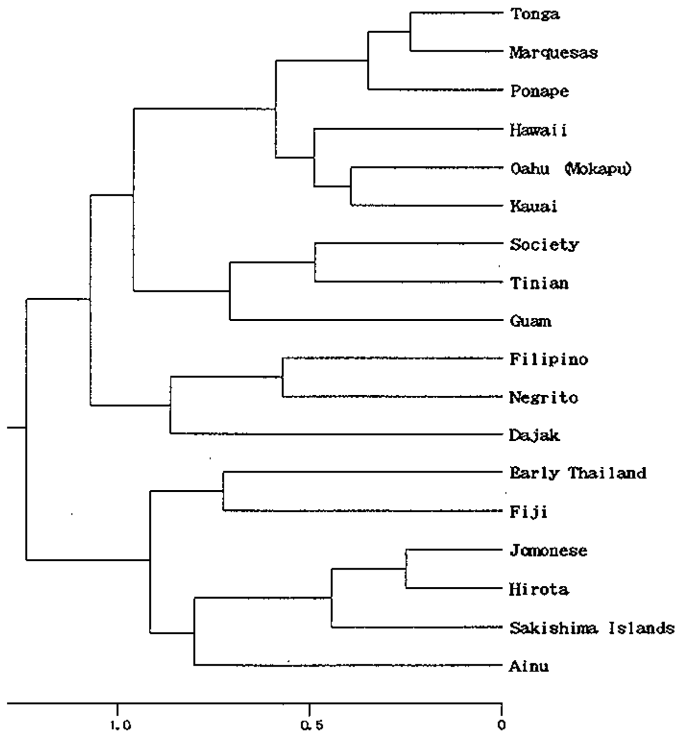

Fig. 5. Group average cluster analysis applied to the distance matrix shown in Table 6.

Society sample is within the Micronesian one. As seen in Figure 5, the Tonga and Marquesas samples are closely related to each other.

The multidimensional scaling method was applied to the same distance matrix (Figures 6a & 6b). The first two dimensions account for 70.0% of the total variance (Figure 6a), the first and third axes express 67.5% of total variance (Figure 6b), and 91.8% of the total variance can be accounted for in these representations.

The most peripherally positioned sample is Fiji in Figure 6a. The Polynesian and Micronesian samples are closely related to each other and form one group in Figure 6a, while samples from Guam and Tinian form a sub-branch within the Polynesian-Micronesian group in Figure 6b. A clear separation between the Jomonese and their lineages and the Polynesian-Micronesian group is evident. The Southeast Asian samples occupy an intermediate position between the two groups on the first axis. In the four Southeast Asian groups, the early Thailand sample is plotted at an isolated position on the second axis, suggesting a temporal difference. However, this sample is linked with the recent Southeast Asians on the first and third axes.

Figure 7 represents the inter-group relationship produced by the neighbor joining method based on the distance matrix of Table 6. Here again, the result indi-

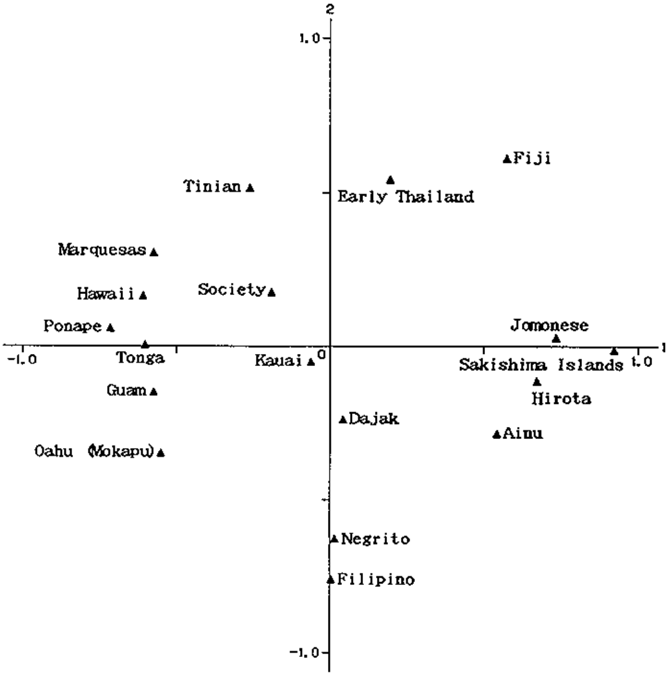

Fig. 6a. Two dimensional graph of MDS applied to the same distance matrix used in Figure 5, 70.0% of total variance is expressed in this Figure.

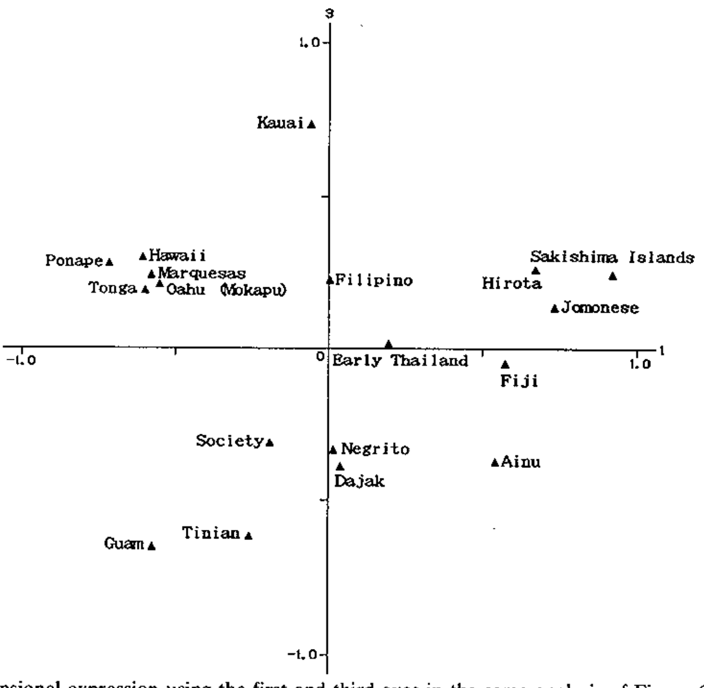

Fig. 6b. Two dimensional expression using the first and third axes in the same analysis of Figure 6a, 67.5% of total variance is accounted for.

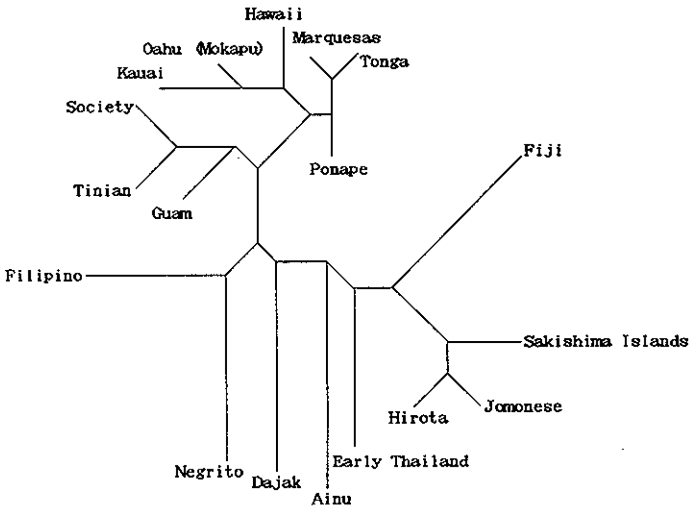

Fig. 7. Inter-population relationships drawn by the neighbor joining method applied to the distance matrix in Table 6.

cates an isolation of the Fijian sample from the others. The Polynesian-Micronesian cluster includes the association of the Society and Guam-Tinian samples, and the Ponape and Polynesian samples. In the Polynesian sub-branch, the Tonga and Marquesas samples show a close tie, and samples from the Hawaiian Islands form a final cluster. In this figure, the Southeast Asian samples occupy an intermediate position between the Polynesian-Micronesian group and the Jomonese and their lineage.

DISCUSSION

The results obtained in this study allow a few tentative conclusions regarding biological relationships and possible origins and affinities of Polynesian and circum-Polynesian populations.

Colonization within Polynesia

Concerning the initial peopling of Polynesia, the west Polynesian Archipelagoes of Tonga and Samoa along with certain small islands, such as Futuna and Niuatoputapu, were colonized by members of the Lapita Cultural Complex about 3,000-3,600 years B.P. (Goldman, 1970; Groube, 1971; Bellwood, 1975, 1978, 1979; Green, 1979, 1981; Kirch, 1982, 1986; Pietrusewsky, 1985; Kirch *et al.*, 1989). Colonization of the uninhabited Fiji-Tonga-Samoa area proceeded the final populating of the Polynesian triangle (Green, 1981; Kirch, 1982). As regards the initial settlement and colonization of eastern Polynesia, the Marquesas Islands seem to have served as a major dispersal center to Society, Hawaiian, Easter, and New Zealand Islands based on archaeological evidence (Suggs, 1961; Sinoto, 1968, 1970, 1979, 1983). The Society Islands served, moreover, as a secondary dispersal center to Hawaii and New Zealand (Jennings, 1979). This dispersal reconstruction, illustrated in Figure 8, has supported from linguistic analysis (Green, 1966). On the other hand, Kirch (1986) has rejected these hypotheses as being inaccurate and not useful models of eastern Polynesian settlement. He regards the available evidence as being insufficient (Kirch, 1986). Some minor criticism for the orthodox view has also been offered by Biggs (1972) and Bellwood (1975).

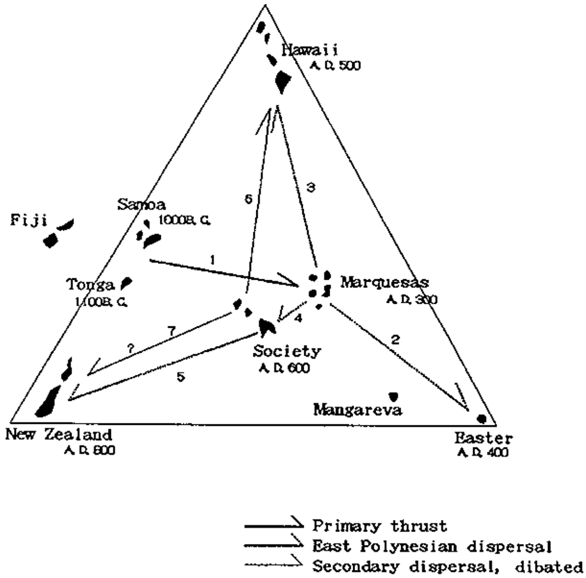

Fig. 8. The orthodox scenario of East Polynesian dispersals, modified from Jennings (1979, Figure I,1).

The results obtained in the present study suggest that the samples from Marquesas show relatively close affinities to those from Tonga. As far as metric dental traits are concerned, the results support the hypothesis for the colonization of the Marquesas from western Polynesia. On the other hand, the sample from Society forms a single branch separated from the division containing other Polynesian samples. The sample from Hawaii is most closely related to that of Society. The Society sample is slightly more like the Marquesan sample than like those of Tonga, Oahu, and Kauai on the basis of dental measurements (Table 5). The metric dental characters of the samples from the Hawaiian Islands have something in common with those of the Tonga-Marquesas group and Society. This indicates that the Hawaiian Island group has a probability of being both Tonga-Marquesas and Society related. The relationships found in Table 5 and Figures 3 & 4 may be, therefore, in part parallel to the ordered stages of Polynesian prehistory (Suggs, 1961; Sinoto, 1968, 1970, 1979; Jennings, 1979): (1) settlement of the Marquesas Islands from Tonga-Samoa; (2) settlement of the Society Islands from Marquesas; (3) initial colonization of Hawaii from Marquesas and secondary settlement from the

Society Islands. However, the dental evidence presented here does not necessarily provide further support for the ordered stage of colonization within Polynesia proposed by Sinoto (1968, 1983), Jennings (1979), and others.

Extending the comparisons to include Southeast Asians, the Jomonese and their lineages, Micronesians, and Melanesians (Fijians) re-affirms the distinctiveness of the Polynesian populations. The comparison based on non-metric dental traits provides further assessment fot the relative homogeneity within the Polynesian populations.

Origins and affinities of Polynesians and Micronesians

A number of prehistorians, archaeologists, and linguists are willing to accept the hypothesis that the modern Austronesian speaking cultures of eastern Melanesia and Polynesia share a common origin in the Lapita Cultural Complex as described previously (Bellwood, 1975, 1978, 1979; Green, 1979; Kirch, 1986; Pawley and Green, 1986; Kirch and Green, 1987). Based on archaeological and historical linguistic evidence, the immediate homeland of the Lapita Cultural Complex is now believed to have been located somewhere in the Bismark Archipelago region or the New Britain-New Ireland area. Ancestral Polynesian Society developed in this western homeland (Bellwood, 1979; Jennings, 1979; Kirch, 1986). The biological evidence suggests that the people with physical affinities with East and Southeast Asians, or the makers of Lapita pottery, occupied a number of coastal niches in Melanesia. By about 3,300 years B.P., the Lapita people, who may have been relatively little influenced by the Melanesian populations, moved east to settle Fiji and western Polynesia. It is also probable that the Fiji Island group received later Melanesian settlers, while the Polynesians are direct descendants of the original Lapita settlers (Howells, 1979; Pietrusewsky, 1984, 1985, 1990b; Serjeantson, 1984; Turner, 1987, 1989; Kirch *et al.*, 1989). Table 6 indicates that among the 6 Polynesian samples, Tongans show closer metric dental affinities to Southeast Asians than any other Polynesians. At the same time, the distance between the Fijian sample and the Polynesian samples is relatively large. These suggest that the Tongans were derived not from the eastern Melanesian dental stock but from the Southeast Asian dental stock.

According to Bellwood (1979), the islands of Micronesia fall into two basic categories, which are paralleled precisely in the western and nuclear categories based on linguistics. Physical anthropological studies substantiate the west-nuclear division (Howells, 1973; Pietrusewsky, 1990b). The close association of the sample of Ponapeans with those of Polynesians, and Mariana Islanders (Guam and Tinian) with the island Southeast Asians found in this study supports the west-nuclear dichotomy within Micronesia.

Biological relationships between Polynesians, Micronesians, Jomonese, and Southeast Asians

The ancestral roots of the Polynesians and Micronesians are traced back to the Jomonese and the geographical route for the peopling of the Polynesian and Micronesian regions to the Nansei Island chain by Brace and his colleagues (Brace, *et al.*, 1989, 1990; Brace and Hunt, 1990) and Katayama (1990). The grounds for this argument are based mainly on the similarity between the cranial morphology of the Jomonese and those of the Polynesians as well as the Micronesians. Brace and Hunt (1990) felt that the oldest human skeletal materials which solidly aligned with the members of the "Jomon-Pacific cluster" were the early Jomon specimens themselves from approximately 6,000-10,000 years ago in Japan. However, morphological associations in this case do not necessarily imply causal relationships. Turner (1976, 1979, 1985, 1987, 1989, 1990a, b; Turner and Swindler, 1978) offered the Late Pleistocene Sundaland as the source from which subsequent expansion produced the distribution of the Polynesians and Jomonese. Turner (1987, 1990a) went on to say that most evidence indicates that modern Southeast Asians evolved in Southeast Asia, and their dental pattern, or sundadonty, would have to be considered as the late Pleistocene stock from whom evolved directly or indirectly many of the populations in East Asia and Oceania, perhaps even the Australians. Recently, Pietrusewsky (1988) stressed a close biological connection between the Neolithic inhabitants of mainland Southeast Asia and the more recent inhabitants of Polynesia.

Negritos, one of the probable representatives of the aboriginal populations in Southeast Asia, may have evolved in the tropical rain-forest of Sundaland in the late Pleistocene, some 20,000-30,000 years B.P. (Omoto, 1984; Hanihara, 1989c, 1990a, b, c, 1991a, b, c, 1992a, b, c, d). They have been regarded as people with lesser admixture with the East Asian migrants from the north within the past 2,000-4,000 years, and have been the best known of the "Australoids" in modern times in Southeast Asia (Coon, 1962; Jacob, 1967; Howells, 1976; Birdsell, 1977; Brues, 1977; Bellwood, 1978, 1985; Kennedy, 1979). However, as far as human genetics as well as dental and craniofacial morphology is concerned, there is not necessarily a connection between the Negritos and the Australians and Melanesians, despite their phenotypic resemblance (Omoto, 1984; Hanihara, 1989c, 1990a, b, c, 1991a, b, c, 1992a, b, c, d). I have pointed out that the original dental traits of the Southeast Asians may have occurred as the result of convergent microevolution under a similar environmental condition, such as the tropical rainforest, based on diachronic comparison (Hanihara, 1992a, b, c, d). It is probable, therefore, that the formation of Negrito-like features may have occurred in this kind of environmental condition at a sufficient time-depth, say, 20,000 years or so.

The present findings indicate that the dental traits of Polynesians and Micronesians are more like those of Southeast Asians with lesser admixture of the East Asian invaders (probably southern Chinese), or Negrito-like generalized Asian populations, than those of the Jomonese and their lineages. The results do not favor, therefore, the prehistoric Jomonese as the most likely racial source and the Nansei Island chain as the geographical route for the peopling of Micronesia and Polynesia proposed by Brace and his colleagues (Brace, *et al.*, 1989, 1990; Brace and Hunt, 1990), and Katayama (1990). The findings presented here are consistent with those reported by Turner (1987, 1989, 1990a, b), Pietrusewsky (1988, 1990a, b), Howells (1990), etc. All lines of evidence obtained indicate that the Polynesians, Micronesians, and Jomonese share a common gene pool which can be traced back to Southeast Asians, most likely, from dental morphological viewpoints, the generalized Asian populations. This finding supports Turner's dental hypothesis stating that the sundadont ancestor of the Jomonese could have arrived from Southeast Asia, or Sundaland, via the now-submerged East Asian continental shelf in the Late Pleistocene and Early Holocene times, and could have colonized the Pacific Basin in the Late Holocene times (Turner, 1987, 1989, 1990a, b).

It is likely that a group of Austronesians, the makers of Lapita pottery, who had more Southeast Asian dental characters than their predecessors and were adept at canoe construction and navigation are good candidates for the pioneer colonist of the Pacific Basin and Rim. In addition, it should be kept in mind that there is no evidence of sailing technique in the Jomon age of Japan.

SUMMARY AND CONCLUSIONS

The following are the principal conclusions to be drawn from the present study:

(1) Dental features are relatively homogeneous within the several Polynesian populations.

(2) Western Polynesia may have been first settled by people with dental affinities with the indigenous Southeast Asians.

(3) The Tongans are closely related to the Marquesans, suggesting the first settlement of the Marquesas Islands in eastern Polynesia from western Polynesia, Tonga-Samoa.

(4) Dental evidence provided here does not necessarily provide further support for the ordered stage of colonization within the Polynesian region proposed by Sinoto (1968) and Jennings (1979).

(5) Micronesian dentition is most like that of the Polynesians and some Southeast Asians.

(6) The association of Mariana Islanders (Guamanians and Tinian islanders) with island Southeast Asians, and Ponapeans with Polynesians indicates the west-nuclear dichotomy within Micronesia.

(7) The present findings do not favor the prehistoric Jomonese as the most likely source for the present people in Polynesia and Micronesia.

(8) The Jomonese may be linked with the Polynesians and Micronesians through a common gene pool derived from somewhere in Southeast Asia.

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ポリネシア諸集団の歯冠形質について

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要旨：ポリネシア人の起源と拡散過程については考古学、言語学、形質人類学等の研究領域から様々な仮説が提唱されている。しかしこれらの研究結果は必ずしも一致しておらず、多角的な研究結果の統合が不可欠である。「太平洋民族の起源に関する人類学的研究」班では頭骨、四肢骨、古病理、歯の研究からポリネシア集団をはじめとする太平洋地域諸集団の形質的特徴を比較検討してきたが、ここでは太平洋民族の歯冠形態を明らかにすると共に歯の形態からみた彼らの起源と系統を検討した。

ポリネシア6集団、ミクロネシア3集団、メラネシア1集団、東アジア7集団、東南アジア4集団の計21集団を比較対象とし、歯冠計測値および非計測的歯冠形質のデータを多変量解析法により分析した。詳細は本文に記載した通りであるが、歯冠形質については次のような結果が得られた。

(1) ポリネシア諸集団の歯冠形態は比較的均質である。

(2) ポリネシア諸集団はミクロネシア集団、東南アジア集団に類似した歯冠形質を示す。

(3) 西ポリネシア地域集団ートンガ・サモア集団ーがポリネシア諸集団中もっとも東南アジア集団に類似する。このことは東南アジア集団と類似した形質的特徴をもつ集団が、西ポリネシア地域に最初に移住したとする従来の主張と矛盾するものではない。

(4) 東ポリネシア集団のなかではマルケサス諸島集団がトンガ集団と最も類似性を示す。この結果は、東ポリネシア地域への移動の過程でマルケサス諸島が最も初期の居住地であったとする考古学的仮説と一致する。

(5) マルケサス諸島がポリネシア地域において最初の拡散中心となり、ソサイアティー諸島が第2の拡散中心となったとする考古学的、言語学的仮説と歯冠形質に基づく分析結果とは必ずしも平行するものではない。

(6) ミクロネシア集団はポリネシア集団および東南アジア集団に類似した歯冠形態をもつ。

(7) ミクロネシア集団中ではマリアナ諸島集団がより東南アジア集団に類似し、ポナペートラック諸島集団はポリネシア集団に比較的類似する。このことは多くの研究者が指摘するようにミクロネシアがポリネシアよりも複雑な民族史を示すことを示唆する。

(8) ポリネシア集団、ミクロネシア集団の歯冠形質は縄文人よりも東南アジア集団に類似性を示し、太平洋民族の縄文人起源説に関しては否定的である。

(9) 縄文人と太平洋民族（ポリネシア、ミクロネシア集団）の類似性は東南アジアを介して共通の祖先をもつことによると考えられる。