Distribution of Tubercle-shaped Incisors in South Pacific Populations

Eisaku Kanazawa¹, Yuji Shirono¹, Mitsuko Nakayama¹,
Hiroyuki Yamada², Hajime Hanamura², and Shintaro Kondo³

¹Department of Anatomy, Nihon University School of Dentistry at Matsudo, Chiba

²The Second Department of Anatomy, School of Dentistry, Aichi-Gakuin University, Nagoya

³The First Department of Oral anatomy, School of Dentistry, Showa University, Tokyo

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Abstract The basal tubercle and its related traits on the basal part of the lingual surface of maxillary central incisors vary in developmental grades. Although a well-developed basal tubercle was observed in fossil humans, much attention to this trait has not been paid in modern humans. We compared five morphological traits on the lingual surface of maxillary incisors among seven Pacific populations. Results showed that the South-Pacific populations examined in this study especially Fijians and New Guinea Highlanders had a well-developed basal tubercle, but with a low frequency of shovel-shaped incisors. On the contrary, Japanese and Kiribatian populations of this study had a high frequency of shovel-shaped incisors, but a low frequency of tubercle-shaped incisors. It was suggested that the basal tubercle is one of the key dental traits in characterizing Pacific populations.

Keywords: basal tubercle, shovel shape, upper incisors, Oceania, Pacific

Introduction

The basal tubercle and its related traits on the basal part of the lingual surface of maxillary incisors vary in developmental grades and in population diversity. Weidenreich (1937), who studied *Homo erectus* (*Sinanthropus pekinensis* in his literature), reported that shovel-shaped incisors were often observed in this sample. Adloff (1938) proposed that the central incisor of *Sinanthropus* should be called tubercle-shaped, because the basal tubercle on the lingual surface was remarkably developed. Since Gorjanovic-Kramberger's (1906) report of this type of incisor in Neanderthals, few reports have been published on this matter in modern humans (Hanihara, 1997, Yamada et al., 1999). Yamada et al. (2000) found well-developed basal tubercles similar to that of *Sinanthropus* on the lingual surface of the central incisor of the native Cook Islanders in Polynesia, during long-termed dental anthropological research in these islands (Yamada et al., 1988). Their study was one of the

Corresponding author: Eisaku Kanazawa

Department of Anatomy, Nihon University School of Dentistry at Matsudo

2-870-1 Sakaecho, Nishi, Matsudo-shi, Chiba-ken, Japan

E-mail: kanazawa@masc.nihon-u.ac.jp

few reports on this trait in modern humans, and it was suggested that the trait was of importance in Oceanic dental anthropology. The present study aims to describe the distribution of this trait in a wider scale in Oceania, and to explore the relationship between this trait and some other characters of the upper incisors.

Materials and Methods

The dental cast sample from Cook Islands is a collection housed at the Second Department of Anatomy, School of Dentistry, Aichi-Gakuin University, and the data used in this study were cited from Yamada et al. (2000). The other dental cast samples are housed at the Department of Anatomy, Nihon University School of Dentistry at Matsudo. These casts were collected strictly from indigenous people of each country during a period of 1992 to 1997, at Koror in Palau, Tarawa in Kiribati, Apia in Samoa, Suva in Fiji, and Wabag in Papua New Guinea (PNG) Highlands. Locations of these populations were shown in Fig. 1. Details of the materials were described elsewhere (Kanazawa et al. 1998, 2000).

Dental traits investigated were basal tubercle, spines, shovelling, and double shovel in both the central and lateral incisors, and winging in the central incisor. Yamada's

Figure 1. Geographical presentation of the Pacific populations investigated in this study.

- ① Japan ② Palau ③ Kiribati ④ Samoa ⑤ Cook Islands
⑥ Fiji ⑦ Papua New Guinea

standard plaque (Yamada et al., 2000) was used for scoring the basal tubercle. The developmental grades of the basal tubercle and spines were expressed in three steps ranging from absent to most developed. For the other traits, the plaques by Dahlberg and Mikkelsen (1947) and Turner et al. (1991) were used. Frequencies of the three or four grades in males and females were tabulated for each sample to test for difference between sex. Then the combined data were also tabulated as usually carried out in dental non-metric studies (Turner, 1990). In the cluster analysis of the present study, the sum frequencies of trait positive grades were used, and the Ward method from Smith's distances was adopted. The statistical package JMP (SAS incorp.) was used for this analysis.

Results

Tables 1 to 7 show frequencies of five incisor traits in the central and lateral incisors of both sexes in each population, expressed in three grades from (–) to (++) and in four grades in case of shovelling. Although a significant sex difference of trait occurrence was found in the basal tubercle in Palauans (Table 2), the basal tubercle and spine in Kiribadians (Table 3) and the basal tubercle in Cook Islanders (Table 5), both sexes were combined for the purpose of population comparison.

In the central incisor, a well-developed basal tubercle (++) appeared most frequently in the Fijian sample (42.6%) followed by the Cook Islanders (29.4%), the

Table 1. Frequency distribution of dental traits in upper incisors in Japanese

Male: <i>n</i> = 72	BT	SP	S	DS	W	BT2	SP2	S2	DS2									
(-)	46	51	2	54	63	65	72	10	69									
(+)	24	21	42	17	9	7	0	56	3									
(++)	2	0	26	1	0	0	0	6	0									
(+++)	—	—	2	—	—	—	—	0	—									
Female: <i>n</i> = 45																		
(-)	25	30	2	32	38	42	45	7	42									
(+)	19	15	22	13	4	3	0	34	3									
(++)	1	0	19	0	3	0	0	4	0									
(+++)	—	—	2	—	—	—	—	0	—									
Total <i>n</i> = 117																		
(-)	71	60.6%	81	69.2%	4	3.4%	86	73.5%	101	86.3%	107	91.5%	117	100%	17	14.5%	111	94.9%
(+)	43	36.7%	36	30.8%	64	54.7%	30	5.6%	13	11.1%	10	8.5%	0	0.0%	90	76.9%	6	5.1%
(++)	3	2.6%	0	0.0%	45	38.5%	1	0.8%	3	2.6%	0	0.0%	0	0.0%	10	8.5%	0	0.0%
(+++)	—	—	4	3.4%	—	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

Note: Abbreviations are as follows. BT: basal tubercle, SP: spine, S: shovel-shaped, DS: double shovel, W: winging.

The number 2 after these abbreviations denotes lateral incisor.

PNG Highlanders (29.4%) and the Palauan sample (26.9%). In the Samoan and Kiribatian samples, the frequencies were moderate at 18.4% and 12.0%, respectively. A well-developed tubercle was rare in the Japanese sample (2.6%). An example of the well-developed basal tubercle is shown in Fig. 2. Frequencies of trait-positive grades (total of + and ++)
also showed the same trend, in which the tubercle ap-

Table 2. Frequency distribution of dental traits in upper incisors in Palauans

Male: <i>n</i> = 48	BT*	SP	S	DS	W	BT2	SP2	S2	DS2									
(-)	19	21	4	40	37	41	47	17	48									
(+)	20	22	20	8	10	6	1	29	0									
(++)	9	5	21	0	1	0	0	6	0									
(+++)	—	—	3	—	—	—	—	0	—									
Female: <i>n</i> = 45																		
(-)	7	13	1	38	33	32	41	28	45									
(+)	22	20	20	6	11	13	4	16	0									
(++)	16	12	22	1	1	0	0	1	0									
(+++)	—	—	2	—	—	—	—	0	—									
Total <i>n</i> = 93																		
(-)	26	27.9%	34	36.5%	5	5.4%	78	83.8%	70	75.3%	73	78.5%	88	94.6%	45	48.4%	93	100%
(+)	42	45.2%	42	45.2%	40	43.0%	14	15.0%	21	22.6%	19	20.4%	5	5.4%	45	48.4%	0	0.0%
(++)	25	26.9%	17	18.3%	43	46.2%	1	1.1%	2	2.2%	1	1.1%	0	0.0%	3	3.2%	0	0.0%
(+++)	—	—	—	5	5.4%	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

*Significant sex difference of frequency at 5% level was found in basal tubercle by χ^2 test.

Table 3. Frequency distribution of dental traits in upper incisors in Kiribatians

Male: <i>n</i> = 51	BT*	SP*	S	DS	W	BT2	SP2	S2	DS2									
(-)	28	29	13	38	42	49	51	30	45									
(+)	18	20	25	12	9	2	0	20	6									
(++)	5	2	11	1	0	0	0	1	0									
(+++)	—	—	2	—	—	—	—	0	—									
Female: <i>n</i> = 57																		
(-)	21	21	10	31	41	44	57	20	34									
(+)	28	27	33	25	14	13	0	36	23									
(++)	8	9	12	1	2	0	0	1	0									
(+++)	—	—	2	—	—	—	—	0	—									
Total <i>n</i> = 108																		
(-)	49	45.4%	50	46.3%	23	21.3%	69	63.9%	83	76.8%	93	86.1%	108	100%	50	46.3%	79	73.1%
(+)	46	45.2%	47	43.5%	58	53.7%	37	34.3%	23	21.3%	15	13.9%	0	0.0%	56	51.9%	29	26.9%
(++)	13	12.0%	11	10.2%	23	21.3%	2	1.8%	2	1.8%	0	0.0%	0	0.0%	2	1.8%	0	0.0%
(+++)	—	—	—	4	3.7%	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

* Significant sex difference of frequency at 5% level was found in basal tubercle and spine by χ^2 test.

peared in high frequency in Fijians 94.1% and PNG Highlanders 87.3%, in moderate frequency in Kiribatisans 54.6%, Palauans 72.1%, Cook Islanders 67.2% and Samoans 63.2%, and in low frequency in the Japanese sample (39.3%) (Fig. 3).

The spine is a trait with two or three finger-like projections extending incisally from the basal tubercle on the lingual surface of the incisor. The distribution of fre-

Table 4. Frequency distribution of dental traits in upper incisors in Samoans

Male: <i>n</i> = 50	BT	SP	S	DS	W	BT2	SP2	S2	DS2									
(-)	18	26	19	35	42	43	48	26	46									
(+)	24	17	22	15	8	6	2	21	4									
(++)	8	7	9	0	0	1	0	3	0									
(+++)	—	—	0	—	—	—	—	0	—									
Female: <i>n</i> = 37																		
(-)	14	19	8	32	28	31	35	14	37									
(+)	15	14	23	5	9	6	2	21	0									
(++)	8	4	5	0	0	0	0	2	0									
(+++)	—	—	1	—	—	—	—	0	—									
Total <i>n</i> = 87																		
(-)	32	36.8%	45	51.7%	27	31.0%	67	77.0%	70	80.5%	74	85.1%	83	95.4%	40	46.0%	83	95.4%
(+)	39	44.8%	31	35.6%	45	51.7%	20	23.0%	17	19.5%	12	13.8%	4	4.6%	42	48.3%	4	4.6%
(++)	16	18.4%	11	12.6%	14	16.1%	0	0.0%	0	0.0%	1	1.1%	0	0.0%	5	5.7%	0	0.0%
(+++)	—	—	—	1	1.1%	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

Table 5. Frequency distribution of dental traits in upper incisors in Cook Islands

Male: <i>n</i> = 51	BT*	SP	S	DS	W	BT2	SP2	S2	DS2									
(-)	25	16	27	40	49	46	46	22	45									
(+)	18	27	23	20	11	15	10	29	12									
(++)	15	16	11	1	0	0	5	10	4									
(+++)	—	—	0	—	—	—	—	0	—									
Female: <i>n</i> = 61																		
(-)	14	12	16	44	54	36	45	18	45									
(+)	27	26	26	16	6	25	12	33	12									
(++)	20	23	19	1	0	0	4	10	4									
(+++)	—	—	0	—	—	—	—	0	—									
Total <i>n</i> = 122																		
(-)	39	32.8%	28	23.3%	43	35.2%	84	68.8%	103	85.8%	82	67.2%	91	74.6%	40	32.8%	90	73.8%
(+)	45	37.8%	53	44.2%	49	40.2%	36	29.5%	17	14.2%	34	27.9%	22	18.0%	62	50.8%	24	19.6%
(++)	35	29.4%	39	32.5%	30	24.6%	2	1.6%	0	0.0%	6	4.9%	9	7.4%	20	16.4%	8	6.6%
(+++)	—	—	—	0	0.0%	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

* Significant sex difference of frequency at 5% level was found in basal tubercle by χ^2 test.

Note: Frequencies in the Cook Islanders were cited from Yamada et al. (2000).

quencies of this trait was similar to that of the basal tubercle.

The shovel-shaped incisor was most frequently observed in the Japanese sample in which the pooled frequency of trait-positive grades was 96.6%. Frequencies in the other populations were as follows: Palauans 94.6%, Kiribadians 78.7%, Samoans 69.0%, Cook Islanders 64.8%, Fijians 78.7%, and PNG Highlanders 31.7%.

Double shovel was most frequently found in the Kiribatian sample (36.1%) followed by those of the Cook Islanders and Japanese. Fijians (8.1%) and PNG Highlanders (0%) showed rather low frequencies. Winging was neither frequent (13–

Table 6. Frequency distribution of dental traits in upper incisors in Fijians

Male: <i>n</i> = 68	BT	SP	S	DS	W	BT2	SP2	S2	DS2									
(−)	4	12	19	63	62	35	62	28	68									
(+)	36	34	28	5	6	32	6	37	0									
(++)	28	22	19	0	0	1	0	3	0									
(+++)	—	—	2	—	—	—	—	0	—									
Female: <i>n</i> = 68																		
(−)	4	10	10	62	56	37	59	27	68									
(+)	34	32	46	6	11	30	9	40	0									
(++)	30	26	12	0	1	1	0	1	0									
(+++)	—	—	0	—	—	—	—	0	—									
Total <i>n</i> = 136																		
(−)	8	5.9%	22	16.2%	29	21.3%	125	91.9%	118	86.8%	72	52.9%	121	89.0%	55	40.4%	136	100%
(+)	70	51.5%	66	48.5%	74	54.4%	11	8.1%	17	12.5%	62	45.6%	15	11.0%	77	56.6%	0	0.0%
(++)	58	42.6%	48	35.3%	31	22.8%	0	0.0%	1	0.7%	2	1.5%	0	0.0%	4	2.9%	0	0.0%
(+++)	—	—	2	1.5%	—	—	—	—	—	—	—	—	—	0	0.0%	—	—	—

Table 7. Frequency distribution of dental traits in upper incisors in PNG Highlanders

Male: <i>n</i> = 69	BT	SP	S	DS	W	BT2	SP2	S2	DS2									
(−)	11	37	49	69	57	61	65	54	69									
(+)	40	22	19	0	11	8	3	15	0									
(++)	18	10	1	0	1	0	1	0	0									
(+++)	—	—	0	—	—	—	—	0	—									
Female: <i>n</i> = 57																		
(−)	5	28	37	57	48	51	54	44	56									
(+)	33	17	20	0	9	5	3	13	1									
(++)	19	12	0	0	0	1	0	0	0									
(+++)	—	—	0	—	—	—	—	0	—									
Total <i>n</i> = 126																		
(−)	16	12.7%	65	51.6%	86	68.2%	126	100%	105	83.3%	111	88.8%	119	95.2%	97	77.6%	124	99.2%
(+)	73	57.9%	39	30.9%	39	30.9%	0	0.0%	20	15.9%	13	10.4%	5	4.0%	28	22.4%	1	0.8%
(++)	37	29.4%	22	17.5%	1	0.8%	0	0.0%	1	0.8%	1	0.8%	1	0.8%	0	0.0%	0	0.0%
(+++)	—	—	0	0.0%	—	—	—	—	—	—	—	—	0	0.0%	—	—	—	—

24%) nor variable among the populations.

In the lateral incisor, four traits were investigated as shown in Tables 1 to 7. These frequencies were generally lower than in the corresponding trait of the central incisor. As seen in Fig. 4, frequencies of trait-positive grades (total of + and ++)

showed that the basal tubercle appeared most frequently in the Fijian sample (47.1%),

Figure 2. An example of the tubercle-shaped incisor in a Fiji individual.
s: spines, b: basal tubercle

Figure 3. Graphical presentation of frequencies of five traits in the maxillary central incisor in seven Pacific populations.

followed by the Cook Island sample (32.8%). The Japanese sample had the lowest frequency of 8.5%. The frequencies of the spine were much lower than those of the basal tubercle. The highest frequency of this trait occurred in the Cook Island sample (25.4%).

Figure 4. Graphical presentation of frequencies of five traits in the maxillary lateral incisor in seven Pacific populations.

Table 8. χ^2 values and Spearman's rank correlation coefficients between traits in seven populations

		χ^2	significance	Spearman's r	significance
Japanese	BT : SP	67.2	$p < 0.01$	0.758	$p < 0.01$
	S : DS	11.8	n.s.	0.261	$p < 0.01$
Palauan	BT : SP	97.3	$p < 0.01$	0.823	$p < 0.01$
	BT : DS	7.1	n.s.	-0.235	$p < 0.05$
	S : DS	10.8	n.s.	0.249	$p < 0.05$
Kiribatian	BT : SP	104.5	$p < 0.01$	0.738	$p < 0.01$
	S : W	15.2	$p < 0.05$	0.191	$p < 0.05$
Samoean	BT : SP	79.5	$p < 0.01$	0.725	$p < 0.01$
Cook Islands	BT : SP	72.9	$p < 0.01$	0.692	$p < 0.01$
Fijian	BT : SP	140.5	$p < 0.01$	0.817	$p < 0.01$
	BT : S	9.2	n.s.	0.207	$p < 0.05$
PNG	BT : SP	58.9	$p < 0.01$	0.621	$p < 0.01$
	S : SP	19.9	$p < 0.01$	0.361	$p < 0.01$

Note: Test for Cook Islanders was cited from Yamada et al. (2000).

Table 9. Smith's distances between populations computed from frequencies of appearance of five traits in the central incisor

	Japan	Palau	Kiribati	Samoa	Fiji	PNG
Palau	0.1878					
Kiribati	0.1327	0.1055				
Samoa	0.1887	0.1141	0.0158			
Fiji	0.6986	0.1823	0.3827	0.2853		
PNG	0.964	0.6098	0.6295	0.3648	0.379	
Cook	0.3946	0.1684	0.0759	0.0653	0.1889	0.4749

Figure 5. Cluster analysis based on Smith's distance.

The shovel-shaped incisor in the lateral incisor was most frequently observed in the Japanese sample, in which the pooled frequency of trait-positive grades was 85.4%. Frequencies in the other populations were as follows: Palauans 51.6%, Kiribatians 53.7%, Samoans 54.0%, Cook Islanders 67.2%, Fijians 59.5%, PNG Highlanders 22.4%. Double shovel was most frequently found in the Kiribatian sample (26.9%) followed by the Cook Island sample (19.6%), but it was hardly found in the other populations.

Correlations among five traits were investigated by χ^2 test and Spearman's rank correlations (Table 8). A strong correlation was found between the basal tubercle and the spine in all seven populations. Other significant correlations were found between the shovel and the double shovel in Japanese and Palauans, between the basal tubercle and the double shovel in Palauans, between the shovel and winging in Kiribatians, between the basal tubercle and the shovel in Fijians and between the shovel and the spine in PNG Highlanders. However, four of these traits were not significant in χ^2 test.

Table 9 shows Smith's distances between populations, computed from the frequencies of the five traits of the central incisor. The smallest distance was found

Figure 6. Two-dimensional expression of Smith's distance by means of multi-dimensional scaling.

Symbols denote: ● PNG, ○ Fiji, ● Polynesia, ⊙ Micronesia, ○ Japan.

between Samoa and Kiribati (0.016), while the largest distance was between PNG and Japan (0.964). PNG also had large distances from Palau (0.610) and Kiribati (0.630).

Fig. 5 shows the results of cluster analysis based on the matrix of Smith's distances. The seven populations were divided into two major clusters, the Fiji/PNG group and the other populations. Japan was included in the latter group.

Fig. 6 shows a two-dimensional plot of Smith's distances by means of the multi-dimensional scaling method. PNG and Japan were confirmed to be positioned at both ends of the first axis. The first axis had a high contribution (81%), expressing geographic location of the populations, i.e., Melanesia, Polynesia, Micronesia and Japan from left to right. On the other hand, the second axis showed a lower contribution (19%), indicating local variation within Polynesia and Micronesia. Fiji's position showed a close affinity to Polynesia rather than to PNG.

Discussion

Dental anthropology has taken an important role in the recent advance of the research on microevolution of Asian peoples. One of the most prolific achievements was Turner's hypothesis regarding the Asian dental complex, i.e., Sinodont and Sundadont (Turner, 1990), indicating a dual population history reconstructed for eastern Asia in the Late Pleistocene and Holocene. Peoples of Sundaland, from the relatively shallow Sunda continental shelf linking mainland Southeast Asia to the East Indian Archipelago in the Late Pleistocene, was hypothesized to have had migrated

to the vast Pacific area. From dental characters, the modern southeast Asian and Pacific peoples were subdivided into Sunda-Pacific and Sahul-Pacific populations. The former includes Southeast Asia, Polynesia and Micronesia, and the latter includes Australia, New Guinea and Melanesia (Scott and Turner, 1997). Dental anthropological studies in the Pacific area are, however, still few because of sampling difficulty especially in Melanesia. Knowledge so far obtained from this area are limited to a few case-studies with insufficient sample sizes. The accumulation of comparative data sets by a single research team encompassing various samples are hoped for (Kanazawa et al., 1998, 2000).

The basal tubercle in incisors is a cingulum-derived character. Weidenreich (1937) described this character in *Homo erectus* (Peking man), and considered the basal tubercle as a buttress which developed on the lingual surface base of the crown for the purpose of strengthening the tooth against the pressure or force operating in labiolingual direction. He also stressed that Peking man was a direct ancestor of Mongoloids, because they had well-developed shovelling in addition to the basal tubercle on the lingual surface of the upper incisors. Adloff (1938) gave the contrary opinion on this fossil man, proposing that Peking man had a well-developed basal tubercle in the central incisor, so that the tooth did not appear shovelled in spite of distinct shovelling in the lateral incisor. He suggested that the central incisor should therefore be called 'tubercle-shaped' rather than 'shovel-shaped'. As far as we have observed the illustrations (Weidenreich, 1937), many of the Peking man's central incisors were judged to be of the tubercle-shaped type as seen in samples of this study.

The tubercle-shaped incisor was also reported in other fossil *Homo erectus* such as in KNM-WT 15000 (Walker and Leakey, 1993), and in Neanderthals (Gorjanovic-Kramberger, 1906), although Robinson (1956) stated that tubercle-shaped incisors were not found in African australopithecines. In modern humans, this trait has largely been ignored in dental non-metric studies. Suzuki and Sakai (1973) observed basal tubercles in the Japanese dentition, and reported that the frequencies of this trait, among the upper front teeth, were highest in the canine, followed by the central incisor and the lateral incisor. They showed that the frequency of the tubercle in their Japanese sample varied from 4.4% to 16.5%. These figures are comparable to the frequency observed in the Japanese sample of the present study. Smith (1981) reported the frequency of this trait in a recent Australian aboriginal population as 64.0%. This figure, falling in the range of the Pacific populations shown in this study, may indicate close relationship between Australian Aborigines and other Pacific populations. Hanihara (1997) mentioned that tubercle-shaped incisors might be observed regionally in African people and in Australian Aborigines, but did not give detailed data. So far, a world-wide comparison of this trait has not yet been undertaken. For example, there is no sufficient description of this trait in a recent monograph on the dental anthropology of non-metric morphological features (Scott and Turner,

1997), in which a trait similar to this tubercle was described as 'tuberculum dentale' on the canine, but without paying attention on the basal tubercle.

Yamada et al. (2000) described a well-developed basal tubercle on the lingual surface of the upper central incisor of the inhabitants of Cook Islands. Their study revealed that the trait was infrequently found in the lateral incisor, and that it was not associated with the shovel shaped incisor. This description suggested that there might be other Oceanic populations with a high frequency of this trait. It was revealed in the present study that the frequency of the basal tubercle was high in PNG Highlanders and Fijians, moderate in Polynesians and Micronesians, and lowest in the Japanese. The Cook Islanders, reported by Yamada et al. (2000) to have a high percentage of presence of this trait, were found to exhibit a moderate frequency in the wider Oceanic comparison of this study.

The frequency distribution of shovel-shaped incisors in Oceania showed a different pattern from that of the basal tubercle. It was highest in the Japanese, moderate in Micronesians and Polynesians, and lowest in PNG Highlanders and Fijians. Because shovelling is a key trait of the Sinodont populations of Northeast Asia (Turner, 1990), it was anticipated that the Japanese sample would have a high frequency. Harris et al. (1975) hypothesized two distribution patterns of this trait. One concerns the Papua New Guinean, Australian and Tasmanian group whose dentition is characterized by megadonty, conservative characters in molars and low frequency of shovelling. The other concerns the Polynesian and Micronesian group showing relatively small teeth, reduction of molar cusps and high frequency of shovelling. Our results agree with their hypothesis.

Double shovel is also a Sinodont character which is frequently seen in North and South American natives (Turner, 1990). As for Polynesians and Micronesians, its frequency in the central incisor of the present study was higher than that reported by Scott and Turner (1997). The frequency of winging was relatively low in all populations investigated in the present study, although higher frequencies were previously reported especially in Micronesia (Scott and Turner 1997). The reason for this inconsistency can be probably due to the different regions from where samples were collected, and/or to inter-observer error.

As for correlations between traits, Yamada (2000) described that the basal tubercle was associated with the spine, but that there were no significant associations in frequency between the basal tubercle and shovelling, nor between shovelling and the spine in Cook Islands samples. The correlations among these three traits in the other populations were found to be similar to Yamada's results as seen in the present study. Adloff (1938) regarded these traits to exist independently. He inferred that the basal lingual tubercle had been generated from the cingulum, and that it was a feature common to mammals. In addition, he concluded that shovelling had been derived secondarily from the tubercle-shaped type through reduction of the lingual

tubercle. Mizoguchi (1985) also demonstrated that shovelling itself seemed to function relatively independently of the lingual tubercle, based on principal component analysis of a large data set that included world wide variation of incisors. Our present data give additional information on this issue. It is possible to propose a hypothesis that shovelling is particularly a Sinodont character, but that the basal tubercle is a Sahul-Pacific character of the Asia-Pacific region.

Conclusion

South-Pacific peoples, especially Fijians and PNG Highlanders tend to have well-developed basal tubercles, but with a low frequency of shovel-shaped incisors. On the contrary, Japanese and Micronesians had high frequencies of shovel-shaped incisors, but low frequencies of tubercle-shaped incisors. It is suggested that the discordant expression of the basal tubercle and shovelling is one of the key issues in reading the migration history of Asia-Pacific populations.

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