

Tooth Size of Living Peoples in Western and Eastern Micronesian Populations

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Abstract Tooth size of two populations from Micronesia was measured and compared with other Pacific populations. Subjects were high school students of Kiribati and Palau, surveyed in 1995 and 1996. Mesiodistal diameters were generally larger in Palau than in Kiribati in both sexes, while buccolingual diameters of Kiribati were slightly larger than those of Palau. Mahalanobis' distances were computed on the basis of these parameters among 10 Pacific populations. Two dimensional expression of the distances in multi-dimensional scaling showed that Palau and Kiribati were plotted in the center of the first axis closely to Samoa, while Fiji and Negritos were plotted on both ends of the axis. The two Micronesians were separated on the second axis. The results of cluster analysis revealed that Kiribati was classified into Fiji group, while Palau was grouped with Samoa and modern Philippines.

Keywords: tooth size, Micronesia, dental anthropology

Introduction

Micronesia covers the northern half of the Pacific, extending from Palau in the west to Gilbert Islands in the east. Islands in Micronesia are separated into three groups, Western, Central and Eastern Micronesia (Figure 1). Four major movements of human dispersals into Micronesia from surrounding islands since 3600 years B.P. are proposed based on archaeological evidence (Intoh, 1997). Various trials to trace the route of migration of peoples and to confirm the archaeological evidence have been made from the physical anthropological point of view. For example, skeletal analysis revealed that inhabitants in Micronesia were of mixed ancestry, while there is a discernible Melanesian contribution to some of the modern populations in Micronesia (Howells, 1973). Turner (1990a) found that Micronesians, including prehistoric Guamanians, were dentally most similar to Borneo peoples, followed closely by samples from Fiji-Rotuma, Marquesas, Hawaii, and Java-Sumatra. Several dental studies on the descriptions of dental crown and root traits in Micronesia have been reported (Leigh, 1929; Harris and others, 1975; Sakai and others,

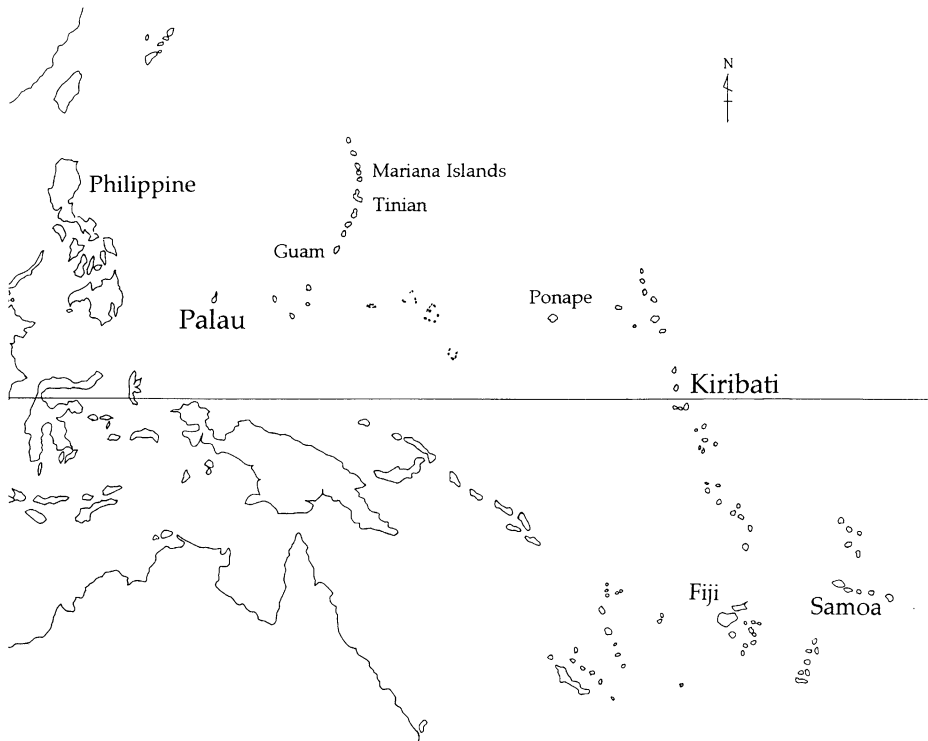


Figure 1 Geographical representation of Palau and Kiribati in Micronesia.

1985; Sakuma and others, 1987; Mine and others, 1987). However, reports on tooth size of South Pacific populations are very few (Kieser, 1990), especially in Micronesia. Brace (1981) studied Oceanic tooth size variation including Micronesia, but the results did not lead significant affinity of Micronesian populations from the dental size evidence, probably because of the small sample size. This implies that more data on tooth size is needed to discuss their affinity to the surrounding area. This study aims to describe dental size variation in Micronesia and its relation to other Pacific peoples.

Materials and Method

Materials were plaster dental casts obtained from high school students in Tarawa Island in Republic of Kiribati, and from primary and high school students in Koror in Republic of Palau. These casts were obtained by the field survey by ourselves in 1994 and 1995, and they are housed in Department of Anatomy, Nihon University School of Dentistry at Matsudo, Chiba, Japan. Subjects were 48 males and 46 females in Palau and 50 males and 58 females in Kiribati.

Populations used for comparison were three generations of Fiji (Kanazawa, 1997), those of Samoa (Matsuno, 1997) housed in Nihon University School of Dentistry at Matsudo, and modern Philippines and Philippine Negritos (Kanazawa, 1997). Materials of modern Philippines were from the collection in Showa University School of Dentistry and those of

Table 1 Mesiodistal and buccolingual diameters in Palau

| Mesiodistal Diameters (mm) | | | | | | | | | | |
|-----------------------------|----|------|-------|-----|-------|--------|-------|-----|-------|-----|
| | | Male | | | | Female | | | | P |
| | | N | Mean | | S. D. | N | Mean | | S. D. | |
| Upper | I1 | 48 | 9.13 | ++ | 0.51 | 46 | 8.94 | + | 0.46 | |
| | I2 | 47 | 7.57 | +++ | 0.46 | 45 | 7.33 | ++ | 0.51 | * |
| | C | 44 | 8.73 | | 0.58 | 45 | 8.31 | | 0.45 | *** |
| | P1 | 46 | 7.98 | ++ | 0.47 | 46 | 7.82 | | 0.40 | |
| | P2 | 44 | 7.62 | + | 0.47 | 45 | 7.47 | | 0.41 | |
| | M1 | 44 | 11.34 | ++ | 0.62 | 42 | 11.07 | +++ | 0.55 | * |
| | M2 | 30 | 11.11 | ++ | 0.72 | 28 | 10.82 | +++ | 0.48 | |
| Lower | I1 | 47 | 5.91 | | 0.36 | 45 | 5.79 | | 0.31 | |
| | I2 | 48 | 6.53 | | 0.35 | 46 | 6.42 | | 0.34 | |
| | C | 45 | 7.51 | | 0.49 | 46 | 7.15 | | 0.40 | *** |
| | P1 | 47 | 7.92 | ++ | 0.53 | 46 | 7.78 | +++ | 0.38 | |
| | P2 | 47 | 7.93 | | 0.53 | 46 | 7.75 | | 0.38 | |
| | M1 | 47 | 12.49 | | 0.65 | 44 | 12.15 | | 0.55 | ** |
| | M2 | 23 | 11.73 | | 0.57 | 29 | 11.49 | | 0.60 | |
| Buccolingual diameters (mm) | | | | | | | | | | |
| Upper | I1 | 43 | 7.75 | | 0.53 | 44 | 7.67 | | 0.42 | |
| | I2 | 44 | 7.09 | | 0.61 | 39 | 6.96 | | 0.49 | |
| | C | 46 | 8.63 | | 0.68 | 37 | 8.54 | | 0.56 | |
| | P1 | 48 | 10.13 | | 0.51 | 44 | 9.98 | | 0.55 | |
| | P2 | 47 | 9.95 | | 0.62 | 43 | 9.84 | | 0.57 | |
| | M1 | 45 | 12.09 | | 0.53 | 42 | 12.01 | | 0.58 | |
| | M2 | 30 | 12.49 | | 0.73 | 25 | 12.01 | | 0.59 | * |
| Lower | I1 | 43 | 6.48 | | 0.43 | 41 | 6.34 | | 0.35 | |
| | I2 | 46 | 6.68 | | 0.42 | 44 | 6.70 | | 0.37 | |
| | C | 46 | 7.92 | | 0.58 | 41 | 7.79 | | 0.54 | |
| | P1 | 48 | 8.69 | | 0.60 | 44 | 8.45 | | 0.55 | * |
| | P2 | 48 | 9.04 | | 0.54 | 44 | 8.89 | | 0.42 | |
| | M1 | 45 | 11.37 | | 0.53 | 45 | 11.14 | + | 0.51 | * |
| | M2 | 35 | 11.24 | | 0.56 | 28 | 11.15 | | 0.50 | |

Significant sex differences were denoted by asterisks,

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Diameters with crosses denote significantly larger values compared with the correspondent tooth of Kiribati population in Table 2, +: $P < 0.05$, ++: $P < 0.01$, +++: $P < 0.001$.

Negritos were from the University Museum, the University of Tokyo.

Teeth on the right side of these casts were measured by ourselves. Sample size of each tooth was, however, often less than the number of subjects, because some subjects had lost or unerupted teeth on both sides (Tables 1 and 2). Mesiodistal and buccolingual crown diameters of the teeth from the central incisor to the second molar both in maxillary and mandibular arches were measured on the dental cast by digital calipers with the accuracy of 0.01 mm. Statistical procedures for t-test and following multivariate analysis including

Table 2 Mesiodistal and buccolingual diameters in Kiribati

| Mesiodistal Diameters (mm) | | | | | | | |
|-----------------------------|------|-------|-------|--------|-------|-------|------|
| | Male | | | Female | | | P |
| | N | Mean | S. D. | N | Mean | S. D. | |
| Upper I1 | 48 | 8.84 | 0.51 | 57 | 8.73 | 0.50 | |
| I2 | 49 | 7.17 | 0.49 | 56 | 7.07 | 0.43 | |
| C | 50 | 8.56 | 0.47 | 58 | 8.33 | 0.40 | *** |
| P1 | 50 | 7.70 | 0.48 | 58 | 7.67 | 0.39 | |
| P2 | 50 | 7.39 | 0.48 | 58 | 7.35 | 0.37 | |
| M1 | 50 | 10.97 | 0.51 | 57 | 10.72 | 0.42 | ** |
| M2 | 46 | 10.60 | 0.62 | 57 | 10.37 | 0.51 | * |
| Lower I1 | 48 | 5.80 | 0.27 | 54 | 5.89 | 0.30 | |
| I2 | 49 | 6.41 | 0.37 | 55 | 6.34 | 0.27 | |
| C | 50 | 7.46 | 0.41 | 58 | 7.09 | 0.33 | *** |
| P1 | 50 | 7.61 | 0.46 | 58 | 7.51 | 0.38 | |
| P2 | 50 | 7.76 | 0.56 | 58 | 7.66 | 0.38 | |
| M1 | 45 | 12.34 | 0.63 | 52 | 11.99 | 0.59 | * |
| M2 | 46 | 11.66 | 0.73 | 57 | 11.40 | 0.57 | |
| Buccolingual diameters (mm) | | | | | | | |
| Upper I1 | 48 | 7.97 | | 53 | 7.72 | 0.51 | * |
| I2 | 48 | 7.19 | | 57 | 6.97 | 0.49 | * |
| C | 50 | 9.01 | ++ | 57 | 8.53 | 0.54 | *** |
| P1 | 49 | 10.31 | | 58 | 9.91 | 0.47 | *** |
| P2 | 49 | 10.17 | | 58 | 9.88 | 0.55 | * |
| M1 | 50 | 12.54 | +++ | 57 | 12.00 | 0.66 | *** |
| M2 | 47 | 12.77 | | 54 | 12.21 | 0.71 | *** |
| Lower I1 | 42 | 6.69 | | 49 | 6.51 | + | 0.43 |
| I2 | 46 | 7.03 | +++ | 52 | 6.87 | + | 0.41 |
| C | 49 | 8.57 | +++ | 56 | 8.00 | | 0.54 |
| P1 | 50 | 8.63 | | 58 | 8.31 | | 0.43 |
| P2 | 50 | 9.00 | | 58 | 8.80 | | 0.46 |
| M1 | 46 | 11.24 | | 53 | 10.92 | + | 0.52 |
| M2 | 48 | 11.41 | | 55 | 10.94 | | 0.53 |

Significant sex differences were denoted by asterisks,

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Diameters with crosses denote significantly larger values compared with the correspondent tooth of Kiribati population in Table 1, +: $P < 0.05$, ++: $P < 0.01$, +++: $P < 0.001$.

Mahalanobis' distances among populations for the multi-dimensional scaling method and cluster analysis by Ward method were carried out by SAS routines (1994).

Results

Tables 1 and 2 show means and standard deviations of tooth measurements in the two populations. Significant sex differences were found frequently in the buccolingual diameter in Kiribati. Mesiodistal diameters were generally larger in Palau than in Kiribati in both

Table 3 Mahalanobis' distance of dental dimensions between 10 groups

| | Palau | FS | FM | FA | SP | SS | SA | Kiribati | Philippine |
|------------|-------|-------|-------|-------|-------|------|------|----------|------------|
| FS | 59.3 | | | | | | | | |
| FM | 30.0 | 23.0 | | | | | | | |
| FA | 54.1 | 45.3 | 13.6 | | | | | | |
| SP | 8.6 | 52.1 | 21.9 | 35.3 | | | | | |
| SS | 30.7 | 92.6 | 32.1 | 29.3 | 22.2 | | | | |
| SA | 28.9 | 105.7 | 41.5 | 40.2 | 20.9 | 6.8 | | | |
| Kiribati | 37.8 | 66.0 | 18.5 | 13.2 | 26.1 | 9.6 | 18.3 | | |
| Philippine | 52.1 | 128.0 | 55.7 | 48.8 | 44.1 | 11.9 | 13.9 | 21.2 | |
| Negrito | 121.5 | 284.4 | 173.2 | 162.4 | 124.7 | 77.6 | 63.1 | 108.4 | 45.6 |

Abbreviations denote, FS: Fiji Secondary School, FM: Fiji Medical School, FA: Fiji Adults, SP: Samoa Primary School, SS: Samoa Secondary School, SA: Samoa Adults.

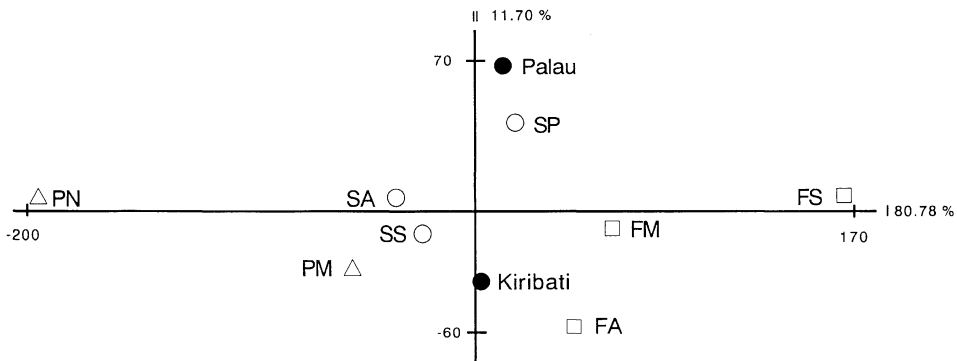


Figure 2 Two dimensional expression of multi-dimensional scaling applied to Mahalanobis' distance based on 28 crown diameters in 10 South Pacific groups.

FS: Fiji Secondary School, FM: Fiji Medical School, FA: Fiji Adult, SP: Samoa Primary School, SS: Samoa Secondary School, SA: Samoa Adult, PM: Philippines Modern, PN: Philippines Negritos.

sexes, while many of buccolingual diameters in male Kiribatians were larger than those of Palau.

The search for the affinity of the Oceanic populations on the basis of male tooth size was attempted with Mahalanobis' distances computed on the basis of 28 parameters of both mesiodistal and buccolingual diameters (Table 3). Two dimensional expression of multi-dimensional scaling based on Mahalanobis' distances was shown in Figure 2 with the axes of the first (80.8%) and second (11.7%) highest contribution. Palau and Kiribati populations were plotted in the center of the first axis close to Samoa, while Fiji and Negritos were plotted on both ends of the axis. The two Micronesians were separated on the second axis. Principal component analysis (PCA) was also performed using the same 10 populations, and the eigen vectors were shown in Table 4. Two dimensional expression based on the first and second component of the PCA showed close resemblance of the

Table 4 Eigen vectors of tooth measurements in principal component analysis of 10 populations

| | | PC1 | PC2 | PC3 |
|--------------------|----------|--------|--------|--------|
| M-D | Upper I1 | 0.175 | -0.189 | 0.390 |
| | I2 | 0.105 | -0.330 | 0.445 |
| | C | 0.198 | 0.055 | -0.146 |
| | PM1 | 0.183 | -0.218 | -0.127 |
| | PM2 | 0.187 | -0.236 | -0.125 |
| | M1 | 0.167 | -0.238 | 0.245 |
| | M2 | 0.205 | -0.155 | -0.133 |
| | Lower I1 | 0.196 | -0.182 | 0.043 |
| | I2 | 0.200 | -0.105 | 0.204 |
| | C | 0.204 | -0.019 | -0.043 |
| | PM1 | 0.189 | -0.208 | -0.151 |
| | PM2 | 0.210 | -0.053 | -0.206 |
| | M1 | 0.191 | -0.120 | -0.126 |
| | M2 | 0.200 | 0.035 | -0.282 |
| B-L | Upper I1 | 0.163 | 0.209 | 0.286 |
| | I2 | 0.209 | 0.107 | -0.109 |
| | C | 0.158 | 0.294 | 0.190 |
| | PM1 | 0.210 | 0.141 | -0.059 |
| | PM2 | 0.214 | 0.080 | -0.098 |
| | M1 | 0.200 | 0.129 | 0.127 |
| | M2 | 0.206 | 0.119 | -0.059 |
| | Lower I1 | 0.179 | 0.227 | 0.058 |
| | I2 | 0.140 | 0.352 | 0.218 |
| | C | 0.113 | 0.402 | 0.092 |
| | PM1 | 0.211 | 0.063 | -0.025 |
| | PM2 | 0.213 | 0.019 | 0.054 |
| | M1 | 0.201 | -0.133 | 0.118 |
| | M2 | 0.205 | 0.066 | -0.273 |
| Eigen Value | | 20.486 | 4.219 | 1.3195 |
| Percent | | 73.165 | 15.068 | 4.7125 |
| Cumulative Percent | | 73.165 | 88.232 | 92.945 |

distribution of these populations. This indicated that the first and second axes of the figure 2 might express general tooth size and balance of mesiodistal and buccolingual diameters, respectively.

A dendrogram was also drawn by the Ward method with the use of Mahalanobis' distances (Figure 3). Kiribati was classified into Fiji group, while Palau was grouped with Samoa and the modern Philippines. Negrito was an independent population among the groups analysed in this study.

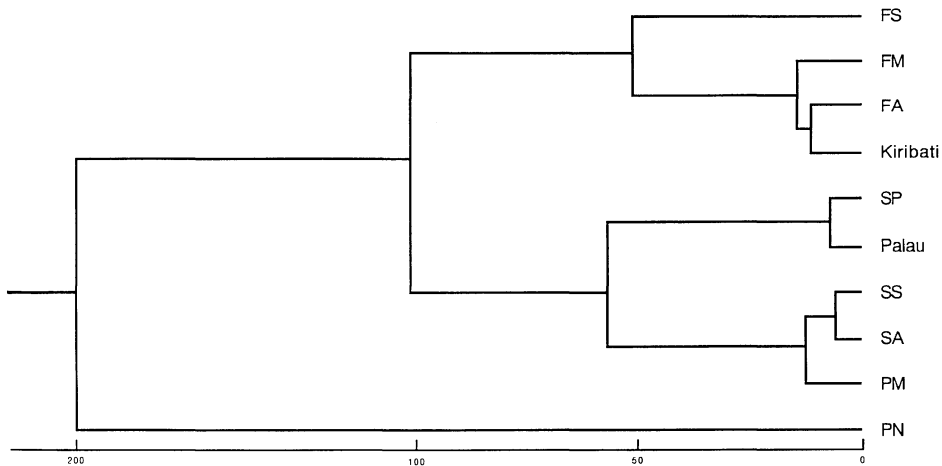


Figure 3 Dendrogram based on cluster analysis calculated from Maharanobis' distance using 28 crown diameters in 10 South Pacific groups. Abbreviations for populations were denoted in Figure 2.

Discussion

Sample size and inter-population comparison are the primary importance in physical anthropology, because small sample size and inter-observer error may mislead the conclusion. Studies on tooth size variation in South Pacific populations so far reported were mainly from Melanesian populations (Kieser, 1990), while Polynesian and especially Micronesian samples are few in this field. The cause of the small sample size in this area is, firstly, the small number of dry skull specimens from archaeological sites. Secondly, the geographical difficulty of these areas limits the dental impressions taken by dental anthropologists. Our survey made it possible to send sufficient number of dental materials and dentists to the small islands in Micronesia. There are controversies about whether there is a difference between tooth size measured from dried skull materials and that from dental casts, and about whether inter-observer error confuses inter-population comparisons of tooth size. To avoid confusion about these issues, we strictly used only our data which are from dental casts of living people measured by the same person (M.M.).

Tooth size varies with time, even in a single population without any change of gene flow. Tooth size enlargement, or positive secular trend of dentition, has been observed in present day populations due to the change of nutritional status and life styles (Garn and others, 1968; Corruccini and Lee, 1984; Kieser and others, 1984). The typical example is recent size enlargement in industrial countries (Garn and others, 1968; Corruccini and Lee, 1984) and also in developing countries such as Fiji (Kanazawa, 1997) which is indicated in Figure 2. However, Kieser (1990) suggested that the current information was inadequate and speculative on the causation of tooth size enlargement in recent populations. Although there is controversy about the causation of positive odontometric trends, tooth size enlargement in a few decades implies that the data obtained in the

present study might not reflect the original tooth size of these Micronesian populations when they migrated into the islands some hundreds years ago. This is the difficulty of using a dental metric study as a tool to define anthropological affinity.

Problems of physical anthropology in Micronesia were overviewed by Pietrusewsky (1990). He concluded that the work in Micronesian physical anthropology has been sporadic and often restricted to a single region in Micronesia. However, a few dental studies have been reported. Hanihara (1992a) presented a clustering of Oceanic populations including Micronesians, i.e., Ponape, Guam and Tinian, based on mesiodistal tooth diameter from skeletal materials, and discussed that Ponape in Central Micronesia or Caroline Islands, was clustered in the group of Polynesians. On the other hand, Guam and Tinian in Mariana Islands were independently clustered together separated from Polynesians, although the sample size was small. Craniometric study on these populations also performed by the same author (Hanihara, 1997) revealed that Ponape samples were clustered with Melanesian populations and Mariana samples were included in South East Asians. This result did not coincide with our result of cluster analysis which indicated Melanesian influence to Kiribati and Polynesian influence to Palau.

There are two opinions in dental anthropology on Melanesian influence to Micronesia. Brace (1981, 1990) used some Polynesian and Micronesian populations to discuss Oceanic tooth size variation and routes of migration of the Pacific people, although the sample size from these populations was small. He proposed that the slightly larger tooth size of the Micronesians might indicate that they have absorbed something from the Australo-Melanesians to their immediate south, although their craniofacial proportions firmly ally them with the Jomon-pacific cluster. On the other hand, Turner (1990b) suggested that the dental characteristics of Guam and other Micronesians were more like those of Polynesians and southern Island Southeast Asians, than like Australians and Melanesians. This suggested that different results might be obtained from different physical characters chosen and that there might be a complicated route of migration into Micronesia.

Turner (1990a) proposed two major dental groups in Mongoloid populations, i.e., Sundadonty and Sinodonty, based on non-metrical dental characters. In addition to them, Proto-Sundadont or Sahul-Pacific has also been proposed to represent the dentition of Australian Aboriginals, New Guineans and some Melanesian populations (Hanihara, 1992b; Scott and Turner, 1997). The Sahul-Pacific group has relatively large teeth compared with other Asian and Pacific populations, as shown by the Fijians in the present study (Figure 2), although genetical influence from Polynesia to Fiji is suggested. This indicates the coincidence of the affinity of Melanesians both in non-metric and in metric study. However, it seems difficult to have single cluster of Micronesians apart from Polynesians in metric study. They are also in a same cluster, i.e., Sunda-Pacific as shown in Kiribati in the present study from the metric point of view.

Micronesia's archaeology suggested that Yap and Palau were settled by pottery making populations about 2,000 years ago (Intoh, 1997). It was also suggested that Palau was

settled from further west, such as the Philippines or the Indonesian islands based on linguistic evidence (Intoh, 1997). This statement was not supported by the tooth size evidence shown in this study. Tooth size of Palau was not as small as modern Philippines, but large comparable to Polynesians. Kiribati was said to be settled from eastern Melanesia first, about 3,000 years ago (Shutler and Marck, 1975) although archaeological data are not sufficient (Intoh, 1997). Tooth size evidence in the present study confirms this possible influence from Melanesia.

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