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Morphological Examination of the Human Skeletal Remains from Fais Island, Federated States of Micronesia

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We report a total of fourteen new skeletal remains (eight adults, one juvenile and five infants) excavated from the Hasahapei burial site (A.D. 1300–1600) on Fais Island, Federated States of Micronesia. The Fais crania show an average or medium morphology with two individuals showing high skull morphology. The morphological trait of shoveling incisors, indicating Asian ancestry, is also present. The two females, SK7 and SK11, exhibit differences under PCA analysis. More cranial samples are needed in order to draw robust conclusions, however. Estimates of stature indicate that, compared to Micronesian and Polynesian populations, the Fais males are shorter and the Fais females are similar in height or taller. Marks of occupational stress and of trauma to the vertebrae, as well as evidence of degenerative joint diseases, may indicate that Fais individuals lived a rather active and physical lifestyle. A treponemal disease, most likely yaws, was also present in two Fais individuals; this indicates childhood disease. A high rate of enamel hypoplasias also suggests poor nutrition or illness among the Fais. The similarly high incidence of caries and calculus formations indicate a carbohydrate-rich diet and poor oral hygiene. Brown stains on the enamel are due to hypocalcification and hypoplasia, meaning the stains originated in food and plaque and not in the betel chewing common in the Marianas.

Key words: human skeleton, Fais Island, Micronesia, pathology, morphology.

1. Introduction

The history of human migration in Micronesia[1] is complex and further complicated by the paucity of skeletal remains everywhere except the Mariana Islands (Weisler et al., 2000; Hanson and Pietrusewsky, 1997; Pietrusewsky, 1990a, b). Various population affinity studies have been carried out using Micronesian cranial data (Tagaya and Katayama, 1988; Howells, 1989; Brace

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[1] The term 'Micronesia' in the present paper refers to the geographical area of the many small islands, covering the northwestern part of the Pacific. The term 'Micronesian' therefore refers to the people living in that region and the terms do not denote a single unified culture or people.

et al., 1990; Pietrusewsky, 1990b; Hanihara, 1993, 1997; Ishida and Dodo, 1997; Hanihara and Ishida, 2001a, b, c, d, e) and dental data (Brace et al., 1990; Turner, 1990; Kanazawa et al., 2000; Swindler and Weisler, 2000; Toma et al., 2007; Hanihara and Ishida, 2005; Hanihara, 2008). A prehistoric association with the Japanese has been suggested (Brace et al., 1990), as well as possible Southeast or East Asian origins (Pietrusewsky, 1990b; Hanihara, 1993; Ishida and Dodo, 1993, 1997; Hanihara, 1997; Hanihara and Ishida, 2001a, b, c, d, e). An east-west division within Micronesia may exist, paralleling linguistic (Howells, 1973; Pietrusewsky, 1990b), dental (Kanazawa et al., 2000) and genetic studies (Lum, Jorde, and Schiefenhovel, 2002). Dental metric comparative studies have also found that Micronesian samples share characteristics with Southeast Asian and Melanesian samples (Hanihara and Ishida, 2005; Toma et al., 2007). mtDNA and STR allele studies have also suggested a possible Micronesian origin in Southeast Asia (Lum and Cann, 1998, 2000). In a study based on Y chromosomes, however, a Melanesian and Eastern Indonesian origin was posited (Hurles et al., 2002).

Several human dispersal routes to Micronesia have been suggested: the first into western Micronesia (i.e. Marianas, Yap and Palau) from the west, and the second from the south into central and eastern Micronesia (Intoh, 1997). The central Caroline Islands, with their position in the geographical center of Micronesia, play a key role in the investigation of these dispersals (Intoh, 2008). Fais Island, located in the central Caroline Islands (9°46'N and 140°31'E), is a raised coral island about 2.7 km in length and 1.1 km in width (Figure 1). The nearest island to Fais is Ulithi Atoll, about 80 km to the west. The Yap Island complex, about 180 km west of Ulithi, is the nearest high island to Fais. Other nearby high islands are Palau, 600 to 700 km SW, and the Marianas, 600 to 900 km NE.

Past archaeological research in the central Caroline Islands has generally been scanty and limited to Ulithi, Faraulep, Woleai, Lamotrek, and Ngulu (Rainbird, 2004; Intoh, 2008). Fais Island, however, has been the focus of research on three occasions by Intoh (1993, 1995, 2008). As a result, a chronology of Fais history has been established and divided into four cultural phases (Intoh, 2008). The initial colonization phase lasted from about A.D. 1 to A.D. 400. Remains of Asian rats (*Rattus rattus*) and domesticated animals date to this period (Intoh and Shigehara, 2004; Intoh, 2008). Excavated Yapese pottery also suggests continuous contact with Yap during this time. Excavated remains from Phase II (A.D. 400–800) and Phase III (A.D. 800–1400) indicate interregional contacts with the Marshalls and Solomons, as well as with the Philippines, in those years (Intoh, 2008).

In 1994, Intoh carried out archaeological research at the Hasahapei burial site on Fais Island. Six undisturbed burials, one secondary burial, and six incomplete sets of skeletons were excavated (Intoh, 1995). All the *in situ* burials were lightly crouched, with heads toward the west. The burials date from approximately A.D. 1300–1600, and associated artifacts indicate that they

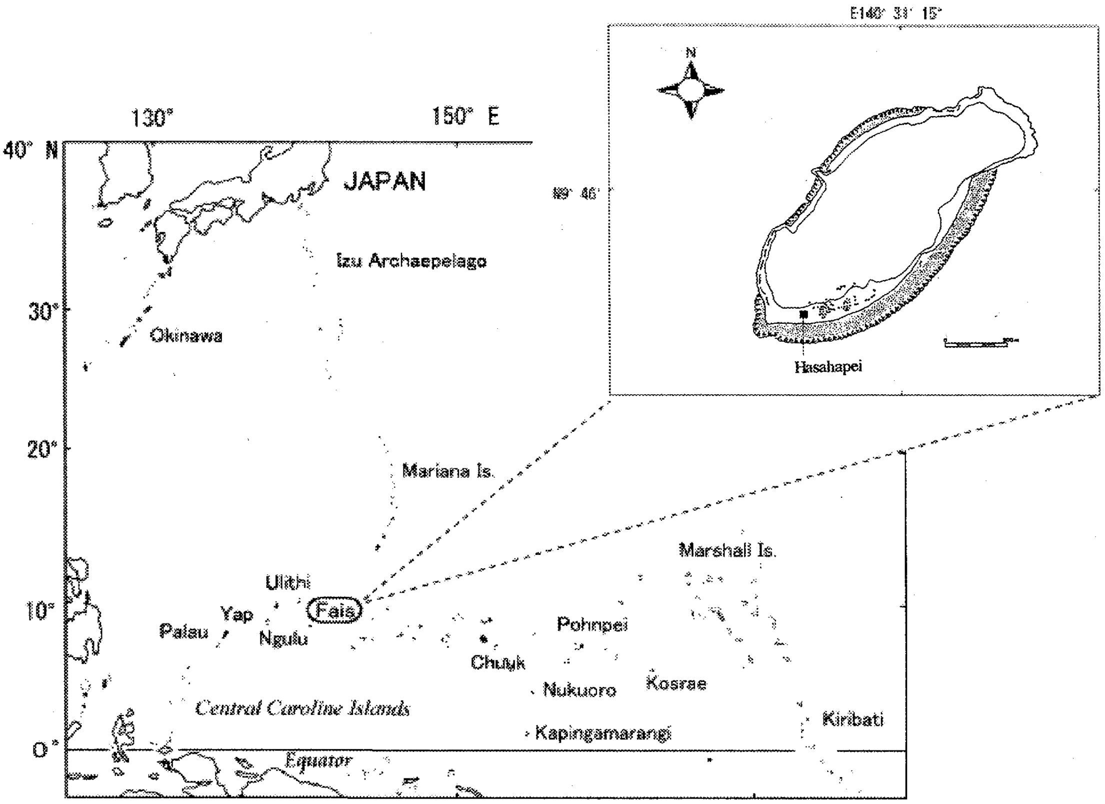

Figure 1. Map of Micronesia and Fais Island. The Hasahapei burial site is shown (after Intoh and Shigehara, 2004)

predate European contact, though the secondary burial and associated bones from the subsurface layer do not (SK1~3). The goods buried with the individual SK1 indicate a post-contact burial.

This paper aims to provide a general description of the skeletal remains excavated from the Hasahapei site. Descriptions and discussions of the skeletal inventory, cranial measurements and comparisons, metric and non-metric traits, paleopathology, and dental morphology and pathology of the Hasahapei individuals are given here. Although the Hasahapei individuals appear to be relatively late arrivals in the 1800-year history of humans on Fais, the data reported here may provide new insight into the island's demographic history. Principal component analysis is performed using cranial measurements from two female skeletons to discover any similarities or dissimilarities with female samples from surrounding islands. In addition, the process of unraveling the complex history of human colonization in the Micronesian Islands is still impeded by scant well-sourced human skeletal remains from this region. Although reports of human skeletal remains from Palau (Fitzpatrick, 2003; Nelson and Fitzpatrick, 2006; Gallagher, 2008; Berger et al., 2008; Fitzpatrick, Nelson, and Clark, 2008) and the Marshalls (Weisler et al., 2000) have been reported recently, these islands represent only a fraction of Micronesia. The Hasahapei discoveries, then, increase significantly the number of well-preserved human skeletal remains available for study in the region.

2. Materials and Methods

2.1 Morphological Examinations

Of the burials excavated, a minimum of fourteen individuals were identified, including eight adults (two males and six females), one juvenile, and five infants (Table 1, Figure 2). The archaeological context of the excavation has been reported by Intoh (1995). The age of the Hasahapei burial site was determined by radiocarbon dating (Intoh, 1995). Charcoal samples associated with two burials (SK7, SK11) were sent to the Waikato Radiocarbon Dating Center in New Zealand (Intoh, 1995). The C14 dates obtained for SK7 and SK11 are 601±69 BP (Wk-3354: A.D. 1287–1434) and 518±59 BP (Wk-3353: A.D. 1300–1590) respectively.

Standard guidelines for the recording and identifying of human skeletal remains were followed (Buikstra and Ubelaker, 1994; Bass, 1995; White, 2000; Scheuer and Black, 2000; Hillson, 2001, 2002). Age at death was determined following Ubelaker and Grant (1989), Liversidge, Dean, and Molleson (1993), Liversidge, Herdeg, and Rösing (1998), Scheuer and Black (2000), and Hillson (2002) for infants/juveniles and Lovejoy et al. (1985), Brooks and Suchey (1990), Buikstra and Ubelaker (1994), Bass (1995), and White (2000) for adults. Skeletal measurements were taken following Martin's definitions (Martin and Saller, 1957). Cranial

Table 1. List of the Fais Human Skeletal Remains

Individuals	Preservation	Age	Criteria for sex	Sex
SK1	Nearly complete adult skeleton in good preservation	30-50 yr	Skull morphology Pelvic morphology	Male
SK2	Cranial vault	30-50 yr	Cranial morphology	Female
SK3(1)	Skull and several infracranial bones in poor preservation	30-50 yr	Skull morphology	Male
SK3(2)	Several neurocranial fragments	40-60 yr	Cranial morphology	Female
SK3(3)	Fragmented scapula and sutural bones	8-16 yr	—	—
SK4	Majority of the skeletal elements are present in poor preservation	< 6 mo	—	—
SK5	Mandible, dentition, several cranial fragments and infra-cranial bones	1-4 yr	—	—
SK6	Nearly complete infant skeleton in poor preservation	6 mo-2 yr	—	—
SK7	Well preserved adult skeleton	17-30 yr	Skull morphology Pelvic morphology	Female
SK8(1)	Several cranial and infracranial fragments in poor preservation	< 1 yr	—	—
SK8(2)	Cranial fragments in poor preservation	< 0 mo	—	—
SK9	Nearly complete adult skeleton in good preservation	45-60 yr	Skull morphology Pelvic morphology	Female
SK10	Cranial fragments and few tarsal and metatarsal bones	18-35 yr	Cranial morphology	Female
SK11	Nearly complete adult skeleton in good preservation	45-60 yr	Skull morphology Pelvic morphology	Female

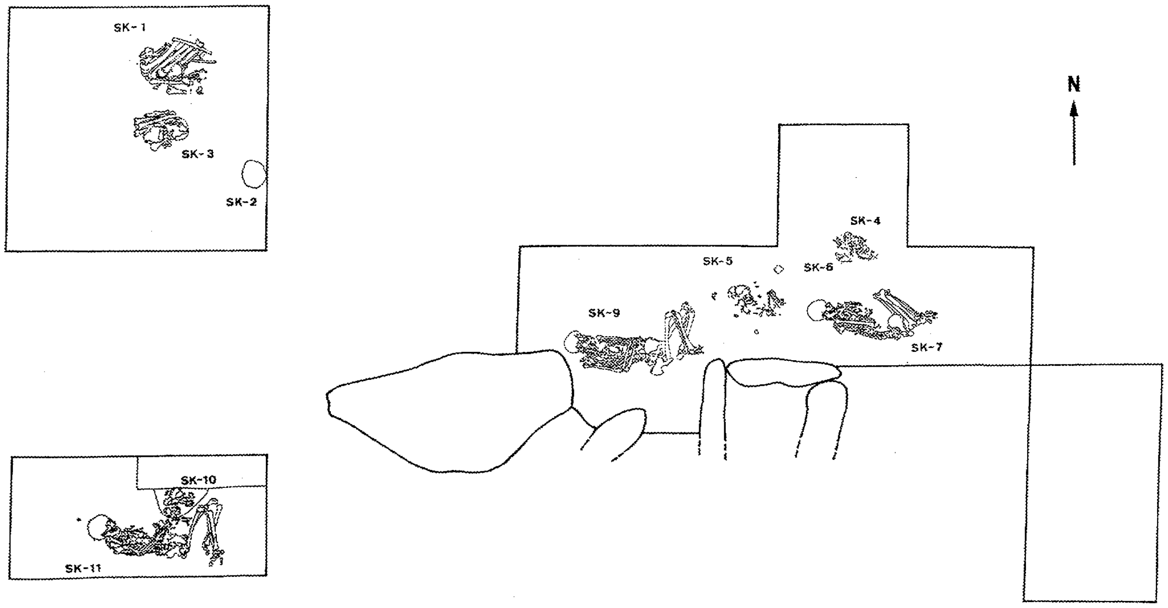

Figure 2. Distribution of the Excavated Burials at Hasahapei Site

indices are calculated following Bass (1995) and facial flatness indices following Yamaguchi (1973).

Nonmetric traits observed in the skeletal remains were recorded based on studies by Saunders (1989), Hauser and De Stefano (1989), and Buikstra and Ubelaker (1994). Stature estimates were calculated following Houghton's Polynesian formula based on the maximum length of the tibia (Houghton, 1996), as this was the only bone present in the majority of individuals. Evidence of pathologic changes to the skeletal remains such as infection and degenerative changes (Merbs, 1989; Turkel, 1989; Iscan and Kennedy, 1989; Roberts and Manchester, 1997; Aufderheide and Rodriguez-Martin, 1998; Buckley and Tayles, 2003) as well as dental pathologies (Hillson and Bond, 1997; Langsjoen, 1998; Hillson, 2001, 2002) were observed and recorded.

2.2 Multivariate Analysis

This study also aims to examine biological relationships using craniometric analysis to compare Fais female cranial samples with female series from the neighboring Pacific Islands, Japan, and the Taiwan (Atayal) series. Only two female crania, SK7 and SK11, are well preserved and intact, and therefore these are chosen for the comparative analysis. A comparative analysis of the male cranium, SK1, will be discussed in a future paper. The female samples used in the craniometric comparison study are presented in Table 2. The comparative data were taken from published resources of Pietrusewsky (1977), Howells (1989) and Dodo, Doi, and Kondo (2001). Unfortunately, female cranial measurements from the islands of Southeast Asia were not

Table 2. Comparative Female Samples for the Craniometric Analysis

Sample name	n	Brief description	Source
Micronesia			
Fais Island (SK7 and SK11)	2	From the Hasahapei Burial site. Prehistoric (600 to 500 BP)	Present study
Guam	27	From the H. G. Hornbostel collection. B. P. Bishop Museum, Honolulu. Prehistoric Chamorro (Latte Period)	Howells (1989)
Melanesia			
New Caledonia	81	From Musée de l'Homme, Paris (including the Broca collection). Majority of the specimen were collected at the end of the 19th century	Pietrusewsky (1977)
Vanuatu	49	From Musée de l'Homme, Paris (including the Broca collrction). Exact dates for specimens unknown	Pietrusewsky (1977)
Fiji	24	From Viti Levu, Vanua Levu, Ova lau and Lau Islands. Exact dates for the specimens unknown	Pietrusewsky (1977)
Tolai (PNG)	54	From the Felix von Luschan collection. American Museum of National History, New York. Exact dates for specimens unknown	Howells (1989)
Polynesia			
Tonga-Samoa	10	From numerous museum collections and the Auckland Institute and Museum, New Zealand	Pietrusewsky (1977)
Mokapu (Hawaii)	159	From the B. P. Bishop Museum, Honolulu. Prehistoric Hawaiians	Pietrusewsky (1977)
Marquesas	61	From Musée de l'Homme, Paris; British National History Museum, U.K. Exact dates for specimens unknown	Pietrusewsky (1977)
Japan			
Ainu (South and Southeast Hokkaido)	38	From the Faculty of Medicine, University of Hokkaido and the University Museum of Tokyo University, Japan. Specimens collected in 1888-1889	Howells (1989)
Ryukyu (Amami and Okinawa)	34	From the collections housed in Kyoto University, University of the Ryukyus and University of Tokyo. Specimens are found at burial caves and are believed to date from early modern Edo period	Dodo et al. (2001)
Northern Kyushu	41	From the Department of Anatomy, Kyushu University, Fukuoka, collected from 1904 to 1928	Howells (1989)
Taiwan			
(Atayal tribe) Taiwan Aboriginals	18	From the Academia Sinica, Taiwan and National Taiwan University, Taiwan. Specimens are from the Wushei incident of 1932	Howells (1989)

available for this study due to the scarcity of published data.

Ten cranial measurements are used, following definitions given by Martin and Saller (1957). These measurements were chosen for the comparative analysis because they are the only ones in common with the data published by Pietrusewsky (1977), Howells (1989), and Dodo , Doi, and Kondo (2001). They are maximum cranial length, cranial base length, basion and bregma height, maximum cranial breadth, facial length, bizygomatic breadth, orbital height, orbital breadth, nasal height and nasal breadth.

To evaluate the relationships between the Fais female crania and the Asia-Pacific cranial series, principal component analysis (PCA) is performed on log shape ratios calculated using the geometric mean (Darroch and Mosimann, 1985, Jungers, Falsetti, and Wall, 1995). According to Darroch and Mosimann (1985), size is defined as the geometric mean of all the variables; shape ratios are then calculated as ratios of each variable to the geometric mean, which is then log-transformed. These shape ratios may or may not be correlated with size, but they represent the ratios of the geometric mean and are dimensionless or scale-free. Cluster analyses based on the unweighted pair group method with arithmetic mean (UPGMA) using the principal component scores is performed in order to assess relationships between the samples. All statistical analyses are calculated using XLSTAT for Microsoft Excel by Addinsoft.

3. Results and Discussion

3.1 Descriptions

3.1.1 SK1

SK1 is a well preserved and nearly complete adult skeleton that was found beneath a large paving stone used as a grave stone. This was a secondary burial and the bones were found in a cluster, about 60 cm in diameter, together with a number of shell artifacts. The skull suffered from minimal post-mortem damage (Figure 3). All of the permanent dentition is present. The long bones are present with minimal postmortem damage, so their original lengths can be estimated. The long bone epiphyses are completely fused. All of the cervical, thoracic, and lumbar vertebrae and eleven pairs of rib bones are present. The pubes of both sides are missing. Most of the carpal, metacarpal, tarsal, and metatarsal bones are present. Age at death was estimated as 30–50 years based on the auricular surface examination and the degree of cranial suture closure. A well-developed nuchal crest, thick and rounded supraorbital margin, moderately large mastoid process, prominent glabella and mental eminence, and narrow greater sciatic notch indicate that SK1 is male. The estimated stature is 168 cm.

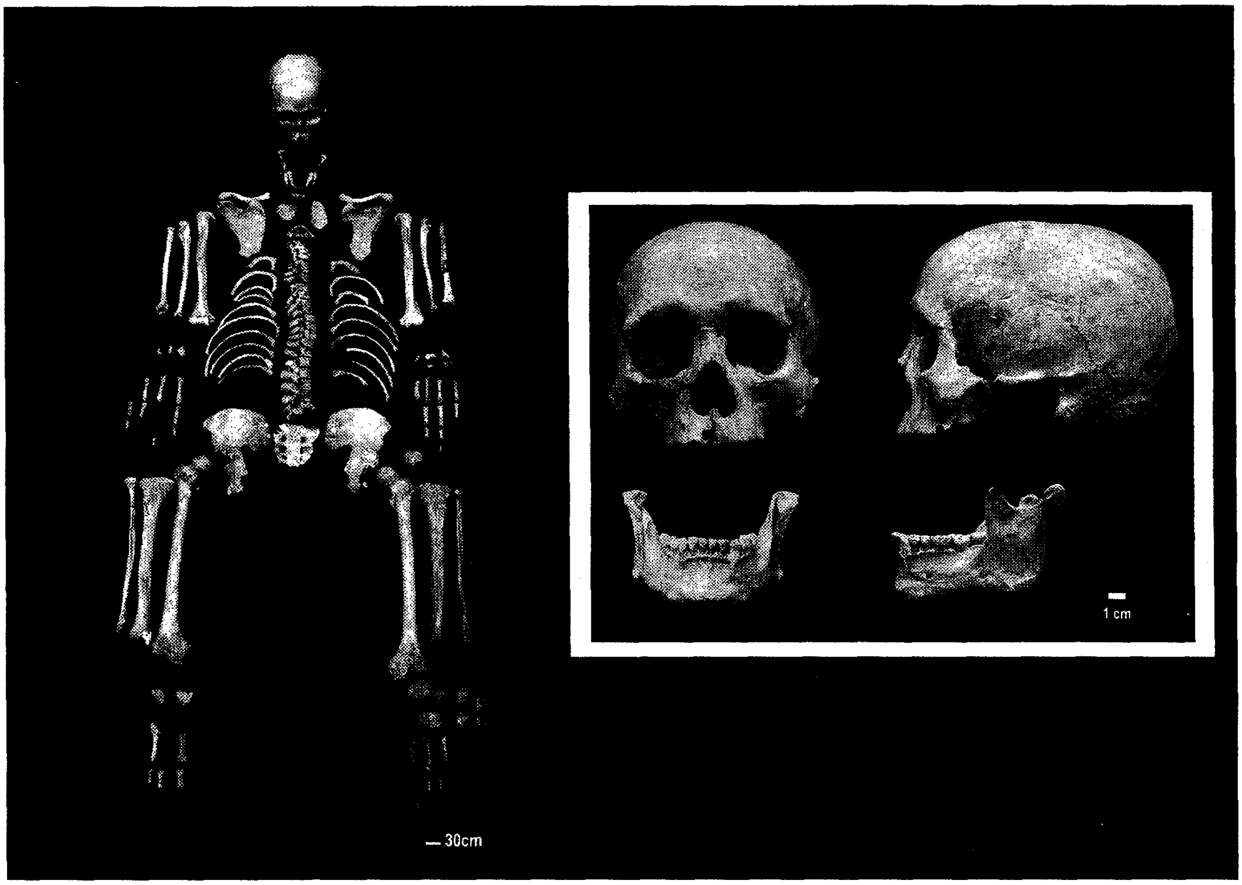

Figure 3. SK1 Skeleton with Frontal and Lateral Skull Views

3.1.2 SK2

SK2 is a damaged adult cranial vault with facial and basicranium bones mostly missing. SK2 was found together with bone fragments from SK3(1)~(3), and many bones were missing. It is very likely that these bones were dug up from the original grave and reburied. No dentition is present. Suture closure indicate that SK2's age at death was between 30 and 50 years. Relatively weak nuchal crest development and less pronounced supraorbital margin and glabella suggest that SK2 is female.

3.1.3 SK3(1)

Three individuals were identified in a shallow deposit devoid of gravestones. These bones may have been dug up accidentally and then reburied. SK3(1) is represented by an adult skull and several infra-cranial bones in poorly preserved condition. The cranium is damaged and most of the facial and temporal bones are missing. The mandible is preserved but the right condyle and ramus are broken. All dentition is present except for that of the upper left first incisor, upper second incisors, upper right canine, upper first premolars, lower first incisors, and lower left second incisor. Upper limb bones include the right clavicle, humerus, and ulna, and fragments of the right scapula. Only the cervical vertebrae are preserved in the infracranial axial skeleton. The right pelvic bone has postmortem damage to the iliac crest and pubis. Lower limb bones present are the right femur shaft, fragments of the fibular shaft, and both tibiae. Age at death is estimated to be 30 to 50 years based on the degree of suture closure. Damages to the pubic symphyseal and auricular surfaces preclude more precise estimation. Based on the moderate supraorbital margin, prominent glabella, and mental eminence, SK3(1) is thought to be male. The estimated stature is 172 cm.

3.1.4 SK3(2)

This is the second individual from the SK3 burial. SK3(2) is an adult represented by several fragments of the neurocranium. No dentition is preserved. Suture closure and morphology of the nuchal crest, mastoid process, and supraorbital margin suggest that SK3(2) was a 40- to 60-year-old female.

3.1.5 SK3(3)

SK3(3) is a juvenile represented by only a fragmented scapula and fragments of the cranial vault with sutures. The general size and the unfused epiphyses of the glenoid, acromion, and inferior angle suggest that SK3(3) was 8–16 years old.

3.1.6 SK4

SK4 is an infant skeleton. Although many skeletal elements are preserved (except for the pubis and ischium), most are fragmented. All the deciduous tooth crowns are present. Measurements of the pars basilaris, clavicle, scapula, humeral and femoral shafts, as well as an examination of the deciduous teeth, suggest that SK4 was around 6 months old or younger at death.

3.1.7 SK5

SK5 is an infant represented by complete deciduous dentition with permanent first molar crowns, mandible, several cranial fragments, and infracranial bones. The mandible is nearly complete but the left condylar process is broken. Several neural arches and centrums as well as fragments of rib bones are present. Limb long bones are fragmented, though several metacarpals, metatarsals, and phalanges are relatively well preserved. Most epiphyseal unions of the infracranial bones are not complete, whereas two pairs of the thoracic and lumbar neural arches are fused. The complete mandibular symphysis, halfway closure of the metopic suture, and early formation of the Huschke's foramen indicate that SK5 was older than one year at death, but the degree of dental developmental suggests that the age was less than four years.

3.1.8 SK6

SK6 is a nearly complete but mostly fragmented infant skeleton. Fragments of most cranial bones and hemi mandibles are present, as are all deciduous dentitions. There are no signs of fusion of the epiphyseal union and primary ossification centers except for the neural arches. The Huschke's foramen is just beginning to form. These observations, as well as deciduous tooth development and comparative measurements of the pars basilaris's length and width, puts SK6 at the age at death to be around six months to two years—apparently younger than SK5.

3.1.9 SK7

SK7 is a well-preserved adult skeleton (Figure 4). The skull is nearly complete and all dentition is present. The infracranial elements are also nearly complete. The age at death is estimated to be between 17 and 30 years, based on examinations of the auricular surface, pubic symphysis, and suture closure and epiphyseal union. The upper third molars are still in their crypts and have not yet erupted, while the lower third molars were just beginning to erupt; all dentition showed minimal wear. A clear subpubic concavity, a wide subpubic angle, and a wide greater sciatic notch indicate SK7 was female. The estimated stature is 163 cm.

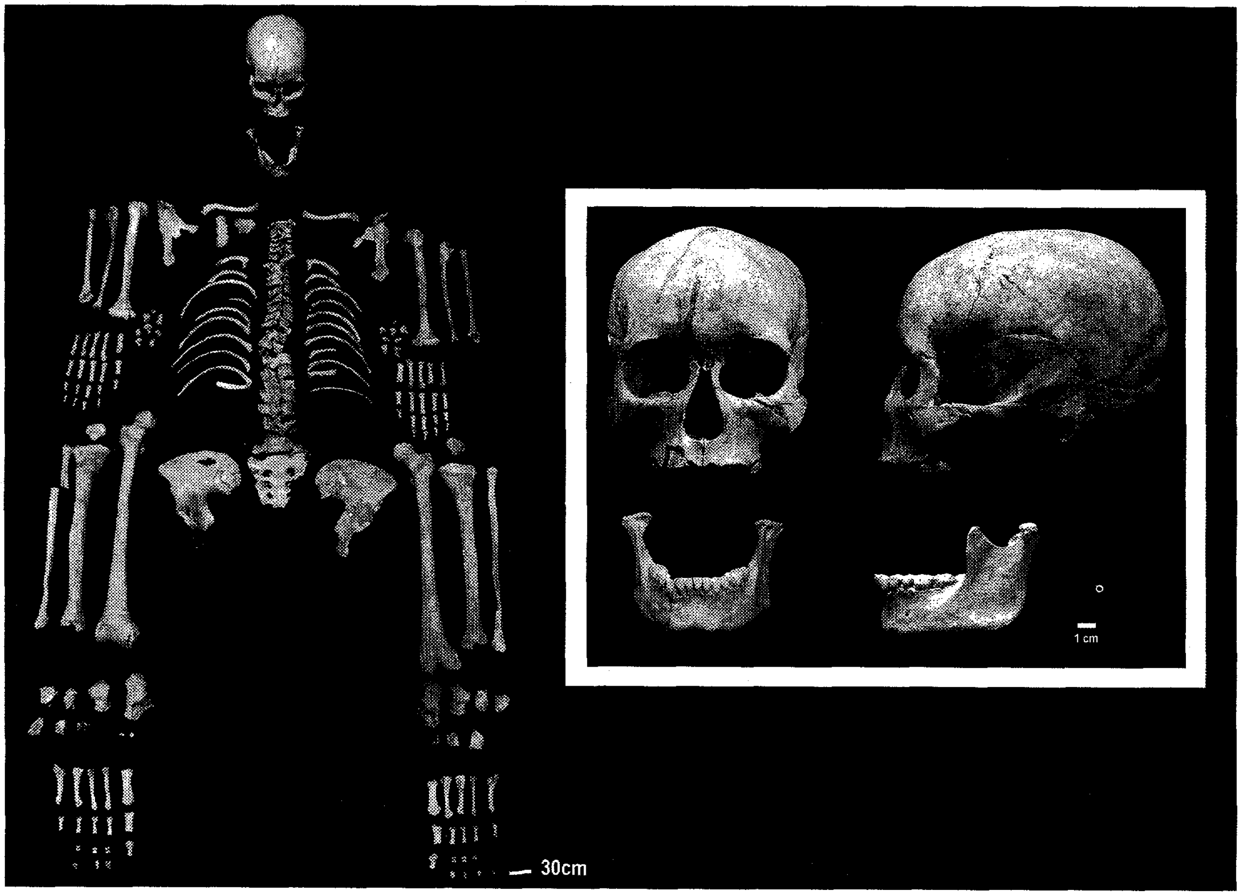

Figure 4. SK7 Skeleton with Frontal and Lateral Skull Views

3.1.10 SK8(1)

Two infants were discovered buried together. SK8(1) is an infant represented by several cranial fragments and infracranial fragments in a poor state of preservation. The infracranial elements of SK8(1) were distinguished from those of the other infant by their greater size. Only fragments of the frontal, temporal, and occipital bones are present. Comparative measurements of the pars basilaris and the morphology of the combined squamotympanic and petromastoid bone suggests that SK8(1) was less than one year old.

3.1.11 SK8(2)

SK8(2) is the other infant buried with SK8(1). Skeletal elements are fragmentary. Several pars squama fragments, pars petrosa and pars basilaris of the occipital bone, fragments of the greater wing of the sphenoid, fragments of the frontal and zygomatic bones, and hemi mandible pieces are present. No dentition is found. Comparison of the length and width measurements of the pars basilaris, greater wing of the sphenoid, zygomatic bone, and ilium indicate that SK8(2) was younger than SK8(1).

3.1.12 SK9

SK9 is a nearly complete adult skeleton, although the facial region is mostly broken (Figure 5). Several permanent teeth are present. The mandible shows considerable antemortem tooth loss. The infracranial bones exhibit minimal damage. Based on an examination of the right pubic symphysis surface, auricular surfaces, and cranial suture scores, the age at death of SK9 is estimated to be between 45 and 60 years. Pubic morphology and the greater sciatic notch indicate that SK9 was female. The estimated stature is 166 cm.

3.1.13 SK10

The skeletal remains of SK10 consist of several cranial fragments and a few tarsal and metatarsal bones from an adult. All upper dentition and the lower right second incisor are present. Estimations of the age and sex are greatly hindered by the lack of skeletal remains. The suture of the cranial vault ectoplate appears open. The upper incisors and canines show slight dentin exposures. Both upper premolars and molars show only slight wear facets on the cusps. SK10 was probably in early adulthood or middle age. A small mastoid process and sharp supraorbital margins suggest that SK10 was likely female.

3.1.14 SK11

SK11 is a well preserved and nearly complete adult skeleton (Figure 6). The alveolar

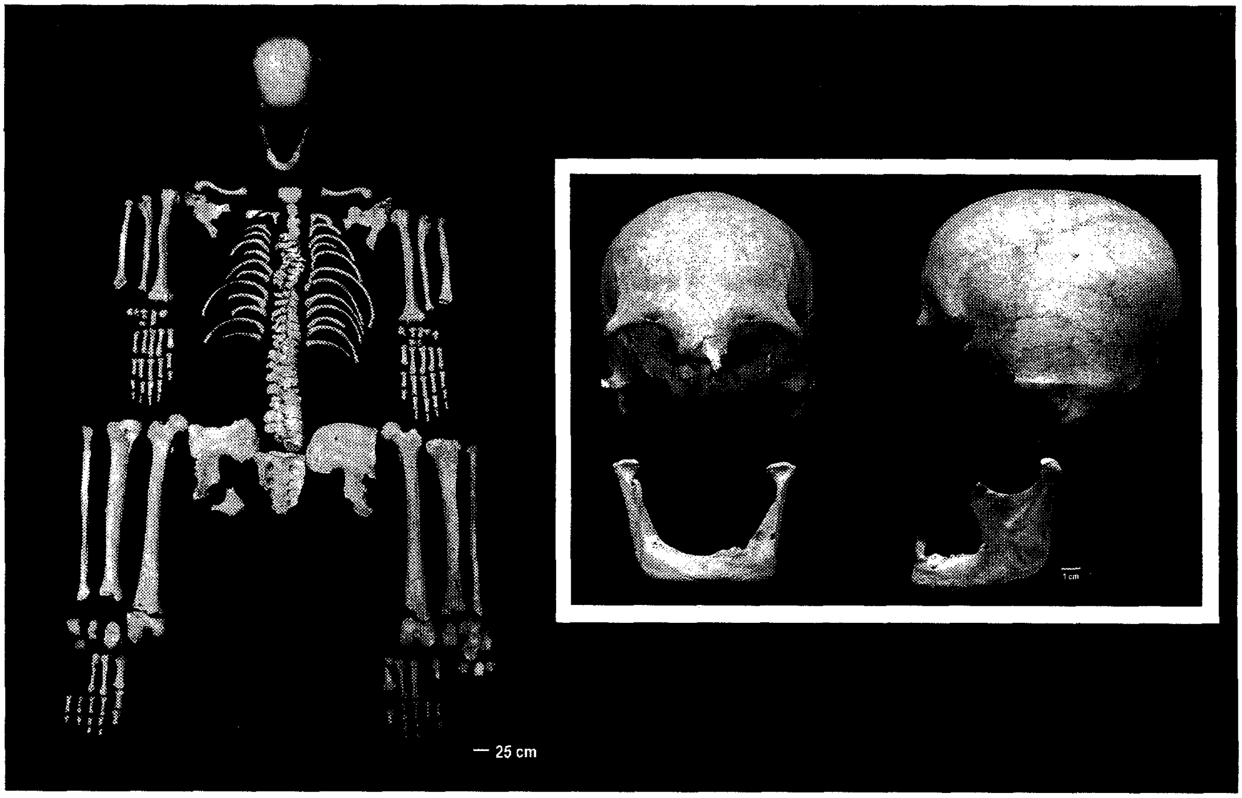

Figure 5. SK9 Skeleton with Frontal and Lateral Skull Views

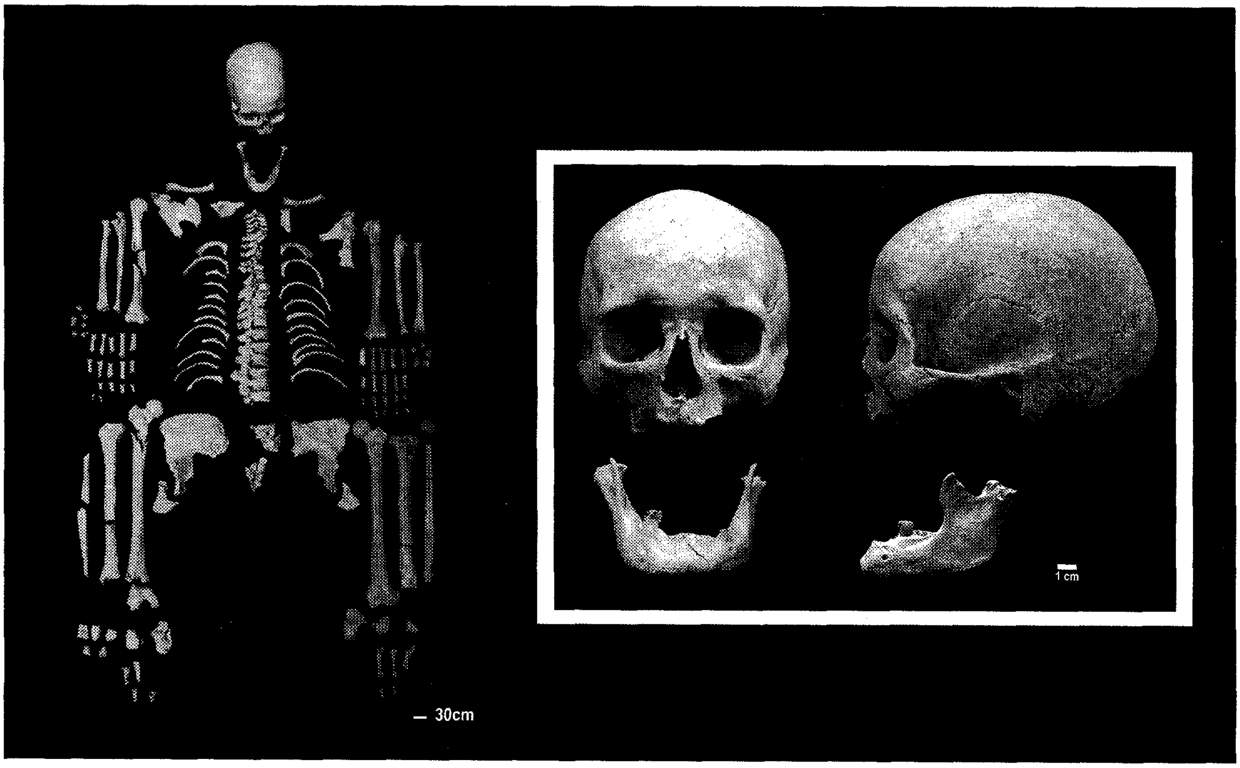

Figure 6. SK11 Skeleton with Frontal and Lateral Skull Views

process of the left maxilla is broken. Several isolated teeth are associated with the skeleton, which suffered from severe antemortem mandibular tooth loss. Infracranial skeletal remains are nearly complete, but both pubic bones are broken off. Morphology of the pubic symphyseal and auricular surfaces and the degree of suture closure suggest that SK11 was 45 to 60 years old. Osteophyte formations are evident in the thoracolumbar vertebrae. Preauricular sulcus and dorsal pitting are observed on the ilia. Morphologies of the innominate bone and cranium indicate that SK11 was female. The estimated stature is 162 cm.

3.2 Comparative Cranial Morphology

3.2.1 Fais Individuals

The best preserved cranial specimens are from SK1 (male) and SK7, SK9, and SK11 (females). Basic measurements and indices of the adult crania are presented in Table 3. While the cranial shape of SK11 falls within the dolichocephalic range (low cephalic index: long head), others (SK1, SK2, SK3(2), SK7, and SK9) fall within the mesocephalic range. SK1 and SK11 exhibit average medium cranial length to height indices while SK7 and SK9 show high skull morphology. The cranial shape of these individuals generally corresponds with precontact Latte Period (A.D. 1000–1521) Chamorro skeletal remains from Guam, which range from mesocephalic to slightly dolichocephalic and typically have high cranial vaults (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997).

The total and upper facial indices of SK7 and SK11 are of slender proportions. SK1 exhibits medium nasal aperture, while Chamorro males have narrow nasal openings (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997). Orbital shape varies from narrow (SK1) to wide (SK11), while Chamorro males and females both exhibit medium morphology. This may indicate that variation is greater among the Fais individuals than among Chamorros, although the Fais sample size is admittedly small. Prognathism is not observed in the Fais as it is in the Chamorro skulls.

The frontal indices (flatness of the frontal bone) of SK1, SK7, and SK11 are 16.2, 17.6, and 17.8, respectively. All three numbers fall within the range of average frontal indices from the Marianas, the Carolines, Hawai'i, and other Polynesian groups, which range from 16.0 to 18.5 (Ishida and Dodo, 1997; Hanihara, 2000). The simotic index (flatness of the nasal bone) for SK1 is 34.0, which is again within the range recorded in the Marianas, the Carolines, and Hawai'i; this index, however, generally exhibits large standard deviation within a single population (Hanihara, 2000). Zygomaxillary indices (lower facial flatness) for SK1 (25.0) and SK11 (24.4) are similar to those of Carolinians and Polynesians, while SK7 shows a higher index value (28.9), closer to Melanesian indices (Hanihara, 2000).

While cranial nonmetric traits are useful in studying biological relationships between

Table 3. Cranial Measurements and Indices

M	Measurement	SK1	SK2	SK3(1)	SK3(2)	SK7	SK9	SK11
1	Maximum cranial length	176	177	(196)	(187)	171	173	187
2	Glabello-inion	168	—	177.5	(170)	154	155	163
3	Glabello-lambda	172	173	(190)	(175)	170	169	178
5	Basion-nasion length	103	—	—	—	102	108	108
8	Maximum cranial breadth	136	133	—	142	131	135	136
9	Minimum frontal breadth	98	96	101.5	93	96	94	97
10	Maximum frontal breadth	—	115	—	(120)	114	117	113
11	Biauricular breadth	121	—	—	130	(121)	120	125
12	Biasteronic breadth	103	—	—	—	97	105	113
13	Bimastoid breadth	99	—	—	104	(96)	100	98
16	Foramen magnum breadth	28	—	—	—	21	26	27
17	Basion—bregma height	130	—	—	—	139	140	138
23	Horizontal circumference	494	498	—	(520)	485	496	515
24	Transverse arc	350	—	—	(333)	307	324	313
25	Sagittal arc	361	—	—	—	362	361	374
26	Frontal arc	130	126	126	—	123	123	127
27	Parietal arc	118	120	—	(136)	120	134	122
28	Occipital arc	112	—	—	—	115	97	124
30	Bregma—lambda chord	105	109	127	121	109	115	112
40	Facial length	96	—	—	—	97	—	94
43	Upper facial breadth	106	111	116	—	104	110	102
43(1)	Inner orbital breadth	93	—	—	—	99	—	94
44	Biorbital breadth	91	—	—	—	99	—	96
45	Bizygomatic breadth	135	—	—	—	125	—	129
46	Bimaxillary breath	102	—	—	—	103	—	98
47	Total facial height	—	—	—	—	118	—	117
48	Upper facial height	(73.5)	—	—	—	72.5	—	63
51	Orbital breadth	39	—	—	—	(43)	—	42
52	Orbital height	38	—	—	—	36	—	34
54	Nasal breadth	26.5	—	—	—	25	—	24
55	Nasal height	53	—	—	—	55	—	49
57	Simotic chord	10	—	—	—	—	—	—
65	Bicondylar breadth	120	—	—	—	110	116	(120)
66	Bigonial breadth	95	—	—	—	87	85	(84)
67	Bimental breadth	48	—	—	—	46	43	48.5
68	Mandibular length	—	—	—	—	104	99	97
69	Symphyseal height	32	—	23	—	28	—	27
70	Ramus height	64	—	—	—	61	61	(61)
71	Ramus breadth	33	—	40	—	35	38.5	36
8/1	Cranial index	77.3	75.1	—	75.9	76.6	78.0	73.1
17/1	Cranial length/height index	73.9	—	—	—	88.3	123.6	74.2
17/8	Cranial breadth/height index	95.6	—	—	—	115.3	103.7	—
47/45	Total facial index	—	—	—	—	94.9	—	90.7
48/45	Upper facial index	—	—	—	—	58.0	—	48.8
9/8	Fronto-parietal index	72.1	—	—	65.5	73.3	71.3	71.3
54/55	Nasal index	50.0	—	—	—	45.1	48.9	49.0

52/51	Orbital index	95.0	—	—	—	83.7	—	81.0
1/1d	Infraglabellar notch (%)	102.9	—	—	—	101.2	102.4	102.2
40/5	Alveolar index (%)	193.2	—	—	—	96.1	—	—
29/26	Sagittal frontal index (%)	85.4	—	—	—	86.2	91.1	88.2
*No.43c	Nasion subtense	15.1	—	—	—	17.5	—	16.7
*43c/43(1)	Frontal index (%)	16.2	—	—	—	17.6	—	17.8
*No.57a	Simotic subtense	3.4	—	—	—	—	—	—
*57a/57	Simotic index (%)	34.0	—	—	—	—	—	—
*No.46c	Zygomaxillary subtense	25.3	—	—	—	29.5	—	23.8
*No. 46b	Zygomaxillary chord	101.0	—	—	—	102.0	—	97.4
*46c/46b	Zygomaxillary index (%)	20.8	—	—	—	28.4	—	22.1

All measurements are in mm. ( ) denotes estimation. * as defined by Yamaguchi (1973)

skeletal populations, the small Fais sample size limits comparisons to other populations. No rare nonmetric traits are observed (Appendix 1).

3.2.2 PCA Analysis

The eigenvalues, cumulative variance percentages and factor loading scores of the first five principal components are given in Table 4. The first principal component (PC1) accounts for about 40% of the cumulative variance. The second (PC2) and third (PC3) principal components represent 23% and 19% of the cumulative variance respectively. In total, the first five principal components account for more than 90% of the cumulative variance. Based on the factor loading scores, PC1 distinguishes the groups by both nasal and orbital breadth and height measurements.

Table 4. Factor Loading Scores, Eigenvalues, and Cumulative Variability Percentages of the First Five Principal Components

Measurements	Factor loading scores				
	PC1	PC2	PC3	PC4	PC5
Max cranial length	0.642	-0.056	0.632	0.166	-0.324
Cranial base length	-0.321	-0.635	0.630	0.178	-0.100
Basion-bregma height	-0.415	-0.667	0.183	-0.427	0.282
Max cranial breadth	0.385	-0.736	-0.390	-0.062	0.049
Facial length	0.383	0.801	0.280	-0.181	0.238
Bizygomatic breadth	0.730	-0.130	-0.165	0.467	0.408
Orbital height	-0.772	0.031	-0.486	0.315	-0.017
Orbital breadth	-0.722	0.355	0.490	0.053	0.191
Nasal breadth	0.844	0.117	-0.365	-0.239	-0.169
Nasal height	-0.822	0.233	-0.391	-0.012	-0.185
Eigenvalue	4.019	2.246	1.849	0.655	0.519
Variability (%)	40.187	22.461	18.489	6.550	5.194
Cumulative (%)	40.187	62.647	81.136	87.686	92.880

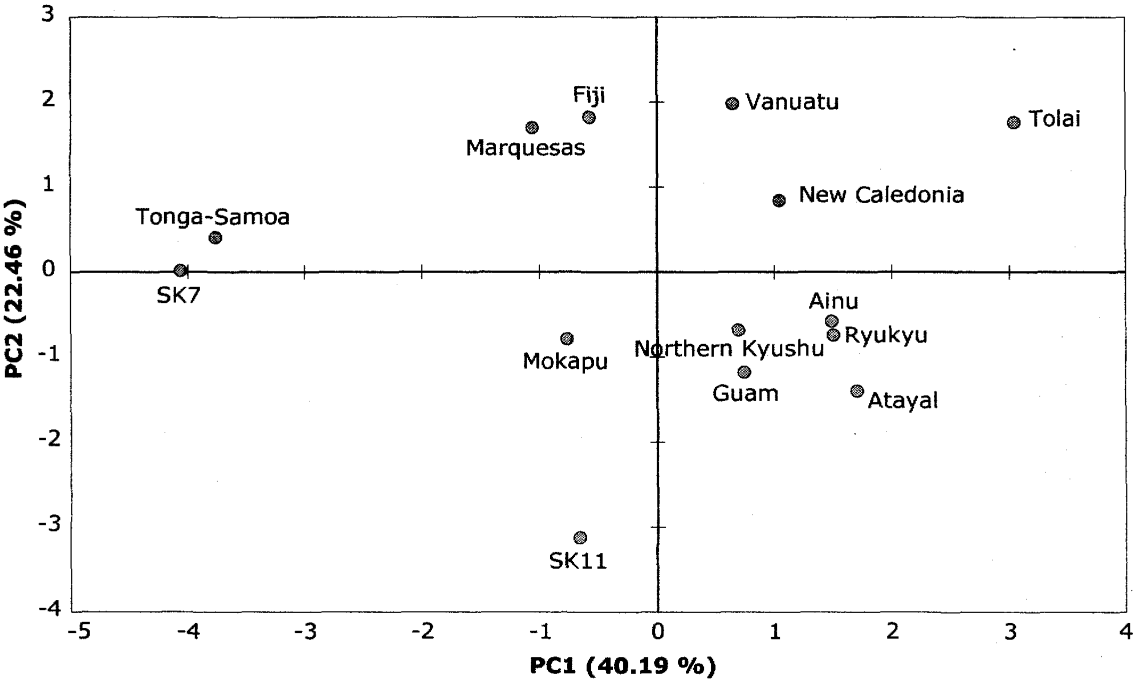

Figure 7. Scattergram of the First and Second Principal Component Scores

PC2 separates the groups on the basis of facial length and maximum cranial breadth measurements, while PC3 distinguishes the groups on the basis maximum cranial and cranial base length measurements.

Figure 7 is a two dimensional graph plotted using PC1 and PC2 scores. The closest group to SK7 is Tonga-Samoa, while SK11 appears to be the outlier. The Guam series is located near the Japanese and Atayal samples, and the Melanesian samples are separated from the rest by their PC2 scores. The Mokapu sample is situated close to the Japanese and Guam series, while the Marquesas is located near the Fiji series. Cluster analysis is carried out using the first three principal component scores that have eigenvalues above one (Kaiser, 1960) (Figure 8). SK7 and Tonga-Samoa are clustered together, while SK11 again appears to be the outlier. The Melanesian samples from Vanuatu, Fiji, New Caledonia, and Tolai are clustered together with the Marquesas sample. The rest of the Asian samples formed another cluster, together with the samples from Guam and Mokapu.

In general, the Melanesian series are grouped together, while the Japanese and Atayal series form another grouping that also includes Guam and Mokapu. The Polynesian female samples appear diverse, however, showing associations with various series. As for the Fais females, it is interesting that they are separated from each other in this analysis. SK11 appears to be the outlier in both the PCA and cluster analyses, while SK7 shows close association with the Tonga-Samoa series. The lack of association in the case of SK11 may be due to the limited female cranial series used in the comparative analyses, especially from Micronesia and Polynesia. With

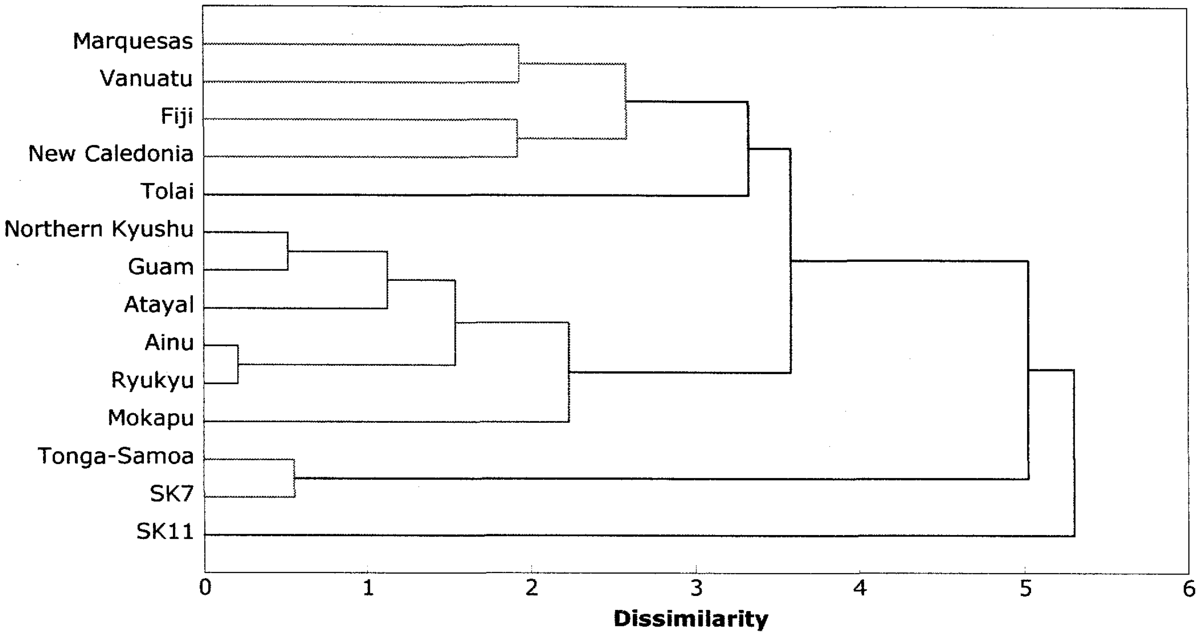

Figure 8. Cluster Analysis of the First Three Principal Component Scores Using the UPGMA Method

more cranial series to compare, we might better understand the relationship between SK11 and the neighboring islands. Furthermore, SK11 shows no distinctive traits and no anomaly such as deformation is observed in the cranial morphology.

The association of SK7 with Tonga-Samoa is rather interesting. This is because mtDNA and Y chromosome studies have shown that Central Micronesians and Polynesians have common origins in the islands of Southeast Asian and Melanesia (Lum and Cann, 2000; Hurles et al., 2002; Cann and Lum, 2004). Excavated remains, however, demonstrate that prehistoric Fais people had some kind of contacts with other Micronesian Islands, Melanesia, and even Indonesian islands—but not with Polynesia. Evidence for this includes faunal remains of dogs, pigs, and chickens and lure shanks (Intoh, 1996, 2008; Intoh and Shigehara, 2004). It would be interesting if the female population of Fais shared cranial features with the Polynesians.

However, the current sample size is too small for any conclusions to be drawn. In order to examine more closely the internal variation among the Fais and their relationship with neighboring populations, more skeletal remains from Fais are required and at present unavailable. The lack of published data on Micronesian and Polynesian female series also impedes the investigation of relationships among these groups.

3.3 Infra-cranial Metric and Non-metric Traits

A few marks of occupational stress are observable in the Fais skeletal remains. Costoclavicular sulcus, an occupational stress marker caused by strenuous use of the shoulder

(Capasso, Kennedy, and Wilczak, 1998; Houghton, 1980), is present in one adult male and one female (SK1 and SK9) out of four individuals examined. This marker is common in the Marianas (44.1% in Chamorro males and 17.6% in females) (Douglas *et al.*, 1997; Roy, 1989). Tibial squatting facets, indicators of habitual squatting posture (Kennedy, 1989), are present in three individuals: SK3(1), SK1 and SK10. Tibial squatting facets appear in 90.6% of skeletal remains from Guam (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997), Saipan, and Tinian (Roy, 1989).

The Fais male (SK1) appears short in stature compared to other Micronesian and Pacific series. The population averages equal or exceed 172 cm (Houghton, 1996, Douglas, Pietrusewsky, and Ikehara-Quebral, 1997; Pietrusewsky Douglas, and Ikehara-Quebral, 1997). However, the average stature of Fais females (165cm) is similar to that of Chamorro females (163 cm) and other Marianas samples (159–163 cm) (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997; Pietrusewsky, Douglas, and Ikehara-Quebral, 1997).

The mid-femoral shafts of both SK1 and SK11 fall within the platymeric range (anteroposteriorly flat), while those of SK7 and SK9 fell within the eurymeric range. The morphology of the femoral shafts is similar to that of femoral shafts in Chamorro males (platymeric) and females (eurymeric) (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997). The tibial shaft of SK7 has the highest platycnemic index, falling within the eurycnemic range. Both SK1 and SK3(1) have indices within the mesocnemic range. In general, the tibiae of the Fais individuals are triangular and share morphology with the Chamorros (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997).

3.4 Paleopathology

Some of the Fais skeletons exhibit pathological conditions. Osteophytes, formed through the deterioration and protrusion of the fibrocartilaginous invertebral disc, are present in the thoracic and lumbar vertebrae in SK9 and the cervical-to-lumbar spine in SK11. In SK9, spondylolysis of the fifth lumbar vertebra and Schmorl's nodes are observed, and the latter is also observed in SK3(1). Spondylolysis is a complete separation of the neural arch through the pars interarticularis, usually of the fifth lumbar vertebra, while Schmorl's nodes are caused by vertical disk hernia. While the etiology of spondylolysis may vary (Merbs, 1989; Turkel, 1989; Aufderheide and Rodriguez-Martin, 1998), mechanical stress probably accounts for it in this case. Spondylolysis also occurs in the lumbar vertebrae of the skeletons from the Marianas with an overall frequency of 4.3% (Pietrusewsky, Douglas, and Ikehara-Quebral, 1997).

The tibiae and fibulae of SK9 and SK11 exhibit proliferative bony lesions consistent with a treponemal disease, possibly yaws (Figure 9). The tibiae and fibulae show osteoblastic lesions, formed as a response to infection and characterized by uneven distribution and/or appositions of

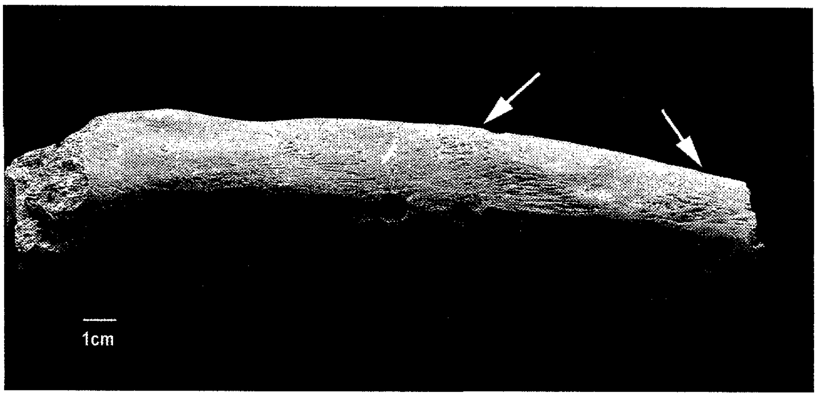

Figure 9. Possible Signs of Treponemal Infection of the Left Tibial Shaft of SK11 (indicated by arrows)

subperiosteal new bone, as well as abnormal porosity on the cortical surface. Yaws is a chronic and recurrent form of treponematosis of nonvenereal origin, characterized by granulomatuous, primary skin lesions in the first stage and bone involvement in the secondary stages (Aufderheide and Rodriguez-Martin, 1998). Periosteal reactions of the bone will result in considerable cortical thickening and bony expansion. The tibia is the most common bone involved, followed by the fibula. However, neither SK9 nor SK11 shows any signs of osteomyletis on the bones or skull. Treponemal infections, including yaws, are commonly found in precontact western Micronesia, particularly in the Marianas and other Pacific islands (Hackett, 1967; Roy, 1989; Trembly, 1996; Hanson and Butler, 1997; Douglas, Pietrusewsky, and Ikehara-Quebral, 1997; Pietrusewsky, Douglas, and Ikehara-Quebral, 1997; Buckley and Tayles, 2003). A detailed description and diagnosis of this paleopathology will be given in another paper. Of the infant skeletal remains, only SK5 exhibits possible signs of an infectious disease. The two fibula shafts of SK5 show porosity and enlargements of the distal ends, possibly indicating periostitis.

3.5 Dental Morphology

All the permanent upper incisors of individuals SK1, SK3(1), SK9, and SK10 exhibit the shoveling trait. Regarding deciduous dentition, SK4, SK5, SK6, and SK8(2) exhibit the shoveling trait in their deciduous incisors. The shoveling trait had been widely regarded as a useful racial marker as the incidence and expression of this trait is high among the Mongoloids (Mizouchi, 1985; Hillson, 2002). The trait has also been found in Micronesian skeletal samples from the Marshall Islands (Weisler *et al.*, 2000) and Guam (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997). Only one individual, SK1, exhibits possible winging of the upper incisors.

3.6 Dental Pathology

An overview of the dental pathologies of the adult permanent dentition is shown in

Appendix 2. SK9 and SK11 suffered antemortem tooth loss and alveolar bone loss and resorption, possibly due to their advanced ages. SK3(1) also suffered from one observable instance of antemortem tooth loss. The total frequency of antemortem tooth loss (per tooth or tooth socket basis) is 22%. The overall frequency of antemortem tooth loss in the Marianas is 5.8%, while a frequency of 9.6% has been attributed to the prehistoric Hawai'ians (Pietrusewsky, Douglas, and Ikehara-Quebral, 1997).

Caries affect mainly the upper and lower molars. SK3(1) has the highest incidence of caries formation; SK7 has the lowest. A link has been established between the presence of caries and the agricultural subsystems (Lukacs, 1989; Larsen, 1995). The total frequency of caries in Fais dentition is 20% (per tooth base). The frequency of caries lesions is low in dentition samples from Palau (7%) (Nelson and Fitzpatrick, 2006) and the Marianas (9.9%) compared to prehistoric Hawai'i (14.0%); this is attributed to betel chewing, which has high cariostatic effects (Roy, 1989; Douglas, Pietrusewsky, and Ikehara-Quebral, 1997; Hanson and Butler, 1997; Pietrusewsky, Douglas, and Ikehara-Quebral, 1997). Caries has also been observed in three teeth from the one individual from the Marshall Islands (Weisler et al., 2000).

Calculus formation is also evident, the most affected area being the buccal surfaces of the teeth (frequency=0.54), followed by the lingual (frequency=0.32) and occlusal surfaces (frequency=0.07). SK9 and SK11 exhibit the highest degree of calculus formation, ranging from moderate to heavy formations. The caries and calculus formation could have been due to poor oral hygiene or a soft, carbohydrate-rich diet.

These individuals also appear to suffer from enamel hypoplasia. Linear enamel hypoplasia (LEH) is found in the canines of three individuals—SK1, SK3(1) and SK7—but not in the deciduous dentitions. Based on the Guam Latte Period population chronology of permanent incisor and canine enamel matrix formations (Stodder, 1997), LEH is formed around the ages of 3.5 to 4.5 years. Pit hypoplasia is found in all permanent tooth classes, affecting the incisors, canines and molars on the buccal (frequency=0.64) and lingual surfaces (frequency=0.40). Interestingly, the total frequency of occurrence of dental enamel hypoplasia in the Mariana permanent incisors and canines is 32.5%, which is significantly higher than in prehistoric Hawai'ians (7.7%) (Pietrusewsky, Douglas, and Ikehara-Quebral, 1997). The occurrence of enamel hypoplasia suggests illness and/or poor nutrition during childhood (Goodman and Rose, 1991; Hillson and Bond, 1997; Hillson, 2002).

Brown staining of the enamel is observed in SK1, SK3(1), SK9 and SK11, and in the deciduous dentitions (see Figure 10). Brown staining has also been reported in the Marianas dentitions and has been attributed to the practice of chewing betel nut (Roy, 1989; Hocart and Fankhauser, 1996; Hanson and Butler, 1997; Douglas, Pietrusewsky, and Ikehara-Quebral, 1997;

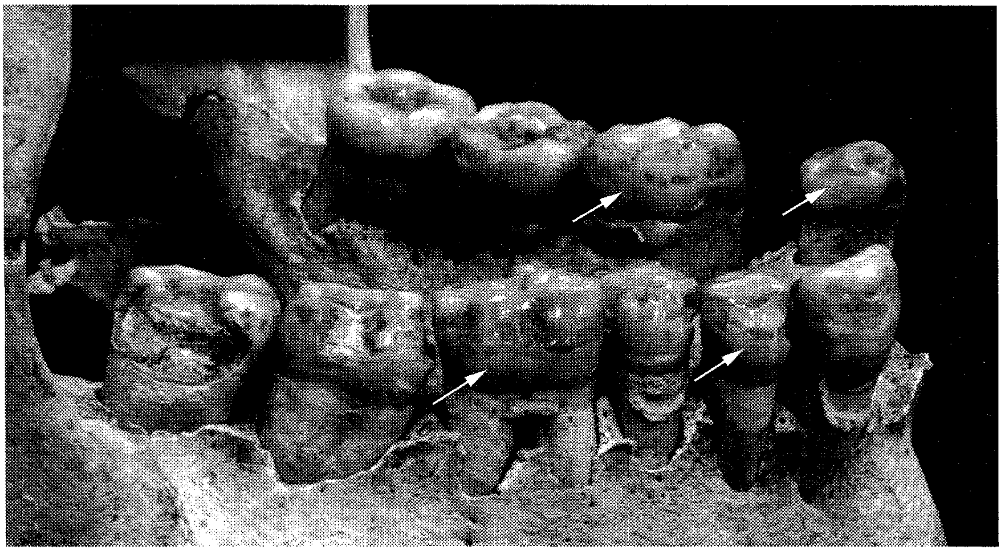

Figure 10. Brown Staining of the Enamel in the Mandibular Dentition of SK3 (1) as Indicated by the Arrows

Pietrusewsky, Douglas, and Ikehara-Quebral, 1997). At the time of first contact with Spanish explorers, as Father Diego Luis de Sanvitores reported in 1669-1670, it was also a common practice among Chamorro women to stain their teeth deliberately instead of engaging in habitual chewing (Hocart and Fankhauser, 1996). Brown staining was also observed in prehistoric Chamorro dentition from the pre-Latte and Latte periods (Pietrusewsky, Douglas, and Ikehara-Quebral, 1997). Deliberate staining will result in a particular pattern of stains on only the visible surfaces of the teeth. This is not seen in the Fais dentition, where light brown stains occurred on all surfaces. An analysis of Fais sample teeth has suggested that their staining was due mainly to poor calcification rather than to practices such as betel nut chewing (Shimabara, 2004). Heavy enamel hypoplasia and poor calcification have caused heavy collapse of the enamel, resulting in opaque white patches on the normally translucent enamel surface that may be stained brown by plaque or food (Hillson, 2002; Shimabara, 2004). It has also been suggested that betel nut chewing may have cariostatic properties (Trivedy, Craig, and Warnakulasuriya, 2002) and this was used to explain the low incidence of caries in the Marianas (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997; Hanson and Butler, 1997; Pietrusewsky, Douglas, and Ikehara-Quebral, 1997). Chronic chewers will also exhibit marked cusp attrition (Trivedy, Craig, and Warnakulasuriya, 2002). All the Fais individuals exhibit caries, and their dental wear is slight to moderate, perhaps indicating that they did not engage in habitual betel nut chewing. The deciduous dentition may have been stained brown due to extrinsic discoloration by metallic or nonmetallic substances found in the ground.

There are no indications of cultural modifications, such as filing, chipping, inlays, dental ablation or purposeful removal of teeth, among the Fais individuals.

4. Conclusion

The excavation of the Hasahapei skeletal remains provides us with the opportunity to observe and examine pre-contact Fais Islanders. The overall state of preservation of the human skeletal remains is generally fair, though the infant skeletons are mostly fragmented. It is interesting to note that there were more adult females and infants than males in the Hasahapei burial site. This might indicate a differential burial practice for males and females as well as for children. The two males, SK1 and SK3 (1), show signs of reburial. SK1 was reburied with great care. For example, a shell bracelet was still worn around the forearm bones. This suggests that SK1 was dug up, perhaps during the digging of another burial pit, and reburied afterwards as is done today.

Comparisons of Fais cranial morphology with those of neighboring islands reveal the similarity in the overall cranial shape of the Fais to the Chamorro series from Guam (Douglas, Pietrusewsky, and Ikehara-Quebral, 1997), though they have generally flatter faces than the Guam and Polynesian series (Ishida and Dodo, 1997). The results of the multivariate cranial analysis show that SK7 and SK11 appear to differ from each other: SK7 shows close association with the Tonga-Samoa series, while SK11 is the outlier in both analyses. Evidence from archaeological sites, such as remains of domesticated animals, indicates active contacts between the prehistoric Fais islanders and those from surrounding Micronesian and/or Melanesian islands. Further examinations of additional skeletal remains from Fais Island are necessary in order to investigate more closely the internal variation among the Fais islanders as well as their affiliations with neighboring Micronesian and other Pacific islands.

Paleopathological and dental pathology observations such as those of possible treponemal disease and enamel hypoplasia indicate that the Fais islanders suffered from illness and/or poor nutrition during their childhood years. The presence of enamel hypoplasia and poor calcification might also have predisposed the Fais individuals to developing caries lesions. While betel nut chewing, a common practice in the western Micronesian Islands, has been posited as the cause of brown stains on the dental enamel of Mariana skeletal remains (Roy, 1989; Hanson and Butler, 1997; Douglas, Pietrusewsky, and Ikehara-Quebral, 1997), in the case of the Fais people, the cause was poor calcification.

While the sample size of human skeletal remains from Fais is small, these remains may nevertheless be important for understanding the occupation and post-contact history of Fais Island. An increase in sample size will yield more robust conclusions about the affinities and physical activities of Fais Island's past inhabitants.

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References

Aufderheide, A.C. and C. Rodriguez-Martin (1998) *The Cambridge Encyclopedia of Human Palaeopathology.* Cambridge: Cambridge University Press.

Bass, W.M. (1995) *Human Osteology: A Laboratory and Field Manual,* 4th ed. Special Publication No. 2. Columbia: Missouri Archaeological Society.

Berger, L.R., S.E. Churchill, B.D. Klerk and R.L. Quinn (2008) Small-bodied humans from Palau, Micronesia. *PLoS ONE* 3: e1780.

Brace, C.L., M.L. Brace, Y. Dodo, K.D. Hunt, W.R. Leonard, L. Yongyi, S. Sangvichien, S. Xiang-Qing, and Z. Zhenbiao (1990) Micronesians, Asians, Thais and relations: A craniofacial and odontometric perspective. *Micronesica,* Supplement 2: 323–348.

Brooks, S. and J. M. Suchey (1990) Skeletal age determination based on the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. *Human Evolution* 5(3): 227–238.

Buckley, H.R. and N. Tayles (2003) Skeletal pathology in a prehistoric Pacific island sample: Issues in lesion recording, quantification and interpretation. *American Journal of Physical Anthropology* 122: 303–324.

Buikstra, J.E. and D.H. Ubelaker (1994) *Standards for Data Collection from Human Skeletal Remains.* Arkansas Archeological Survey Research Series 44. Fayetteville, Ark.: University of Arkansas Press.

Cann, R.L. and J.K. Lum (2004) Dispersal ghosts in Oceania. *American Journal of Human Biology* 16: 440–451.

Capasso, L., K.A.R. Kennedy and C.A. Wilczak (1998) *Atlas of Occupational Markers on Human Remains.* Journal of Paleontology, Monographic Publication 3. Chieti, Italy: Museo di Storia delle Scienze Biomediche.

Darroch, J.N. and J.E. Mosimann (1985) Canonical and principal component of shape.

Biometrika 72(2): 241–252.

Dodo, Y., M. Doi, and O. Kondo (2001) Metric data of the Ryukyuan crania. *Anthropological Science* 109(2): 183–190.

Douglas, M.T., M. Pietrusewsky and R. Ikehara-Quebral (1997) Skeletal biology of Apurguan: A precontact Chamorro site on Guam. *American Journal of Physical Anthropology* 104: 291–313.

Fitzpatrick, S.M. (2003) Early human burials in the western Pacific: Evidence for a c. 3000 year old occupation on Palau. *Antiquity* 77(298): 719–731.

Fitzpatrick, S.M., G.C. Nelson and G. Clark (2008) Small scattered fragments do not a dwarf make: Biological and archaeological data indicate that prehistoric inhabitants of Palau were normal sized. *PLoS ONE* 3(8): e3015.

Gallagher, A. (2008) Size variation in small-bodied humans from Palau, Micronesia. *PLoS ONE* 3(12): e3939.

Goodman, A.H. and J.C. Rose (1991) Dental enamel hypoplasias as indicators of nutritional status. In M.A. Kelley and C.S. Larsen (eds.), *Advances in Dental Anthropoplogy*, pp.279–293. New York: Wiley-Liss.

Hackett, C.J. (1967) The human Treponematoses. In D. Brothwell and A.T. Sandison (eds.), *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Population*, pp.152–169. Springfield, Ill.: Charles C Thomas.

Hanihara, T. (1993) Population prehistory of East Asia and the Pacific as viewed from craniofacial morphology: The basic populations in East Asia VII. *American Journal of Physical Anthropology* 91: 173–187.

Hanihara, T. (1997) Craniofacial affinities of Mariana Islanders and circum-Pacific peoples. *American Journal of Physical Anthropology* 104: 411–425.

Hanihara, T. (2000) Frontal and facial flatness of major human populations. *American Journal of Physical Anthropology* 111: 105–134.

Hanihara, T. (2008) Morphological variation of major human populations based on nonmetric dental traits. *American Journal of Physical Anthropology* 136: 169–182.

Hanihara, T., and H. Ishida (2001a) Frequency variations of discrete cranial traits in major human populations. I. Supernumerary ossicle variations. *Journal of Anatomy* 198: 689–706.

Hanihara, T., and H. Ishida (2001b) Frequency variations of discrete cranial traits in major human populations. II. Hypostotic variations. *Journal of Anatomy* 198: 707–725.

Hanihara, T., and H. Ishida (2001c) Frequency variations of discrete cranial traits in major human populations. III. Hyperostotic variations. *Journal of Anatomy* 199: 251–272.

Hanihara, T., and H. Ishida (2001d) Frequency variations of discrete cranial traits in major human populations. IV. Vessel and nerve related variations. *Journal of Anatomy* 199: 273–287.

Hanihara, T., and H. Ishida (2001e) Os incae: Variation in frequency in major human population groups. *Journal of Anatomy* 198: 137–152.

Hanihara, T., and H. Ishida (2005) Metric dental variation of major human populations. *American Journal of Physical Anthropology* 128: 287–298.

Hanson, D.B., and B.M. Butler (1997) A biocultural perspective on Marianas prehistory: Recent trends in bioarchaeological research. *American Journal of Physical Anthropology* 104: 271–290.

Hanson, D.B., and M. Pietrusewsky (1997) Bioarchaeological research in the Mariana Islands of the western Pacific: An overview. *American Journal of Physical Anthropology* 104: 271–290.

Hauser, G., and G. F. De Stefano (1989) *Epigenetic Variants of the Human Skull.* Stuttgart: E. Schweizerbart'sche Verlagbuchhandlung.

Hillson, S. (2001) Recording dental caries in archaeological human remains. *International Journal of Osteoarchaeology* 11: 249–289.

Hillson, S. (2002) *Dental Anthropology.* Cambridge: Cambridge University Press.

Hillson, S., and S. Bond (1997) Relationship of enamel hypoplasia to the pattern of tooth crown growth: A discussion. *American Journal of Physical Anthropology* 104: 89–103.

Hocart, C.H., and B. Fankhauser (1996) Betel nut residues in archaelogical samples of human teeth from the Mariana Islands. *Experientia* 52: 281–285.

Houghton, P. (1980) *The First New Zealanders.* Auckland: Hodder and Stoughton.

Houghton, P. (1996) *People of the Great Ocean: Aspects of Human Biology of the Early Pacific.* Cambridge: Cambridge University Press.

Howells, W.W. (1973) *The Pacific Islanders.* London: Weidenfeld and Nicolson.

Howells, W.W. (1989) Skull shape and the map. Craniometric Analyses in the Dispersion of Modern Homo. *Papers of the Peabody Museum of Archaeology and Ethnology*. Cambridge: Peabody Museum.

Hurles, M.E., J. Nicholson, E. Bosch, C. Renfrew, B.C. Sykes, and M.A. Jobling (2002) Y chromosomal evidence for the origins of Oceanic-speaking peoples. *Genetics* 160: 289–303.

Intoh, M. (1993) Archaeological research on Fais Island: Preliminary report. In K. Komatsu (ed.), *Cultural Anthropological Research on Historic Media in the Caroline Islands*, pp.69–111. Osaka: Committee for Micronesian Research 1991, Osaka University.

Intoh, M. (1995) Archaeological research at Hasahapei burial site, Fais Island. In M. Intoh (ed.), *The Acceptance of the Outside World on Fais Island in Micronesia: A Preliminary Report*, pp.39–58, A report prepared for Historic Preservation Office, Yap State, Federated States of Micronesia.

Intoh, M. (1996) Multiregional contacts of Fais Islanders in Micronesia. *Indo-Pacific Prehistory Association Bulletin* 15: 111–117.

Intoh, M. (1997) Human dispersals into Micronesia. *Anthropological Science* 105(1): 15–18.

Intoh, M. (2008) Ongoing archaeological research on Fais Island, Micronesia. *Asian Perspectives* 47(1): 121–138.

Intoh, M., and N. Shigehara (2004) Prehistoric pig and dog remains from Fais Island, Micronesia. *Anthropological Science* 112: 257–267.

Iscan, M.Y., and K.A.R Kennedy (1989) *Reconstruction of Life from the Skeleton*. New York: Alan R. Liss.

Ishida, H., and Y. Dodo (1993) Non-metric cranial variation and the populational affinities of the Pacific peoples. *American Journal of Physical Anthropology* 90: 49–57.

Ishida, H. and Y. Dodo (1997) Cranial variation in prehistoric human skeletal remains from the Marianas. *American Journal of Physical Anthropology* 104: 399–410.

Jungers, W.L., A.B. Falsetti and C. E. Wall (1995) Shape, relative size and size-adjustments in morphometrics. *Yearbook of Physical Anthropology* 38: 137–161.

Kaiser, H.F. (1960) The application of electronic computers to factor analysis. *Educational and Psychological Measurement* 20: 141–151.

Kanazawa, E., M. Matsuno, H. Sekiguchi, T. Suzuki, T. Satake, K. Sasaki, and Y. Igarashi (2000) Tooth size of people in Wabag, Papua New Guinea highlanders and its comparison with Pacific peoples. *Anthropological Science* 108: 169–181.

Kennedy, K.A.R. (1989) Skeletal markers of occupational stress. In M. Y. Iscan and K.A.R. Kennedy (eds.), *Reconstruction of Life from the Skeleton*, pp. 129–160. New York: Alan R. Liss.

Langsjoen, O. (1998) Diseases of the dentition. In A.C. Aufderheide and Rodríguez-C. Martín (eds.), *The Cambridge Encyclopedia of Human Paleopathology*, pp.393–441. Cambridge: Cambridge University Press.

Larsen, C.S. (1995) Biological changes in human populations with agriculture. *Annual Review of Anthropology* 24: 185–213.

Liversidge, H.M., B. Herdeg, and F.W. Rösing (1998) Dental age estimation of non-adults: A review of methods and principles. In K.W. Alt, F.W. Rösing, and M. Teschler-Nicola (eds.), *Dental Anthropology: Fundamentals, Limits, and Prospects*, pp.419–442. New York: SpringerWien.

Liversidge, H.M., M.C. Dean, and T.I. Molleson (1993) Increasing human tooth length between birth and 5.4 years. *American Journal of Physical Anthropology* 90: 307–313.

Lovejoy, C.O., R.S. Meindl, T.R. Pryzbeck, and R.P. Mensforth (1985) Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. *American Journal of Physical Anthropology* 68: 15–28.

Lukacs, J.R. (1989) Dental paleopathology: Methods for reconstructing dietary patterns. In M. Y. Iscan and K.A.R Kennedy (eds.), *Reconstruction of Life from the Skeleton*, pp. 261–286. New York: Alan R. Liss.

Lum, J.K., and R.L. Cann (1998) mtDNA and language support a common origin of Micronesians and Polynesians in Island Southeast Asia. *American Journal of Physical Anthropology* 105: 109–119.

Lum, J.K., and R.L. Cann. (2000) mtDNA lineage analyses: Origins and migrations of Micronesians and Polynesians. *American Journal of Physical Anthropology* 113: 151–168.

Lum, J.K., L.B. Jorde, and W. Schiefenhovel (2002) Affinities among Melanesians, Micronesians, and Polynesians: A neutral, biparental genetic perspective. *Human Biology* 74(3): 413–430.

Martin, R., and K. Saller (1957) *Lehrbuch der Anthropologie,* 1. Stuttgart: Gustav Fischer.

Merbs, C.F. (1989) Trauma. In M.Y. Iscan and K.A.R. Kennedy (eds.), *Reconstruction of Life from the Skeleton*, pp. 161–189. New York: Alan R. Liss.

Mizoguchi, Y. (1985) *Shoveling: A Statistical Analysis of its Morphology*. Tokyo: University of Tokyo Press.

Nelson, G.C., and S.M. Fitzpatrick (2006) Preliminary investigations of the Chelechol ra Orrak Cemetery, Republic of Palau: Skeletal biology and paleopathology. *Anthropological Science* 114: 1–12.

Pietrusewsky, M. (1990a) The physical anthropology of Micronesia: A brief overview. *Micronesica* Supplement 2: 317–322.

Pietrusewsky, M. (1990b) Craniometric variation in Micronesia and the Pacific: A multivariate study. *Micronesica* Supplement 2: 373–402.

Pietrusewsky, M. (1977) Étude des relations entre les populations du pacifique par les methodes d'analyse multivariée appliquées aux variations crâniennes. *L'Anthropologie* 81: 67–97.

Pietrusewsky, M., M.T. Douglas, and R.M. Ikehara-Quebral (1997) An assessment of health and disease in the prehistoric inhabitants of the Mariana Islands. *American Journal of Physical Anthropology* 104: 315–342.

Rainbird, P. (2004) *The Archaeology of Micronesia*. Cambridge: Cambridge University Press.

Roberts, C., and K. Manchester (1997) *The Archaeology of Disease*, 2nd ed. New York: Cornell University Press.

Roy, K.J. (1989) A study of early Marianas Islanders: The skeletons under their skins. MA thesis, University of Otago, New Zealand.

Saunders, S.R. (1989) Nonmetric skeletal variation. In M.Y. Iscan and K.A.R. Kennedy (eds.), *Reconstruction of Life from the Skeleton*, pp. 95–108. New York: Alan R Liss.

Scheuer, L., and S. Black (2000) *Developmental Juvenile Osteology*. San Diego: Academic Press.

Shimahara, T. (n.d.) On the colouring of the Fais Island's skeletal remains. Shimahara Shika Iin, Japan. Unpublished MS (in Japanese).

Stodder, A.L.W. (1997) Subadult stress, morbidity and longevity in Latte Period populations on Guam, Mariana Islands. *American Journal of Physical Anthropology* 104: 363–380.

Swindler, D.R., and M.I. Weisler (2000) Dental size and morphology of precontact Marshall Islanders (Micronesia) compared with other Pacific Islanders. *Anthropological Science* 108(3): 261–282.

Tagaya, A., and K. Katayama (1988) Craniometric variation in Polynesians: Multivariate positioning of the male crania from Mangaia, Cook Islands. *Man and Culture in Oceania* 4: 75–89.

Toma, T., T. Hanihara, H. Sunakawa, K. Haneji and H. Ishida (2007) Metric dental diversity of Ryukyu Islanders: A comparative study among Ryukyu and other Asian populations. *Anthropological Science* 115: 119–131.

Trivedy, C.R., G.Craig, and S. Warnakulasuriya (2002) The oral health consequences of chewing areca nut. *Addiction Biology* 7: 115–125.

Trembly, D.L. (1996) Treponematosis in pre-Spanish western Micronesia. *International Journal of Osteoarcheology* 6: 397–402.

Turkel, S.J. (1989) Congenital abnormalities in archaeological populations. In M. Y. Iscan and K.A.R. Kennedy (eds.), *Reconstruction of Life from the Skeleton*, pp. 109–127, New York: Alan R Liss.

Turner II, C.G. (1990) Origin and affinity of the people of Guam: A dental anthropological assessment. *Micronesica* Supplement 2: 403–416.

Ubelaker, G.H. and L.G. Grant (1989) Human skeletal remains: Preservation or reburial. *Yearbook of Physical Anthropology* 32: 260–287.

Weisler, M.I., J.K. Lum, S.L. Collins, and W.S. Kimoto (2000) Status, health, and ancestry of a late prehistoric burial from Kwajalein Atoll, Marshall Islands. *Micronesica* 32(2): 191–220.

White, T.D. (2000) *Human Osteology*, 2nd ed. San Diego: Academic Press.

Willcox, R.R. (1955) The non-veneral treponematoses. *Journal of Obstetrics and Gynaecology of the British Empire* 62(6): 853–862.

Yamaguchi, B. (1973) Facial flatness measurements of the Ainu and Japanese crania. *Bulletin of the National Science Museum* 16: 161–171.

Appendix 1. Nonmetric traits observed in the Fais skulls

The presence of a trait is indicated with the appearance on the right (R) or left (L) side of the cranium/skull with the number given in brackets. Traits that are unobservable are indicated with (—).

Traits	SK-1	SK-2	SK-3(1)	SK-3(2)	SK-7	SK-9	SK-10	SK-11	A/O	Frequency
Metopic suture	No	No	No	No	No	No	—	No	0/7	0
Frontal groove (no.)	No	No	No	No	No	No	—	R(2)/L(3)	1/8	0.13
Supra-orbital notch (single)	R/L	L	R	R	No	No	L	R/L	6/8	0.75
Supra-orbital foramen (single)	No	R	L	No	No	R/L	No	No	3/8	0.38
Infra-orbital suture	L	R		—	R/L	—	—	R	4/4	1
Infra-orbital foramina (single)	R/L	—	R	—	R/L	—	—	R/L	4/4	1
Zygomatico-facial foramina (no.)	No	R	L(3)	—	R/L	R/L	R/L	R(3)/L(3)	6/7	0.86
Frontal foramen (no.)	R(2)/L(2)	No	R: No/L(1)	R: No/(L: —)	R(1)L(2)	L(1)	No	L(1)	5/8	0.63
Sutural bones (no.)										
epiteric bone	No	—	—	—	No	No	—	L	1/4	0.25
coronal ossicle	No	No	No	No	No	No	—	No	0/7	0
bregmatic bone	No	No	No	No	No	No	—	No	0/7	0
sagittal ossicle	No	No	—	No	No	No	—	No	0/6	0
apical bone	No	No	No	No	No	No	No	No	0/8	0
lambdoid ossicle	No	No	L(2)	No	No	No	R(1)/L(1)	No	2/8	0.25
asterionic bone	No	—	—	No	No	No	—	No	0/5	0
ossicle in occipito-mastoid suture	No	—	No	No	No	No	—	R	1/6	0.17
parietal notch bone	No	No	No	No	No	No	—	No	0/7	0
Inca bone	No	No	Single	No	Single	No	No	No	2/8	0.25
Condylar canal										
not patent	L: No	—	—	—	L		—		1/4	0.25
patent					R	R/L		R/L	3/4	0.25
Divided hypoglossal canal										
partial	R	No	R: No						1/6	0.17
complete			(L: —)	—	No	No	—	No	0/5	0
Parietal foramen										
present on parietal	R/L	R	L: No	R	No	No	R	R	5/8	0.63
present on suture			(R: —)					L	1/8	0.13
Foramen ovale (complete)	L/(R: —)	—	R/L	—	L/(R: —)	L/(R: No)	—	R: No/(L: —)	4/5	0.80
Foramen spinosum (complete)	L/(R: —)	—	R/L	—	L/(R: —)	R/L	—	R/L	5/5	1
Huschke's foramen	R/L	—	No	No	L: No/(R: —)	No	—	No	1/6	0.17
Mastoid suture	No	(R: —)/L: No	R	R	R	No	—	R/L	4/7	0.57
Mastoid foramen	R(2)/L(2)	L	R/L	R/L	No	R/L	—	No	5/7	0.71
Auditory exostoses (present)	No	—	No	No	L: No/(R: —)	No	R: No/(L: —)	No	0/7	0

Os japonicum	No	No	No		No	No	No	No	0/6	0
Occipital condylar (double)	No	No	L: No/(R: —)	—	No	No	—	No	0/6	0
Palatine torus	No	—	—	—	No	No	—	—	0/3	0
Medial palatine canal	No	—	—	—	No	No	—	—	0/3	0
Mental foramen (no.)										
single	R/L	—	R/L	—	R/L	R/L	—	L	5/5	1
multiple								R(3)	1/5	0.20
Mandibular torus	No	—	No	—	No	No	—	No	0/5	0
Mylohyoid bridge	No	—	—	—	No	No	—	No	0/4	0
Rocker jaw	No	—	—	—	No	No	—	No	0/4	0
Ramus shape										
coronoid < condyle		—	L	—		R/L	—		2/5	40.0
coronoid > condyle	(R: —)		(R: —)		R/L			R	2/5	40.0
coronoid = condyle	L							—	1/4	20.0
Concavity/ curve near the gonion	Yes	—	Yes (Very slight)	—	R: None L: slighy	Yes (very slight)	—	No	4/5	80.0

(A): number of affected teeth, (O): total number of teeth observed

Appendix 2. Oral-dental pathology in the Fais adult dentitions

Dental Pathology	SK-1 (A/O)	SK-2 (A/O)	SK-3(1) (A/O)	SK-3(2) (A/O))	SK-7 (A/O)	SK-9 (A/O)	SK-10 (A/O)	SK-11 (A/O)	Total (A/O)	Frequency
Caries (present)										
Maxilla										
Incisors	0/4	—	1/1	—	0/4	0/1	0/4	—	1/14	0.07
Canines	0/2	—	0/1	—	0/2	0/1	0/2	—	0/8	0
Premolars	0/4	—	0/2	—	0/4	0/1	0/4	—	0/15	0
Molars	1/6		4/5		0/6	—	1/6	0/5	6/28	0.21
Mandible										
Incisors	0/4	—	0/1	—	0/4	—	0/1	—	0/10	0
Canines	0/2	—	1/2	—	0/2	0/1	—	—	1/7	0.14
Premolars	0/4	—	1/4	—	0/4	0/2	—	0/1	1/15	0.07
Molars	5/6		6/6		3/6	1/2	—	0/2	15/22	0.68
Abscesses										
Maxilla	No	—	No	—	No	—	No	No	0/5	0
Mandible	No	—	No	—	No	No	—	No	0/5	0
Linear Hypoplasia (LEH)										
Maxilla										
Incisors	2/4	—	0/1	—	0/4	0/1	0/4	—	2/14	0.14
Canines	2/2	—	0/1	—	2/2	0/1	0/2	—	4/8	0.50
Premolars	2/4	—	0/2	—	0/4	0/1	0/4	—	2/15	0.13
Molars	0/6		0/5		0/6	—	0/6	0/5	0/28	0
Mandible										
Incisors	0/4	—	0/1	—	0/4	—	0/1	—	0/10	0
Canines	2/2	—	2/2	—	2/2	0/1	—	—	6/7	0.86
Premolars	2/4	—	0/4	—	0/4	0/2	—	0/1	2/15	0.13
Molars	0/6		0/6		0/6	0/2	—	0/2	0/22	0
Pit hypoplasia										
Maxilla										
Incisors	4/4	—	1/1	—	1/4	1/1	1/4	—	8/14	0.57
Canines	2/2	—	1/1	—	0/2	1/1	2/2	—	6/8	0.75
Premolars	4/4	—	2/2	—	3/4	1/1	0/4	—	10/15	0.67
Molars	6/6		2/5		2/6	—	1/6	5/5	16/28	0.57
Mandible										
Incisors	4/4	—	1/1	—	0/4	—	0/1	—	5/10	0.50
Canines	2/2	—	2/2	—	0/2	1/1	—	—	5/7	0.71
Premolars	4/4	—	3/4	—	2/4	0/2	—	1/1	10/15	0.67
Molars	6/6		5/6		2/6	2/2	—	2/2	17/22	0.77

Antemortem tooth loss site (present)										
Maxilla										
Incisors	0/4	—	—	—	0/4	2/4	0/4	4/4	6/20	0.30
Canines	0/2	—	—	—	0/2	1/2	0/2	2/2	3/10	0.30
Premolars	0/4		—		0/4	2/3	0/4	2/4	4/19	0.21
Molars	0/6	—	1/1	—	0/6	—	0/6	0/6	1/25	0.04
Mandible										
Incisors	0/4	—	0/4	—	0/4	4/4	0/1	4/4	8/21	0.38
Canines	0/2	—	0/2	—	0/2	2/2	—	2/2	4/10	0.40
Premolars	0/4	—	0/4	—	0/4	2/4	—	4/4	6/20	0.30
Molars	0/6		0/6		0/6	3/6	—	0/6	3/30	0.10
Calculus (present)										
Maxilla										
Incisors	2/4	—	0/1	—	4/4	1/1	4/4	—	11/14	0.79
Canines	0/2	—	0/1	—	2/2	1/1	2/2	—	5/8	0.63
Premolars	4/4		2/2		0/4	1/1	2/4	—	9/15	0.60
Molars	5/6	—	3/5	—	1/6	—	0/6	5/5	14/28	0.50
Mandible										
Incisors	4/4	—	1/1	—	0/4	—	1/1	—	6/10	0.60
Canines	2/2	—	1/2	—	0/2	1/1	—	—	4/7	0.57
Premolars	4/4	—	2/4	—	1/4	2/2	—	1/1	10/15	0.67
Molars	6/6		2/6		4/6	2/2	—	2/2	16/22	0.73
Alveolar resorption (present)										
Maxilla	Yes	—	Yes	—	No	Yes	Yes	Yes	5/6	0.83
Mandible	Yes	—	Yes	—	No	Yes	—	Yes	4/5	0.80
Attrition (present)										
Enamel	20/32	—	6/22	—	23/32	5/8	10/17	8/8	72/119	0.61
Dentin	12/32	—	16/22	—	9/32	3/8	7/17	0/8	47/119	0.39
Brown staining	32/32	—	22/22	—	0/32	8/8	0/17	8/8	70/119	0.59

(A): number of affected teeth, (O): total number of teeth observed, (*): uncertainty