

DENTAL PATHOLOGY AND SUBSISTENCE CHANGE IN LATE PREHISTORIC OKINAWA

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ABSTRACT

This paper presents the first extensive series of paleopathological data from the Ryukyu Islands, analyzing evidence of dental caries, calculus and enamel hypoplasias from sixteen sites dating from the Early Shellmound phase IV to the early modern period. The results are consistent with our hypotheses that the Late I-III phases were a time of food stress in these islands and that agriculture began there in the Late IV phase. The small samples used here, however, mean that these preliminary results require further confirmation.

Recent research in archaeology and related disciplines has given us a quite extensive picture of the transition from foraging to farming across much of the Japanese archipelago. One region which remains poorly understood in this respect, however, is the Ryukyu or Okinawan Islands (Figure 1). In Okinawa, cultivated plant remains only become common in archaeological sites from the Gusuku period beginning about the 12th century AD. Through the use of flotation techniques, cultivated wheat, barley, foxtail millet and rice have been identified in 8-10th century deposits at the Naazakibaru site, Okinawa Island (Takamiya 1996:149). Recently, rice has also been discovered from layers III and V at the Nagarabaru Higashi site, Iejima Island (Takamiya 1999); an AMS date on charcoal from layer V gave a corrected result of AD 650 (Fujie 1999:34). The absence of weed remains from Nagarabaru Higashi raises the possibility that the rice may have been imported rather than grown locally (Takamiya 1999), but the paleoethnobotanical data from these two sites suggest that agriculture may have begun in Okinawa sometime during phase IV of the Late Shellmound

period. Linguistic evidence that Proto-Ryukyuan split from Japonic during the same phase supports the hypothesis that agriculture spread with the southward movement of people from Kyushu (Hudson 1994, 1999a).

Notwithstanding these new finds, however, the extent of plant cultivation in Okinawa prior to the Gusuku period remains unclear. In an attempt to gain a better understanding of the transition to farming in Okinawa, we are currently using a variety of approaches including skeletal biology, paleoethnobotany, and archaeology. In this paper we focus on dental pathologies which may be related to subsistence and paleodemographic changes in the Ryukyu Islands. Specifically, we are interested in looking for dental evidence relating to the transition from foraging to farming in Okinawa, and also in testing the hypothesis proposed by Takamiya (1997) that the Late I-III phases were a time of resource stress in the central Ryukyus.

This paper reports preliminary results on dental calculus, linear enamel hypoplasia (LEH) and caries from sites in the central Ryukyus. Some data on cribra orbitalia are also presented but the fragmentary nature of most prehistoric samples made full analysis of this condition impossible. Porotic hyperstosis was extremely rare in the Okinawan samples studied here and was not recorded. Pre-mortem tooth loss (PMTL) was recorded for some early modern samples but was impossible to score consistently for the prehistoric period since many of the latter samples consist of fragmentary remains and/or loose teeth. Our impression was that PMTL was more extensive in the early modern samples but this requires further rigorous observation. Dental attrition was also not scored on this occasion, though the inverse relationship between attrition and caries which has been found in many other studies means that this factor needs to be considered in any future research.

MATERIALS

The skeletal remains used in this study derive from sixteen sites dating from the second millennium BC (Early Shellmound phase IV) to the 19th century AD (Table 1). The periodization used here follows that of Hiroe Takamiya (1990) (Table 2). The period following the Gusuku is referred to as "early modern". Teeth from a total of 90 individuals were analyzed, but samples from most sites are quite small. Skeletal remains were analyzed in Okinawa and Kago-shima in December 1997 and June-July 1998. On the first occasion, scoring of the prehistoric samples was done by both authors independently and results compared in the field. Although this paper uses Hudson's data, in over 95% of cases both authors agreed on scored values. Scoring of the early modern remains was done by Hudson in the summer of 1998. Published data relating to caries at the Mashiki Azamabaru site (Oyamada *et al.* 1996) was also included in this study.

With the few exceptions shown in Table 3, all of the individuals analyzed here were adults. Because of the small number of deciduous teeth and the fragmentary nature of most prehistoric samples, deciduous dentition was scored together with permanent teeth. Postcranial skeletons were not available for most of the samples and sexing was done by the authors on the basis of cranial attributes. Where possible these results were compared with the published osteological reports.

Since this paper attempts to investigate diachronic changes in dental pathology, tight chronological controls on all samples are essential. Unfortunately, it was not always possible to maintain the level of chronological hygiene that we would have wished. Several of the sites used here have only been reported in a preliminary fashion and detailed reports on the skeletal remains are not available for most sites. Much of the Okinawan material is housed at the Prefectural Board of Education storage facility at

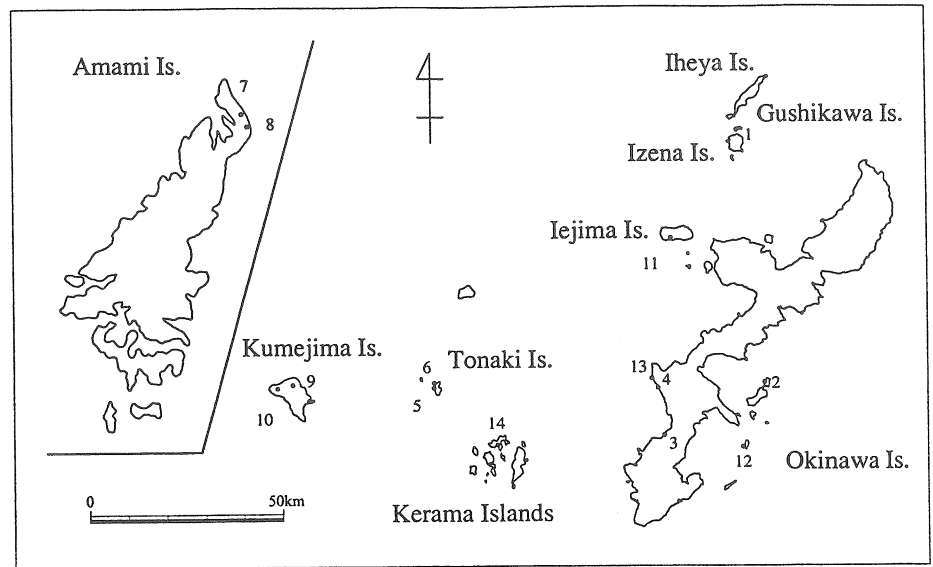


Figure 1: Sites mentioned in the text. 1, Gushikawajima; 2, Nakabaru; 3, Mashiki Azamabaru; 4, Momenbaru; 5, Aakaru; 6, Nishisokobaru; 7, Ushuku East; 8, Wano Tofuru; 9, Hiyajo; 10, Yatchi; 11, Yonazaki; 12, Tsuken 2; 13, Ufutoobaru; 14, Furuzamami.

Table 1. Samples analyzed in this study. Data for the Mashiki Azamabaru site are taken from the analysis published by Oyamada *et al.* (1996)

Site	Location	No. Individuals (Total teeth)	Date
Gushikawajima	Gushikawa Is.	10 (71)	Early IV-V
Nakabaru	Ikei Is.	1 (29)	Early V
Mashiki Azamabaru	Ginowan	28 (412)	Late I-III
Momenbaru	Yomitan	8 (140)	Late I-III
Aakaru	Tonaki Is.	6 (34)	Late I-III
Nishisokobaru	Tonaki Is.	3 (39)	Late IV
Ushuku East	Kasari-cho, Amami	2 (50)	12-13th centuries AD
Wano Tofuru	Kasari-cho, Amami	3 (74)	16-18th centuries AD
Hiyajo	Kumejima Is.	3 (14)	Early modern
Aragusuku	Ryukyu Islands	5 (23)	Early modern
Kanegusuku	Okinawa Is.?	7 (31)	Early modern
Yatchi	Kumejima Is.	20 (120)	Early modern
Yonazaki	Iejima Is.	3 (10)	Early modern
Tsuken 2	Tsuken Is.	6 (120)	? premodern
Ufutoobaru	Yomitan	7 (82)	Late & ? recent
Furuzamami	Zamami Is.	6 (22)	? premodern

Kanegusuku, Itoman, but this material is poorly documented. Although numbers (often written on the skull) exist for most skeletal individuals it is usually hard to relate those numbers with published reports on the sites concerned.

As noted already, most of the samples used here are rather small, a problem which is particularly serious for the prehistoric period. Very few skeletal samples exist for the Late Shellmound and Gusuku periods and in this study we were only able to use two small samples for the Late IV

Table 2. Chronological terminology used in this paper. Based on Hiroe Takamiya (1990)

Okinawa	Kyushu
Early I	Initial Jomon
Early II	Early Jomon
Early III	Middle Jomon
Early IV	Late Jomon
Early V	Final Jomon
Late I	Early Yayoi
Late II	Middle Yayoi
Late III	Late Yayoi
Late IV	Kofun-Heian
Gusuku	Medieval
Early Modern	Tokugawa

Table 3. Subadults with deciduous dentition in the analyzed samples. The Furuzamami specimens have no numbers

Specimen	Approx. Dental Age Teeth	No. of Deciduous
Gushikawajima 15(2)	8 years	1
Gushikawajima 106	5-6 years	3
Furuzamami	9 years	3
Furuzamami	6-8 years	3

phase and the Gusuku period. Since our data do have some quite serious chronological drawbacks, we will first present a brief discussion of the dating of the prehistoric sites in alphabetical order. Okinawan place names are transliterated using double vowels instead of macrons; macrons are, however, omitted for Japanese words.

1. Aakaru

This site is on Tonaki Island about 30 km west of Naha. The Tonaki village history lists this site as Aakarubaru (Tonakison 1983:71). The site was test dug by Tonaki Board of Education in 1976. A series of pits and post-holes around a hearth are possibly the remains of a building. Burials came from the layer beneath these features. A mature female was discovered from this location and a male and another female came from Area II approximately 30 m away. Pottery associated with these burials was of the pointed base type which dates to the early Late Shellmound period.

2. Gushikawajima

Gushikawajima is a small (0.42 km²) islet located between Izena and Iheya Islands approximately 30 km to the north of the Motobu Peninsula of the main island of Okinawa. Though Gushikawajima is presently uninhabited, it contains a complex group of archaeological sites dating primarily to the Early Shellmound period. Major excavations were

conducted from 1975-1980 and 1989-1992. Several dozen human skeletons were found in cliff ledge graves. Though associated artefacts are rare, these burials are thought to date to the Early IV-V phases (Kinoshita 1996:484).

3. Furuzamami

This site is located on Zamami Island which is some 40 km to the west of Naha. The Furuzamami shell midden dates to the Early IV phase (Kishimoto *et al.* 1982), but the Furuzamami skeletal remains come not from this site but from the Shiru locality which is 1700 m further along Furuzamami beach.¹ Five skeletons were discovered at Shiru in 1977 during sand-mining operations and were excavated by China *et al.* (1979). During the 1981 season at Furuzamami, test excavations were also conducted at Shiru in the hope of finding further skeletal remains. As a result, a mandible and cranial fragments were found in a layer of white sand more than 2 m below the surface (Kishimoto *et al.* 1982:143). No artefacts were found associated with any of this skeletal material and its antiquity is therefore uncertain. Sano (1982:144) writes that the condition of the teeth found in 1981 suggests that individual is not modern. Naomi Doi (pers. comm.) has also commented that the craniofacial morphology of the Furuzamami skulls is consistent with a prehistoric date. Burial in coastal sand dunes is considered to be a premodern practice in Okinawa. At present, however, more precise dating of these remains is not possible.

4. Mashiki Azamabaru

This site has two adjacent loci, Azamabaru 1 and Azamabaru 2, and is located in Ginowan City, Okinawa Island. The site was excavated for five years from 1985. The final report from the site has not been published and the following comments are based on brief accounts published by Ginowan City Board of Education (1989:64) and Kinoshita (1996:484). Azamabaru 1 produced burials of Early Shellmound phases IV and V and a settlement from the early Late Shellmound period. At Azamabaru 2, a settlement and two burials dating to the Late III phase were discovered. The shell and other artefacts associated with the burials at Mashiki Azamabaru appear to provide solid support for the proposed dates but detailed comments are, of course, not possible without the final report. Oyamada *et al.* (1996) give few details regarding the dating of their large sample from Mashiki Azamabaru. They write that, "The period of this site is the middle period of the prehistoric shell midden culture on Okinawa island and is equivalent to the latest Jomon and early Yayoi period in Japan" (Oyamada *et al.* 1996:262). It is not clear if this "middle period" refers strictly to the Middle Shellmound phase (i.e., Early V in our terminology), but the "latest Jomon" and "early Yayoi" are presumably the Final Jomon

and Early Yayoi respectively.² Since the Mashiki Aazamabaru sample appears to straddle the Early-Late Shellmound transition it may be useful to sub-divide the sample further in future studies.

5. Momenbaru

This site in Yomitan Village, Okinawa Island is the best dated of the prehistoric sites used here. The site was dug for one month in 1977 and produced seven stone coffins of a type clearly influenced by the Yayoi cultures of Kyushu (Toma and Uehara 1978).

6. Nakabaru

This settlement site on Ikei Island was dug in 1979 and produced 11 pit buildings. One of these buildings contained a burial dug into the floor. From pottery and other artefacts, the buildings and burial are thought to date to Early phase V (Takemoto and Asato 1993:150).

7. Nishisokobaru

Like the Aakaru site, this site is located on Tonaki Island. The skeletal remains analyzed at Kanegusuku were listed only as "Tonaki" but Nishisokobaru is the only other burial site on the island which could have produced these remains. Nishisokobaru was dug by Tonaki Board of Education in 1977 (Tonaki-son 1983:74). Areas A-C produced settlement remains; the burials of eight individuals came from Area D. Burial No. 2 (which was actually two individuals, a female and a child) was associated with Lower Fensa pottery of the late Late Shellmound period. It is thought that the other burials date to the same phase and thus that Nishisokobaru is several centuries younger than Aakaru.

8. Tsuken 2

Tsuken is a small island in Nakagusuku Bay on the east coast of Okinawa Island. An aerial photograph in Takemoto and Asato (1993:4) shows the location of the various prehistoric sites on Tsuken Island. The Tsuken site is a shell midden dating to the early part of the Late Shellmound period. According to Takemoto and Asato (1993:145), however, human skeletal remains did not come from this site but from Tsuken 2 several hundred metres along the coast. The skeletal material we investigated at the Kanegusuku storeroom was marked only as "Tsuken" but it is likely that those remains came from Tsuken 2. Takemoto and Asato (1993:145) write that Tsuken 2 also belongs to the Late Shellmound period, but no evidence in support of this date is presented and according to Toma (pers. comm.), although the Tsuken remains gave the appearance of being prehistoric, no definite dates are available.

9. Ufutoobaru

This site is a shell midden in Yomitan Village located very close to Momenbaru. The site was dug twice in 1972 and 1989 but only a brief report has been published (Takamiya *et al.* 1993). In the 1972 season, a human skull was found covered by a Late Shellmound period pot in Area C of the site. A radiocarbon date on shell from the same layer gave a result of 1940±85 bp (Gak-4180). The pottery covering the skull was similar to pottery from Layer V at Area A of the site; this layer has two radiocarbon dates, 2000±85 bp (Gak-4174; charcoal) and 1860±110 bp (Gak-4179; shell). Other human skeletal material was recovered in both the 1972 and 1989 seasons. These bones, which came from Layers I and II, are clearly modern, however, it is possible that the skeletal remains are redeposited ancient material. From the report published by Takamiya *et al.* (1993), it cannot be determined which skull out of the seven curated at Kanegusuku was found with the Late Shellmound pot.

With the exception of Yonazaki, the early modern sites used here are all curated at the Kanegusuku Prefectural storage facility. Documentation on this material is limited and in several cases the precise location of the sample is unknown. The Kanegusuku material probably comes from Okinawa Island but it is not clear if it originates in Itoman or Haeburu. The source of the Aragusuku sample is unknown. Yatchi is a huge cave burial site on Kumejima which is correctly known as Yatchi-no-gama. The skulls from this site were collected under unknown conditions in the past, but full-scale investigations of the Yatchi-no-gama cave are currently underway in advance of dam construction. The cave may contain as many as a thousand individuals and promises to be an osteological collection of great importance (N. Doi pers. comm.). Skeletal remains from Yonazaki, Iejima Island were investigated *in situ* by Hudson in July 1998. This is a typical early modern cave burial in a presently somewhat inaccessible location. The burials are thought to be shipwrecked sailors from Yonaguni at the southern end of the Ryukyu chain, hence the name "Yonazaki" or Cape Yona (Y. Kishimoto pers. comm.).

RESULTS

Percentages of total teeth affected by caries, LEH (linear enamel hypoplasia) and calculus are given in Table 4 and shown graphically in Figure 2. As can be seen in Table 1, these percentages are based on numbers of teeth which range in size from 140 (Momenbaru) to only 10 (Yonazaki). Table 5 gives the number of individuals with each condition for every sample. Table 6 and Figure 3 combine sites from each phase to show changes between the Early IV-V (Gushikawajima and Nakabaru), Late I-III (Mashiki Azamabaru, Momenbaru and Aakaru), Late IV

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Table 4. Percentages of total teeth affected by caries, LEH and calculus from each site. Results from Mashiki Azamabaru are taken from the analysis by Oyamada *et al.* (1996), which does not include LEH or calculus.

Site	Caries	LEH	Calculus
Gushikawajima	0	11.27	4.23
Nakabaru	10.34	44.83	41.38
Mashiki Azamabaru	16.7	-	-
Momenbaru	5.71	46.43	2.14
Aakaru	0	17.65	0
Nishisokobaru	17.95	2.56	92.31
Ushuku East	8.0	74.0	0
Wano Tofuru	8.11	21.62	43.24
Hiyajo	21.43	7.14	28.57
Aragusuku	4.35	0	30.43
Kanegusuku	0	9.68	38.71
Yatchi	10.0	9.17	88.33
Yonazaki	10.0	0	0
Tsukun 2	2.5	22.5	38.33
Ufutoobaru	2.44	32.93	29.27
Furuzamami	4.54	13.64	0

(Nishisokobaru), Gusuku (Ushuku East), and early modern (Wano Tofuru, Hiyajo, Aragusuku, Kanegusuku, Yatchi and Yonazaki) periods. The Tsukun 2, Ufutoobaru and Furuzamami samples are omitted from this graph. Results for cribra orbitalia are given in Table 7 and Figure 4.

DISCUSSION

Interpretation of the above results is complicated by the small size of most samples and by considerable inter-site variability. Nevertheless, some interesting tentative conclusions can be drawn. Perhaps the clearest results here come from changes in linear enamel hypoplasia. Low at Gushikawajima, LEH increases to over 40% frequency at the end of the Early Shellmound and in the first half of the Late Shellmound. This is followed by a noticeable decrease and, with the exception of the Ushuku East site from which only two individuals were sampled, LEH remains low through the early modern period. Enamel hypoplasias can be linked primarily with systemic physiological stress deriving from disease, neonatal disturbances and nutritional deprivation (Larsen 1997:45). Based on an analysis of faunal remains and settlement patterns, Takamiya (1997) has argued that the Late I-III phases (i.e., Yayoi period in the Kyushu

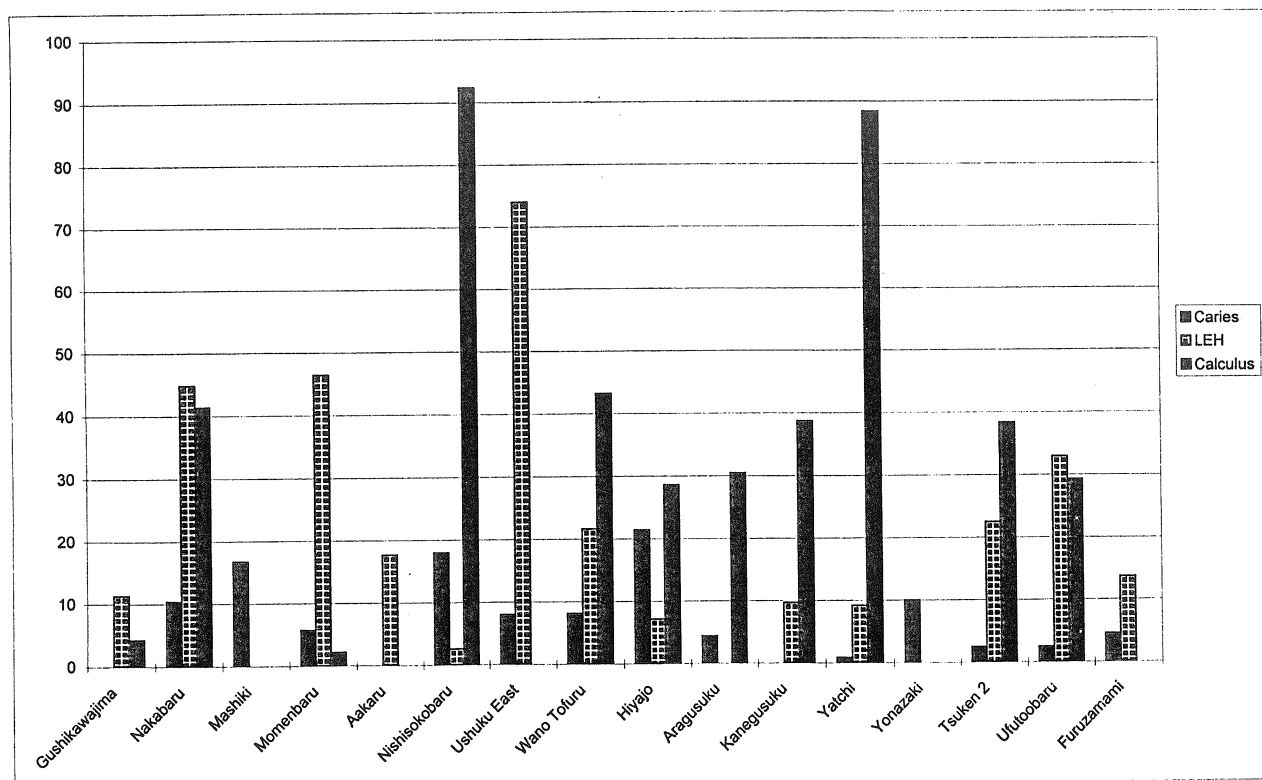


Figure 2: Frequency of caries, LEH and calculus in the samples analyzed in this study.

chronology) were a time of population-resource imbalance and food stress in the central Ryukyus. The high levels of LEH from these phases would seem to support this hypothesis. Analysis of enamel hypoplasias in the large Mashiki Azamabaru sample is essential to test this theory further.

Takamiya (1997:234) has suggested three factors which may account for population-resource imbalance during the Late I-III phases: limited natural resources on small island environments, rapid population growth, and the vulnerability of island environments after successful colonization. In addition to these ecological factors, the historical context of interactions between Okinawa and Japan during these phases also requires further consideration. The trade in shell bracelets between the central Ryukyus and Kyushu is the best-known interaction system in this era (cf. Pearson 1990; Kinoshita 1996), but other links with China and the Korean Peninsula can also be posited. Since interaction, particularly with the chiefdoms of northern Kyushu, is likely to have been conducted on an unequal political and economic basis, one might reasonably ask how the Ryukyus fitted into the political economy of this period of rapid change in East Asia. Pearson (1990:920) has suggested that sites "such as Momenbaru on Okinawa, may have had better access to the north, since the burial methods of their inhabitants imitate the styles of those in northern Kyushu in the use of stone cist coffins which are not found in other Okinawa sites ...". While the people at Momenbaru may indeed have had some sort of control over the shell bracelet exchange networks, however, the high frequency of LEH at Momenbaru shows that they did not escape what, in the Okinawan context, was a high level of physiological stress.

Unlike enamel hypoplasias, caries and calculus can be related more directly to diet. Dental caries is caused by the bacterial fermentation of dietary carbohydrates (Hillson 1996:269). The etiology of calculus, which consists of mineralized plaque deposits, is less well understood but the consumption of carbohydrates as well as poor oral hygiene are thought to be important factors (Hanihara *et al.* 1994; Littleton and Frohlich 1989; Owsley *et al.* 1987). Both caries and calculus are typically low in hunter-gatherers and high in agricultural populations (Larsen 1995:187; Littleton and Frohlich 1989:69). In the Okinawan material analyzed here, the high rate of caries (17.95% of total teeth) at the Late IV Nishisokobaru site is consistent with the botanical evidence for agriculture during this phase at Naazakibaru. The early modern site of Hiyajo has the highest caries frequency of any sample here (21.43%); the other early modern sites have lower rates but this may be the result of high levels of pre-mortem tooth loss in these samples.³

The high levels of dental calculus found for the early modern period would seem to support a link between an

agricultural economy and this condition. High rates of calculus and caries are also found at Nishisokobaru and Nakabaru although these samples are extremely small. Calculus was not reported by Oyamada *et al.* (1996) in their study, but, as noted already, the Mashiki Azamabaru sample has a high level of caries. The caries and calculus results from these prehistoric sites, therefore, require careful consideration. Several authors have suggested that the increased interaction between Okinawa and Kyushu during the Yayoi period may have included the introduction of rice or other cultivated plants into the Ryukyus (e.g., Tomoyose 1970). No botanical evidence for this Yayoi agriculture exists, however, and the archaeological record is also not consistent with a transition to food production at this time (Takamiya 1998; Chinen 1999). Several other prehistoric populations from the Japanese Islands have high rates of dental caries (Turner 1979). The etiology of caries in these populations is poorly understood but possibly relates to the use of roots,

Table 5. Percentage of individuals affected by caries, LEH and calculus from each site. The total number of individuals in each sample is shown in parenthesis

Site	Caries	LEH	Calculus
Gushikawajima	0 (10)	30 (10)	20 (10)
Nakabaru	100 (1)	100 (1)	100 (1)
Momenbaru	50 (8)	87.5 (8)	12.5 (8)
Aakaru	0 (5)	60 (5)	0 (5)
Nishisokobaru	33.3 (3)	33.3 (3)	66.6 (3)
Ushuku East	50 (2)	100 (2)	0
Wano Tofuru	66.6 (3)	100 (3)	100 (3)
Hiyajo	33.3 (3)	33.3 (3)	66.6 (3)
Aragusuku	20 (5)	0 (5)	60 (5)
Kanegusuku	0 (7)	42.9 (7)	57.1 (7)
Yatchi	25 (20)	10 (20)	85 (20)
Yonazaki	33.3 (3)	0 (3)	0 (3)
Tsukun 2	16.6 (6)	100 (6)	100 (6)
Ufutoobaru	14.3 (7)	71.4 (7)	42.8 (7)
Furuzamami	20 (5)	60.5 (5)	0 (5)

Table 6. Changes in frequency of caries, LEH and calculus for each period. For the Late I-III period, the sample for caries includes the Mashiki Azamabaru material whereas the LEH and calculus figures omit this site

Period	Total teeth (No. individ.)	% Caries	% LEH	% Calculus
Early IV-V	100 (11)	3	21	15
Late I-III	586 (41)	13.14	-	-
	174 (13)		40.8	0.02
Late IV	39 (3)	17.95	2.56	92.31
Gusuku	50 (2)	8	74	0
Early modern	272 (41)	4.41	11.4	59.19

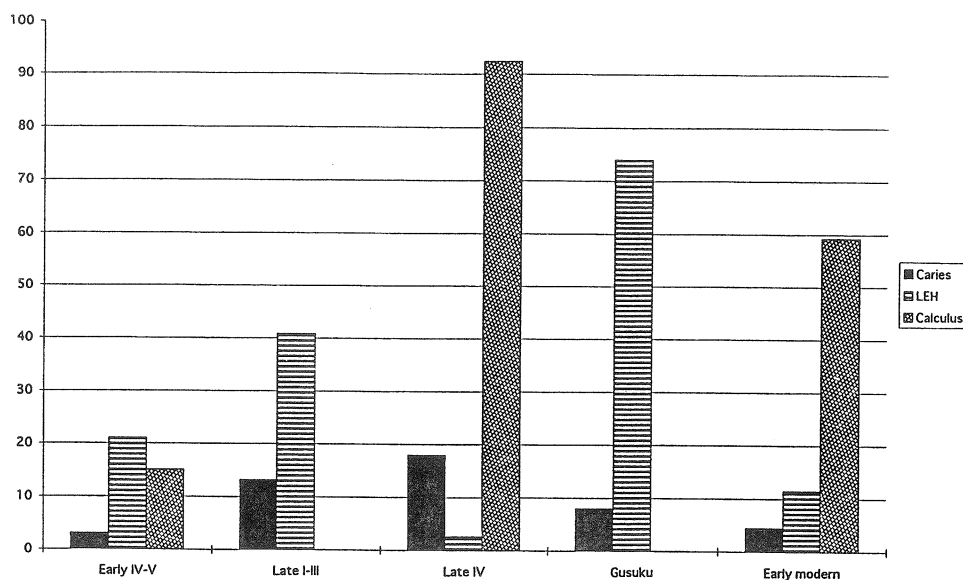


Figure 3: Frequency of caries, LEH and calculus for each sub-phase.

Table 7. Frequency of cribra orbitalia

Site	Individ. with cribra	Total no. individ.	% with cribra	Sex (where known)
Tonaki	0	3	0	
Hiyajo	1	3	33.3	M
Aragusuku	2	5	40	M=1, F=1
Kanegusuku	1	7	14.28	F=1
Yatchi	7	20	35	M=4, F=3
Tsukun	1	6	16.66	M=1

tubers and other starchy foods. Chinen (1999) has argued that the lithic and shell tool assemblages from the Early V to Late III phases suggest the broad use of plant remains, including some possible cultivation. High caries rates from these phases may be consistent with Chinen's interpretation but botanical evidence for root and tuber use in prehistoric Okinawa is unknown. Flotation analysis of deposits from the Late I-III Takachikuchibaru site, Yomitan, Okinawa Island produced beech nuts (*Fagaceae*) and fleshy fruits (*Persea*, *Actinidia* and *Vitis*) but no domesticated plant remains (Takamiya 1997:135).

The basic problem here is that while the absence of or low rates of caries may be used to argue *against* agriculture (e.g., Turner 1978), a high frequency of caries is sometimes found in foraging populations. In their study, Oyamada *et al.* (1996) compare the Mashiki Azamabaru sample with Yayoi-period skeletons from northern Kyushu. Since the frequency of caries in the latter sample (22.6%) was even higher than that from Mashiki Azamabaru, the authors argue

that the difference can be attributed to the basic mode of subsistence, i.e., foraging in Okinawa and farming in Kyushu. In our view this conclusion requires further investigation. However, support for Oyamada *et al.*'s argument may come from their data on sex differences in caries frequency. At Mashiki Azamabaru, they report a frequency of 10.5% for males but 22.2% for females, whereas in the Kyushu Yayoi sample the figures are 20.8% for males and 25.6% for females (Oyamada *et al.* 1996:265). It is argued that these results may be correlated with a gender-based difference in diet where hunter-gatherer females at Mashiki

Azamabaru snacked regularly on cariogenic foodstuffs throughout the day whereas the Kyushu farmers had less of a gender-based division of labour (Oyamada *et al.* 1996:276). Similar patterns have been observed in ethnographic cases (e.g., Walker and Hewlett 1990). Since our own samples were so small it was not possible to test this gender theory further on this occasion.

The data on cribra orbitalia are, with the exception of small samples from Nishisokobaru and Tsukun, limited to the early modern period. Although the frequency of cribra in the pooled early modern Ryukyu sample is only half that recorded from the Hitotsubashi site in Edo by Hirata (1988), it is nevertheless quite high for what were basically rural populations. Hirata (1988) is probably correct that the high rate of cribra from Edo can be explained by poor sanitary and medical conditions in that city but our data from Okinawa suggest the need to look further at regional human biologies in Tokugawa Japan (see also Hudson 1999b).

CONCLUSIONS

Although anthropological studies of population history and variability are highly developed in Japan, bioarchaeological analyses of the type attempted here are still quite rare. We hope that this paper has demonstrated the potential of a bioarchaeological approach for a deeper understanding of Okinawan prehistory. The analysis of LEH conducted here would seem to support the hypothesis that the Late I-III phases were a time of subsistence stress in the central Ryukyu Islands. Links between caries, calculus and

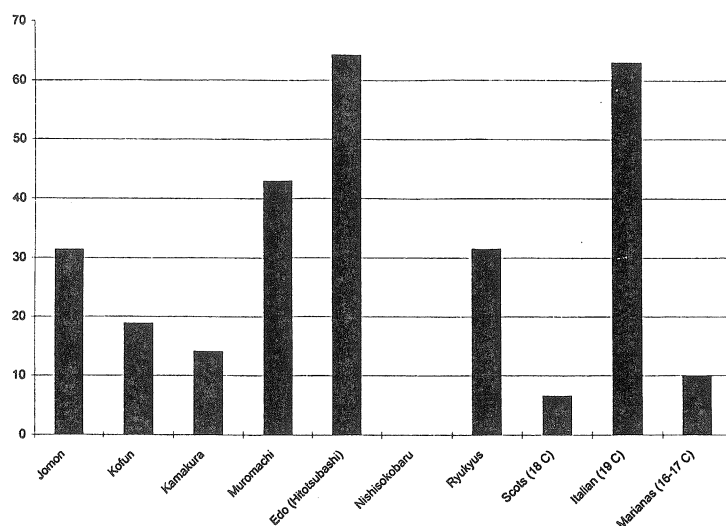


Figure 4: Frequency of cribra orbitalia (%) in Okinawan and other samples. Data from Nishisokobaru and a pooled early modern series (shown here as 'Ryukyus') were analyzed by the present authors. Other samples are taken from Hirata (1988).

agriculture are less clear. The increase in the frequency of both caries and calculus from the Late IV site of Nishisokobaru is consistent with the botanical evidence for agriculture from that phase. However, the considerable variability in the occurrence of these two conditions in the Early V-Late III phases requires further consideration. This variability may reflect major diachronic changes in plant food consumption or else may simply be the result of the small samples used. Further analysis of a larger number of samples is needed to test this relationship in more detail.

NOTES

1. The scale on the map showing the location of these sites in Kishimoto *et al.* (1982:5) is incorrect.
2. Kidder (e.g., 1959:35) has long used "Latest Jomon" for the last stage of the Jomon period but most writers in English prefer "Final Jomon" since it avoids confusion with the preceding Late phase.
3. As noted already, pre-mortem tooth loss (PMTL) was impossible to score consistently in many samples. At Yatchi it reaches 16.6% of all teeth and is 18% at Kanegusuku, although the latter sample consists of maxillary dentition only. These figures are similar to the 15.1% PMTL at Mashiki Azamabaru reported by Oyamada *et al.* (1996:264), something which is consistent with the high rate of caries also reported at this site. Actual PMTL rates for the early modern Ryukyus, however, may be higher than these results suggest since there were several crania from Yatchi and other sites with all teeth lost pre-mortem. Since we had begun scoring on the largely fragmentary prehistoric material, our intention was not to record PMTL and these toothless skulls were therefore excluded from our analysis this time.

ACKNOWLEDGEMENTS

We wish to express our gratitude to the following institutions and individuals for permission to examine skeletal materials: Okinawa Prefectural Board of Education, Dr Naomi Doi, Department of Anatomy, University of the Ryukyus, and Dr Masami Takenaka, Department of Oral Anatomy, Kagoshima University Dental School. Naomi Doi, Glen Doran and Mike Pietrusewsky provided invaluable advice in the field in Okinawa. Financial assistance towards this research came from Grants-in-Aid for Scientific Research from the Japanese Ministry of Education as part of a project titled "Interdisciplinary Study on the Origins of Japanese Peoples and Cultures". Figure 1 was prepared by M. Chinen.

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