Sex difference in oral disease of millet agriculturalists from the Take-vatan lineage of the recent Bunun tribe of Taiwan

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Abstract Biological anthropologists have repeatedly demonstrated a sex difference of caries prevalence in past societies and have often ascribed this difference to cultural factors related to the sexual division of labor, as well as to biological factors stemming from the female reproductive function. Even though archaeological and historical evidence can hint at the prevailing living conditions, they are not detailed enough to confirm the cultural factors influencing oral disease. For this, skeletal remains in which the prevailing subsistence patterns have been documented by cultural anthropologists must be studied. This study demonstrates sex-specific oral disease prevalence (caries, antemortem tooth loss, periapical abscess, alveolar resorption, and calculus accretion) as well as degree of dental attrition, using the recent Bunun skeletal assemblage, one of the Taiwanese aboriginals. During Japanese rule, cultural anthropologists recorded that the staple product of the Bunun tribe was foxtail millet. Males were responsible for cultivation and hunting, while females were responsible for gathering and preparing foods. The results of this study showed the relatively high morbidity of oral disease, except periapical abscess, regardless of sex. The frequency of females suffering caries and alveolar resorption was significantly greater compared to that of males, and the inverse was true for calculus. Taking into account the fact that the Bunun tribe depend greatly on vegetable foods and smoke heavily, their high morbidity of oral disease is understandable. The combination of their higher morbidity in alveolar resorption and calculus is comparable to the Southeast Asian groups chewing betel nuts documented in previous studies. The sex-specific caries prevalence is believed to be related to the Bunun’s typical and strict sexual division of labor. The inconsistency of the sex difference patterns between alveolar resorption and calculus might be related to the multifactorial origin of the alveolar resorption.

Key words: Taiwanese aboriginal, sexual division of labor, dental caries, alveolar resorption, calculus

Introduction Oral pathology is utilized by biological anthropologists worldwide as a method to assess diet and food-preparation techniques in past societies, because oral diseases are strongly related to subsistence patterns (e.g. Turner, 1979; Powell, 1985; Lukacs, 1989; Walker and Erlandson, 1986; Walker and Hewlett, 1990; Larsen, 1997; Pechenkina et al., 2002; Temple and Larsen, 2007; Oyamada et al., 2010). Calculations by Turner (1979) concerning average dental caries prevalence on the basis of a worldwide population study show a 1.3% rate of caries in a foraging economy, a 4.8% rate in a mixed economy, and a 10.4% rate in an agricultural economy. Lukacs (1989) proposed a dental pathology profile (DPP) as a standardized method for recording and reporting dental pathological conditions for comparative research. The variables in DPP are caries, antemortem tooth loss (AMTL), periapical abscess, alveolar resorption, calculus, severe attrition, enamel hypoplasia, and jaw robustness. The components of DPP shift from hunting-gathering to agricultural pursuits: intensive agriculturalists typically have higher frequencies of caries, calculus, alveolar resorption, and enamel hypoplasia, and lower frequencies of severe attrition (unless abrasive materials were mixed with foods during preparation), compared to hunter-gatherers. Hunter-gatherers do not necessarily have lower frequencies of AMTL or periapical abscess, because not only caries but also severe attrition can cause both pathologies. The relationship between subsistence pattern and human health, however, appears not to be straightforward. Several case studies have demonstrated that agricultural development is not accompanied by an increase in caries frequency in Southwest Europe and Southeast Asia (Lubell et al., 1994; Pietrusewsky and Douglas, 2001; Domett and Tayles, 2006; Oxenham et al., 2006).

The sex difference of oral pathology could provide additional clues about life in past societies. It is widely reported that females generally display worse dental health, especially caries prevalence, than males in past and present contexts.
One factor contributing to this sex difference could be female life history connected with reproductive ecology: cariogenic oral environments could be produced by changes in saliva composition and volume accompanying changes in estrogen levels triggered by menstruation and pregnancy (Lukacs and Largaespada, 2006; Lukacs and Thompson, 2008). In addition, two cultural factors may explain the sex difference in caries prevalence, both of which are related to the sexual division of labor in past societies. First, females tend to consume a greater amount of carbohydrate-rich foods, which is thought to be more cariogenic, while males tend to consume greater amounts of meat products, which are less cariogenic (Larsen, 1997). Second, females more frequently access foods during food procurement and production (Walker and Hewlett, 1990).

The variation of oral disease prevalence needs to be further examined, especially by studying recent groups of pre-industrialized societies whose lifestyle has been minutely documented by cultural anthropologists. In this case, more reliable and detailed discussion on the relationship between oral disease prevalence and a society’s lifestyle is possible. The purpose of this study is to document the oral health of the recent (early to mid twentieth century) Bunun tribe, a Taiwanese aboriginal people, who relied on millet agriculture and hunting-gathering. This study specifically aims to examine the relationship between the oral disease prevalence and the tribe’s subsistence pattern, including the sexual division of labor.

Materials

Samples

A total of 850 teeth and 1241 alveoli from 44 individuals from the cemetery around Bahoan village, Wanrong, Hualien county in Taiwan were included in the study (Table 1). These individuals were interred between 1943 and 1957 according to the record of burial markers and the memory of the villagers. These skeletal remains were excavated by Tsai His-Kuei and are curated at the Department of Anatomy and Cell Biology, College of Medicine, National Taiwan University (Doi et al., 2008).

Bahoan village is surrounded by the Malangou and Hudie valleys to the north and Hutou Mountain to the south (Figure 1). The postal address is 979 Wanrong, Hualian county. The village was built under the order of the Governor-General of Taiwan (a department of the Empire of Japan) for the enforced migration of the Bunun people between 1919 and 1921. Most of the villagers came from the Take-vatan lineage of the Bunun people, who had previously resided deep in the mountains of Middle Taiwan (Wanrong administration, personal communication).

Methods

Oral pathology

The presence of AMTL, carious lesions, periapical abscess, alveolar resorption, and calculus accretion, and the degree of dental wear were examined in each tooth using a 10× magnifying lens and a dental mirror in accordance with standards established by Lukacs (1989) and Hillson (1996, 2001). AMTL was defined as a completely closed alveolar socket with reduced alveolar height to a nearly closed alveolar socket with active bone formation (Lukacs, 1989; Pechenkina, personal communication). Carious lesions were identified based on enamel demineralization in stages that ranged from complete destruction of a tooth crown to pin-prick-sized lesions (Lukacs, 1989; Hillson, 1996; Temple and Larsen, 2007). Carious lesions were classified into (1) occlusal surface, (2) interproximal surfaces, (3) smooth surfaces, (4) cervical, (5) root, and (6) large carious lesions (Buikstra and Ubelaker, 1994). Periapical abscesses originate as a chronic cyst and/or an infection in the pulp due to chronic cariogenesis, severe wear, or dental trauma. Because of the difficulty in differentiating between these factors (Dias and Tayles, 1997; Oxenham et al., 2006), only the presence or absence of periapical abscess was recorded (Lukacs, 1989). Alveolar resorption also has a multifactorial etiology (e.g. periodontal disease, caries, periapical abscess, and continuous eruption) (Hillson, 1996; Kaifu et al., 2003). Although making a correct diagnosis is difficult, the following definitions were all counted as affected: (1) slight: resorption confined to the alveolar crest with active bone formation or periodontal pocket or notch-like resorption of the alveolar crest; (2) moderate: horizontal or vertical bone loss limited to half of the length of the tooth root; 3) severe: horizontal or vertical bone loss reaching more than half of the length of the tooth root (Lukacs, 1989; Sakashita et al., 2001). AMTL was defined as a completely closed alveolar socket with reduced alveolar height to a nearly closed alveolar socket with active bone formation (Lukacs, 1989; Hillson, 1996; Temple and Larsen, 2007).

Given that dental wear plays an important etiology in oral

<table>
<thead>
<tr>
<th>Categor y</th>
<th>Number</th>
<th>Observed teeth</th>
<th>Examined alveoli</th>
<th>Mean age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ant N</td>
<td>Ant %</td>
<td>Pre N</td>
</tr>
<tr>
<td>Male 26 (20)</td>
<td>157</td>
<td>50.3</td>
<td>165</td>
<td>79.3</td>
</tr>
<tr>
<td>Female 18 (11)</td>
<td>105</td>
<td>48.6</td>
<td>97</td>
<td>67.4</td>
</tr>
<tr>
<td>All 44 (31)</td>
<td>262</td>
<td>49.6</td>
<td>262</td>
<td>74.4</td>
</tr>
</tbody>
</table>

Abbreviations: Ant, incisors and canines; Pre, premolars; Mol, molars; N, the number of observed teeth or examined alveoli; %, [the number of observed teeth or examined alveoli/the maximum number of teeth or alveoli (in the case that they are perfectly preserved)] × 100. The figures in parentheses show the number of individuals aged 30–39 years.
It is important to compare a measure of this variable among the samples (Lukacs, 1989). Tooth wear was scored according to standards established by Buikstra and Ubelaker (1994) using primary scores for the anterior and premolar teeth and summary scores derived from all quadrants of the molar teeth.

Controlling for biological sex and age

Sex was determined based on pelvic morphology (Phenice, 1969; Bruzek, 2002; Walker, 2005). Cranial morphological traits were used when pelvic bones were not recovered (Buikstra and Ubelaker, 1994). Adult age was estimated based on age-related changes of the morphology of pubic symphysis and auricular surfaces (Todd, 1920; Meindl et al., 1985; Lovejoy et al., 1985), and cranial suture closure was used to estimate age where pelvic bones were unavailable (Meindl and Lovejoy, 1985). The frequencies of pathological conditions should be calculated for each age stage group, because these pathologies are degenerative. Only sex difference was examined after the age distribution was compared between the sexes, since the sample size was not large enough to determine the statistical significance of sex difference for each age group in this study.

Calculations and statistical treatments

The ratio of observable teeth was lower in the anterior dentition, partly because of taphonomic factors influencing tooth preservation (Table 1). Therefore, the 'tooth count manner' was used for calculation to avoid any bias caused by imbalance among teeth segments (Douglas, 2006). That is, the prevalence of carious teeth, calculus, and advanced attrition was calculated as (affected teeth/observable teeth) \times 100. The prevalence of AMTL, pericapical abscess, and alveolar resorption was calculated as (affected alveoli/examined alveoli) \times 100.

Sex differences of frequencies calculated by the tooth count manner were examined by Yates’ chi-squared test. Sex differences of the age distribution and the degree of dental wear were examined by the Mann–Whitney U-test. These analyses were performed using the computer program package Statistica (StatSoft Inc., 1996).

Results

The age distribution did not differ significantly between the sexes according to the statistical analysis (Table 1). The majority of males and females were in their 30s (male, 20; female, 11), followed by people in their 20s (male, 2; female, 4) or 40s (male, 4; female, 2) and one female aged about 17 years. Thus, the commingling of individuals of different ages could lead to the minimum bias for comparing the sexes in the following analysis.

Table 2 and Figure 2 show the results of oral disease. The prevalence of dental caries was very high, 14.1% in total. It was the highest in the molar compartment and the lowest in the anterior compartment (Table 2), which matched the clinical data (Hillson, 1996). The dental caries prevalence of females was much greater than that of males. The sex difference was statistically significant in the molar compartment and in total (Table 2).

The AMTL prevalence was also high, 11.2% in total. It was the highest in the anterior compartment and the lowest in the premolar compartment (Table 2). No statistically significant sex difference was found. The highest AMTL prevalence in the anterior compartment should be attributed to the cultural tooth extraction of the upper incisors and canines. The cultural tooth extraction was observed in 26 of 40 individuals (65.0%), and the combination of upper lateral incisors and canines was the greatest among the extraction combination (found in 17 of 26 individuals).

The periapical abscess prevalence was very low, 1.0% in
The frequency was almost the same among the tooth compartments. No statistically significant sex difference was found.

The alveolar resorption prevalence was considerably high, 16.2% in total. The frequency was the highest in the molar compartment and the lowest in the anterior compartment (Table 2). The alveolar resorption prevalence of females was much higher than that of males. The sex difference was statistically significant in the anterior and molar compartments, as well as in total (Table 2).

The calculus prevalence was also high, 85.8% in total. The frequency was almost the same among the tooth compartments. The calculus prevalence of males was higher than that of females. The sex difference was statistically significant in all tooth compartments (Table 2).

The AMTL prevalence

Table 2. Oral disease prevalence for sex and tooth compartment

<table>
<thead>
<tr>
<th>Caries</th>
<th>Antemortem tooth loss</th>
<th>Periapical abscess</th>
<th>Alveolar resorption</th>
<th>Calculus</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>O</td>
<td>%</td>
<td>Sex diff</td>
<td>A</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ant</td>
<td>6</td>
<td>157</td>
<td>3.8</td>
<td>n</td>
</tr>
<tr>
<td>Pre</td>
<td>16</td>
<td>165</td>
<td>9.7</td>
<td>n</td>
</tr>
<tr>
<td>Mol</td>
<td>42</td>
<td>210</td>
<td>20.0</td>
<td>*</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>532</td>
<td>12.0</td>
<td>*</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ant</td>
<td>5</td>
<td>105</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>13</td>
<td>97</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>Mol</td>
<td>38</td>
<td>116</td>
<td>32.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>318</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ant</td>
<td>11</td>
<td>262</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>29</td>
<td>262</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>Mol</td>
<td>80</td>
<td>326</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
<td>850</td>
<td>14.1</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: A, the number of affected teeth; O, the number of observed teeth; %, (A/O) × 100; Sex diff, P value for sex difference. Significance is set at P < 0.05 for sex difference: **, P < 0.01; *, P < 0.05; n, P > 0.05.

Figure 2. Percentage differences in oral disease prevalence among groups: dental caries, antemortem tooth loss, periapical abscess, alveolar resorption, and calculus accretion. The divisions of the scale on the right are for calculus accretion prevalence, while those on the left are for the other diseases.

Table 3. Distribution of the frequency of dental caries for the location

<table>
<thead>
<tr>
<th>Location</th>
<th>Male %</th>
<th>Female %</th>
<th>All %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusal surface</td>
<td>7</td>
<td>10.9</td>
<td>13</td>
</tr>
<tr>
<td>Interproximal</td>
<td>33</td>
<td>51.6</td>
<td>53</td>
</tr>
<tr>
<td>Smooth surface</td>
<td>2</td>
<td>3.1</td>
<td>4</td>
</tr>
<tr>
<td>Cervical surface</td>
<td>12</td>
<td>18.8</td>
<td>26</td>
</tr>
<tr>
<td>Root</td>
<td>7</td>
<td>10.9</td>
<td>10</td>
</tr>
<tr>
<td>Large</td>
<td>3</td>
<td>4.7</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>96</td>
<td>100</td>
</tr>
</tbody>
</table>

Abbreviation: N, number of affected teeth; %, (Local N/Total N) × 100.
was also relatively high, especially in the anterior tooth compartment (Table 2), due to the cultural tooth extraction (Nakahashi, 2008; this study). The frequency of females was significantly greater than males in dental caries and alveolar resorption, and conversely in dental calculus (Table 2). The severity of dental wear showed little sex difference (Table 4).

Oral disease and the social environment

In the Bunun tribe, recent immigrations led to a widespread area of residence in the mountains of Middle Taiwan (Mabuchi, 1954). The census in 1938 shows that there were 4698 individuals in 35 villages at altitudes of between 1500 and 2000 m, and 705 individuals in four villages at altitudes over 2000 m (Nagasawa, 2002). The Bunun tribe generally engages in slash-and-burn farming in the mountains, as well as hunting and gathering (Miyamoto, 1985). Their slash-and-burn farming is focused on millet. The process is as follows. First, they produce arable land through deforestation, switching to a different area every three or five years. The village moves to a new place whenever the fertility of the soil around the village is exhausted (Lu, 1990). In 1937, the itemized income (the homemade products were converted into the corresponding market price) of the Bunun tribe was investigated by the Governor-General of Taiwan. The survey shows that, in the Bunun tribe, agricultural products account for 65% of the total income, forestry products for 13%, labor and employment for 7%, hunting products for 6%, livestock products for 4%, miscellaneous goods for 3%, and hand crafts for 2% (Governor-General of Taiwan, 1986). Foxtail millet (Setaria italica) ranks first among the cultivated crops, followed by sorghum (Sorghum bicolor), Chinese millet (Panicum miliaceum), ragi (Eleusine coracana), corn (Zea mays), coix (Coix lacryma-jobi var. mayuen), adlay (Coix lacryma-jobi), green

![Figure 3. An example of oral diseases in an adult female (M5 individual) from the Bunun assemblage. The arrowheads indicate calculus accretion of the anterior teeth, while the triangles indicate dental caries of the molars. These molars also exhibit horizontal bone loss (Hillson, 1996).](image)

<table>
<thead>
<tr>
<th>Table 4. Degree of dental attrition on molars for sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper jaw</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Lower jaw</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
</tbody>
</table>

Abbreviations: RM, right molar; LM, left molar; N, the number of observed teeth; M, mean; SD, standard deviation; Significance is set at $P < 0.05$ between males and females (Mann–Whitney U-test); n, $P > 0.05$. 
environments and time periods are so different, the differ-
genics than non-glutinous millet because of the difference in
boiled millet meal is much stickier in Taiwan compared to
(millet dumplings wrapped in bamboo leaves), and certain
the Bunun tribe studied here, lower caries frequencies were
(types of alcohol (Crawford, 2006). In my experience (K.O.
Okazaki et al., in preparation). Although little comparative
on foxtail millet cultivation (Pechenkina et al., 2002;
Alberca and Erlandson, 1986; Walker and Hewlett, 1990; Larsen, 1997;
Pechenkina et al., 2002; Temple and Larsen, 2007; Oyamada
et al., 2010), the relatively high degree of dental caries prev-
alence among the Bunun assemblage is parallel to the expect-
ation based on their subsistence pattern, which is focused on
foxtail millet (Miyamoto, 1985; Governor-General of Taiwan, 1986;
Lu, 1990). There are two cultivars of foxtail millet: non-glutinous millet (uruchi-awa) and glutinous millet (mochi-awa).
The latter variety is cultivated in Taiwan, and it suitable for making mochi (millet cake), chimaki (millet dumplings wrapped in bamboo leaves), and certain types of alcohol (Crawford, 2006). In my experience (K.O. stayed in north China and Taiwan for five years in total), boiled millet meal is much stickier in Taiwan compared to
that in north China. Glutinous millet could be more cario-
genic than non-glutinous millet because of the difference in
its adhesiveness to the tooth crown and root. Compared to the Bunun tribe studied here, lower caries frequencies were
shown in the Chinese Neolithic groups who also depended on
foxtail millet cultivation (Pechenkina et al., 2002; Okazaki et al., in preparation). Although little comparative study between the recent Taiwanese aboriginal and the Chinese Neolithic groups has been done, since their living environments and time periods are so different, the difference in caries frequency might be partly related to the difference in the sort of foxtail millet between that grown in Taiwan and that grown in north China.

We want to note two points that link the results of this
study to the subsistence pattern of the Bunun tribe. First, the
subsistence pattern of the Bunun tribe may have changed from the 1920s to the 1940s due to the control by the
Governor-General of Taiwan. After several armed uprisings
by the Bunun people up to 1934, the residence of all sub-
groups of the Bunun tribe was dealt with as a special admin-
istrative zone, and the Governor-General of Taiwan forced
the Bunun to move to lower-altitude locations more easily
reached by road in order to control them (Nagasawa, 2002).
The group examined in the present study was forced to
migrate to Bahaoan village in 1919 or 1921 by order of the
Governor-General of Taiwan. The research report on the
history of Bahaoan village done by the present local admin-
istration mentions that the villagers mostly preserved their tradi-
tional subsistence pattern (millet agriculture and hunting-
gathering) at least until the 1950s, even though the Japanese
Governor-General of Taiwan recommended that the villag-
ers cultivate wet rice instead of foxtail millet (Wanrong
Administration, personal communication). The possibility
cannot be denied, however, that the villagers bought some
cairogenic foods from peddlers, since some of them earned
money by selling their agricultural products and hunted
game (Wanrong Administration, personal communication).
However, a full-scale change in the Bunun’s diet occurred at
a much later period. Previous studies on the dental health of
the living Bunun people suggest that changes in the tradi-
tional dietary habits during the late 1970s explain the abrupt
deterioration in oral health (Liu, 1977; Fukutome, 1982;
Ozumi, 1983; Miyazaki and Takehara, 1988). Therefore, the
enforced migration under the control of the Governor-
General of Taiwan might have indirectly affected the diet of
the villagers, but the degree should not be significant.

A second point linking the results of this study to the sub-
sistence pattern of the Bunun tribe is that since the tribe re-
gards millet as a culturally special meal, the possibility
cannot be denied that consuming millet was mostly limited
to ceremonies (not daily food), and that most of the millet
grains were just kept inside the house as a symbol of the family’s wealth. The stable isotope analysis conducted by
Yoneda et al. (2008) indicates that the diet of the Bunun
people scores in the middle range between C4 vegetables
and C3 vegetables. The C4 vegetables, which include millet,
are not so dominant. The C3 vegetables, which might be
sweet potato, banana, sugar cane, and the like, were also
consumed in considerable quantity. The high proportion of
vegetable foods consumed could lead to high morbidity in
dental caries.

The high morbidity in both alveolar resorption and cal-
culus accretion among the Bunun assemblage seems to be very
understandable from a clinical viewpoint (Hillson, 1996).
Today, most dentists advise the removal of calculus, because the
coarseness on the surface of calculus accretion can produce
spaces for the propagation of bacteria that can cause
periodontal disease (Hillson, 1996). A relatively high
frequency of both alveolar resorption and calculus accretion
has been repeatedly demonstrated in the past societies of
Southeast Asia (Pietrusewsky and Tsang, 2003; Douglas,
2006; Pietrusewsky and Ikehara-Quebral, 2006). Pietrusewsky
and Tsang (2003) showed a significantly high-
er frequency of both alveolar resorption and calculus accre-
tion compared to AMTL, dental caries, and periapical
abscess in the skeletal assemblage from the Shi-sang-hang
site of the prehistoric Iron Age in northern Taiwan.
Pietrusewsky and Tsang suggest that the chewing of betel
nuts could lead to a more alkaline oral environment, which
might explain the significantly higher frequency of both al-
veolar resorption and calculus accretion. The chewing of
betel nuts (Areca catechu) in combination with leaves (Piper
betel) and/or lime paste (calcium hydroxide) is a ubiquitous
habit in Southeast Asia and the Pacific today. Although the
proportion of chewers in Taiwan during Japanese rule is
unknown, a questionnaire survey conducted in 1991 showed
that, among the Bunun people over the age of 15, 37.0% of
males and 26.3% of the females were chewers at that time
(Ko et al., 1992). Therefore, the high morbidity in the indi-
ces related to periodontal disease of the sample studied here could be attributed to a more alkaline oral environment due
to the chewing of betel nuts, the same as the other prehistoric
groups in Southeast Asia.

Except for calculus accretion, smoking tobacco could also
lead to an increase in alveolar resorption. Smoking is clini-
cally regarded as a strong risk factor for periodontal disease
(e.g. Bergstrom, 2004). The smoking habit is widespread
among the Bunun tribe: they cultivate tobacco themselves,
the males and females generally begin to smoke at the age of
12 or 13 years, and they always carry a pipe with them (Yuasa, 2009). This heavy reliance on smoking could con-
tribute to the poor oral health of the Bunun tribe.

**Sex difference of oral disease prevalence**

The degree of sex difference in caries prevalence among
the Bunun assemblage (male 12.0%, female 17.6%) is consid-
erably greater compared to that of other Asian groups
in past societies reported by Lukacs and Thompson (2008)
(male average 8.1%, female average 10.9%). Therefore, it
appears unlikely that the biological factors described above
exclusively led to the sex-specific caries prevalence of the
Bunun assemblage. Cultural factors should also be consid-
ered.

The Bunun tribe is well known for their rigid personali-
ties, especially as regards social rules (Miyamoto, 1985). For
example, the Bunun have a typical patriarchal society, and
individual economic activities (e.g. the role during hunting
and the share of game) and the regulations of the ceremonial
activities related to millet cultivation are strictly decided ac-
cording to the classification of a particular patrilineal kin
group (Mabuchi, 1974). The sexual division of labor is also
very distinct: females and children take part in gathering and
preparing vegetable foods, while males go hunting (Yuasa,
2009). This rigorous distinction between males and females
is clearly expressed at the highly significant ear shooting
ceremony: females are prohibited from participating in the
ceremony or even approaching shooting instruments before
and during the ceremony, at which boys shoot at deer
carcasses brought in by male hunters. Considering that the
Bunun males often dressed and ate game on the spot during
hunting (Yuasa, 2009), the ratio of consumed meat could be
higher in males than females. Furthermore, females tend to
snack during cooking (Walker and Hewlett, 1990). Bunun
females traditionally have the responsibility to make millet
wine, and they often chew millet grains to aid the fermenta-
tion (The Association for Researching Taiwanese Aborigi-
nals by the Governor-General of Taiwan, 1921; Chang et al.,
2011). These activities could repeatedly decrease the pH, so
that the oral environment changes to being more cariogenic.

The variation in the pattern of sex difference among the
occurrence of dental caries, alveolar resorption, and calculus
accretion prevalence in the Bunun assemblage is difficult to
explain, and multiple factors might cause it. Regarding the
inversion of the pattern in sex difference between the dental
caries and the calculus accretion prevalence, it could be log-
ically explained by noting that the former is a process of
demineralization on the tooth surface, while the latter is a
process of mineralization, and the two conditions should
therefore be mutually exclusive (Manji et al., 1989). A more
alkaline oral environment due to less frequent snacking be-
tween meals and/or more frequent chewing of betel nuts
could lead to higher calculus accretion prevalence in males
of the Bunun tribe. The alveolar resorption prevalence is
higher, while the calculus accretion prevalence is lower in
females of the Bunun tribe. Considering the strong correla-
tion between calculus accretion and periodontal disease as
discussed above, this lack of consistency in the pattern of
sex difference between calculus accretion and alveolar re-
sorption is unexpected. The previous studies using clinical
data suggest there are multiple factors contributing to
periodontal disease, including smoking, diabetes, and the
stresses related to the female life history (menstruation,
pregnancy, delivery, lactation, and menopause)
(Sooriyaamourthy and Gower, 1989; Genco, 1996). Among
these factors, calcium deficiency and hormone (estrogens
and progesterone) balance changes triggered by female life
history might lead to sex differences in alveolar resorption
prevalence (Sooriyaamourthy and Gower, 1989; Shoji et al.,
2007), although we cannot examine this possibility.

In conclusion, the oral environments of the recent Bunun
tribe were characterized by a high morbidity in dental caries,
alveolar resorption, and calculus accretion. Based on cultur-
al anthropological records, the carbohydrate-rich foods con-
sumed, the chewing of betel nuts, and the heavy smoking
habit are suggested to be factors causing this result. Signi-
ficant sex differences were observed in dental caries, alveolar
resorption, and calculus accretion, and the pattern of the dif-
fferences varied: the frequency of females was higher in den-
tal caries and alveolar resorption, while the inverse was true
in calculus accretion. The sex-specific diet and activities, in
particular the chewing of millet to produce an alcoholic
drink, could be related to the result. It is difficult to explain
the inconsistency of the patterns in the sex differences be-
tween alveolar resorption and calculus accretion, even
though clinical data often show a correlation between them.
The factors that are not observed by cultural anthropologists,
e.g. hormone balance changes, might also be related to the
sex differences. The results of this study will provide the
basis for exploring the factors contributing to the oral dis-
ease prevalence and the sex differences of Taiwanese prehis-
toric/historic skeletal assemblages in future studies.

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