ORAL HEALTH IN NORTHERN VIET NAM: NEOLITHIC THROUGH METAL PERIODS

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ABSTRACT

Little is known of the health of people living in northern Vietnam from the post Hoabinhian through to the early Metal periods. This paper reports on results of one component of a larger study of health and disease in prehistoric Vietnam. An examination of the oral health of a population is useful in being sensitive to issues relating to diet, general subsistence strategies, behaviour and disease in general.

Two questions are addressed in this paper. The first asks what was the state of the dental health of Neolithic and Metal period communities in Northern Vietnam? This is addressed through the development of an oral health profile for each sample. The second question asks if light can be shed on the diet and subsistence strategies of these communities? This is tackled by comparing the Vietnamese profiles to a standard oral health profile for various subsistence strategies. Aspects of dental health in prehistoric assemblages from Thailand are also compared with the Vietnamese data.

THE SAMPLES

Collections of human skeletal and dental remains curated by Dr Nguyen Lan Cuong of the Institute of Archaeology, Hanoi, Vietnam provided the material for this research. These collections constitute the majority of available human skeletal material from the post-Hoabinhian through to late Bronze periods, approximately 6500 - 1500 years bp, in northern Vietnam.

Two samples are compared and contrasted that, while deriving from the same region in northern Vietnam, are separated by a temporal hiatus of several thousand years. The evidence is currently equivocal with respect to the biological distance between the two assemblages. In a recent study of epigenetic characters in each population, Parker (1998) suggests homogeneity for the pooled groups. On the other hand, Matsumura *et al.* (2000) suggest, on the basis of dental metrics and morphology, that the Neolithic period sample can be described as Australo-Melanesian in distinction to the Metal period sample which is seen as 'Mongoloid'.

NEOLITHIC PERIOD SAMPLE

The dental remains of 81 individuals (947 permanent teeth), representing the Neolithic Da But period, derive from the single cemetery site of Con Co Ngua. The following account of this site is based on the unpublished site report prepared by Bui Vinh (1980). Con Co Ngua lies in Ha Trung district, Thanh Hoa province, some 30 km from the present coast, approximately 3 km north of the Ma River (Figure 1). The site is a low mound within a small valley at the foot of encircling hills. These hills range from 50 to 350 m above sea level, so the site can be seen as situated within a transitional plains-upland region. However, it is still low enough to be constantly flooded during the rainy season. The occupants would have had access to riverine, estuarine, coastal and dense sub-tropical forest resources within close proximity to the site.

A rather large excavation, some 228.5 m^2, comprising two adjacent pits on and by the mound, was carried out in 1979. In the majority of cases, individuals were buried tightly flexed with respect to both the upper and lower limbs, in a type of squatting or seated foetal position. Graves were generally only earthen pits with no sign of any other lining or covering material. However, at least five single graves were associated with a stone marker on top of or beside the grave. It was not uncommon to find in the graves bones of various vertebrates and invertebrates such as buffalo, pig, turtle, fish, oyster, mussel and snails. Material cultural objects recovered from Con Co Ngua include numerous

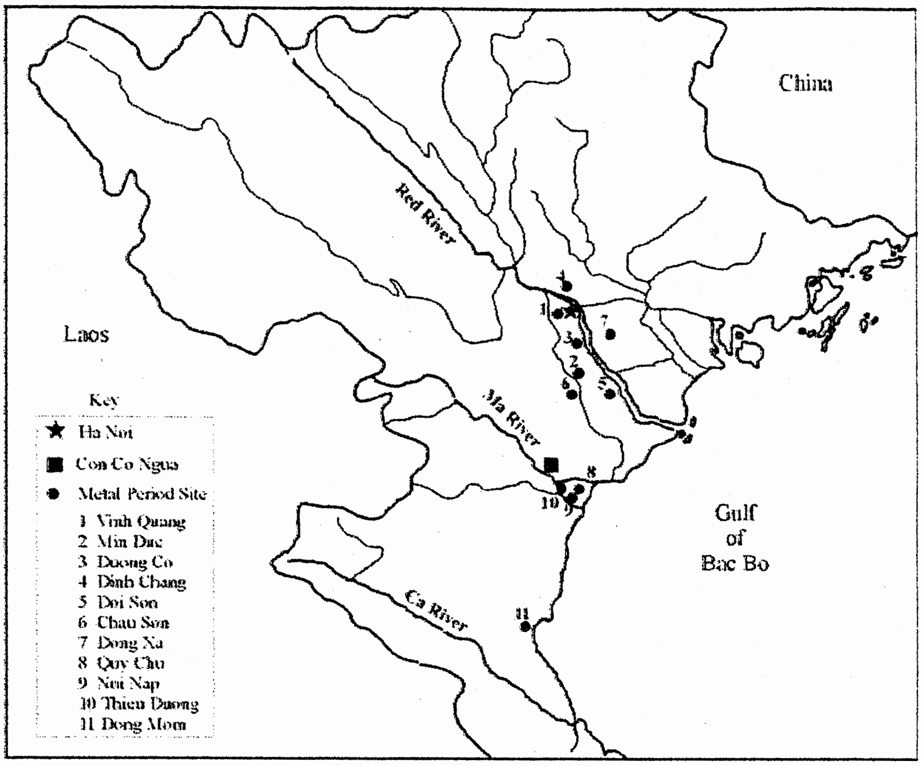

Figure 1: Northern Vietnam: location of Neolithic Con Co Ngua and Metal Period sites.

grinding stones, ground axes and mat-impressed pottery fragments.

Vietnamese archaeologists, using material culture comparisons, associate Con Co Ngua with Da But at approximately 6000 years bp and with Go Trung at about 4800 bp. However, there is an absolute date for the site based on marine shell: Bln 2697: 3020±100 years bp. One of us (NLC) refutes this date and maintains it is too late given the nature of the pottery remains from Con Co Ngua. There is also a radiocarbon date based on a sample of human bone from the site: OZC324: 2740±1050 years bp. This date has an exceptionally large standard deviation and on its own does not help clarify the dating problems associated with this site.

METAL PERIOD SAMPLE

This sample is a composite of dental remains representing 82 individuals (1148 permanent teeth) from 11 separate sites from the Red, Ma and Ca river areas (Figure 1). Over 80% of this assemblage is dated to between 2500 and 1700 years bp, while the remainder of the sample is dated to between 2600 and 3300 years bp.

Much more detailed information is available for this period relative to the Neolithic. The earliest evidence for metal in the Red River delta region appears in late Phung Nguyen culture contexts. These sites are situated on relatively raised areas close to the northern edge of the Red River delta. The Phung Nguyen culture, believed to have endured from 4000 - 3500 years bp, is notable for its rich and technologically sophisticated array of stone jewellery. Following this period, the Dong Dau phase, 3500 - 3000 years bp, ushers in a major development in bronze working technology with the appearance of bronze weapons such as spears and arrowheads, as well as more utilitarian items such as fish-hooks, chisels and axes. The Dong Dau phase is followed by the Go Mun phase, 3000 - 2500 years bp, which is characterised by the development of an enormous range of decorative, utilitarian, ritual and martial items (Higham 1996). Similar cultural sequences are reported for the Ma and Ca River regions immediately south of the Red River delta as well (Ha Van Tan 1985). Emerging from these early metal phases is the Dong Son culture, flourishing in northern Vietnam from 2500 years bp until Han domination in the first centuries of the first millennium AD.

Higham (1989:30) has described the Vietnamese Dong Son as one of several Southeast Asian examples demonstrating social differentiation and a move "from village autonomy towards centralised chiefdoms". Apart from the diverse range and technological sophistication of material culture, including richly decorated bronze drums exceeding 80 kg in weight, there is evidence for marked craft specialisation, a complex ritual life, the development of an aristocratic and centralised elite, maritime trade and sophisticated military skills and equipment.

Higham (1996:134) has also suggested that the Dong Son period:

> developed increasingly centralised social structures which in purely subsistence terms, were raised on the production and deployment of agricultural surpluses. These were used to sustain the central aristocracy and their retainers.

The effects of a reliance on an agricultural subsistence economy should be evident in an oral pathology profile of the Metal period.

SEX AND AGE COMPOSITION OF EACH SAMPLE

Because of the age and sex dependent nature of most dental pathologies it is necessary to examine the age and sex structure of each sample. Figure 2a shows that almost 50% of the Neolithic period sample is aged 40+years. There is also a slight under representation of females in this sample with 44.4% of the sample being female. The Metal period sample has a younger age structure compared to the Neolithic sample (Figure 2b) with 24% aged 40+years.

METHODS

Eight dental conditions have been selected in this study that are related to general diet, behaviour and oral health. Antemortem tooth loss (AMTL) was recognised after Lukacs (1989: 271) as "progressive resorptive destruction of the alveolus". A carious lesion (CAR) was recognised after Turner *et al.* (1991:27) as having "an irregular border and discoloured, easily removed, necrotic dentin at the lesion site". Lesion location was recorded according to the principally affected crown face, if this information was available (Lukacs 1992: 139). Further, it was also noted if the lesion was located at the dental cervix (neck) or root of a tooth. Lesion size was recorded by way of four categories (Metress and Conway 1975 in Lukacs 1992): (1) small pit or fissure lesion; (2) lesion where less than half the tooth crown is destroyed; (3) lesion where greater than half the tooth crown is destroyed; (4) lesion where the entire tooth crown was obliterated. Pulp chamber exposure (PEXP) was categorised by aetiology after Lukacs (1992): attrition induced; caries induced; or unknown aetiology. When present, calculus (CAL) was recorded for severity after Brothwell (1981) as (1) slight: confined to crown and not reaching the cemento-enamel junction (CEJ); (2) medium: confined to crown but extending to CEJ; (3) heavy: extending over the crown and overhanging the roots.

What are often referred to as abscesses are here termed alveolar defects of pulpal origin (ADP). Clarke (1990; Clarke and Hirsch 1991) outline the clinical classification of such bony defects as furcation, angular, lateral, apical and complex defects. This classification is for the most part site or locality specific but also furnishes information on the potential progression of pulpal pathosis. Nonetheless, in this study all ADP are recorded without reference to precise location or whether or not the defect was discrete or continuous with the alveolar crest. Moreover, this classification avoids the difficulties involved in attempting to describe the condition as acute or chronic in the absence of soft tissue information (see Oxenham 2000).

A form of enamel discolouration was also recorded that is believed to be due to the effects of betel nut (*Areca catechu*) staining (BS). This discolouration may have been caused by deliberate staining of the teeth or have occurred incidentally as a side effect of chewing the nut. Here the presence or absence only of such discolouration is recorded.

Interproximal grooves (IG) were recorded following the definition of Frayer and Russell (1987). The chief characteristics of such grooves are that they are artificial, not natural, grooves that run parallel to the CEJ and either cut through the CEJ or are just inferior to it. As the name suggests they are found within the interproximal spaces, and as noted by Frayer and Russell (1987) the grooves commonly exhibit striations within the groove parallel with the long axis of the groove.

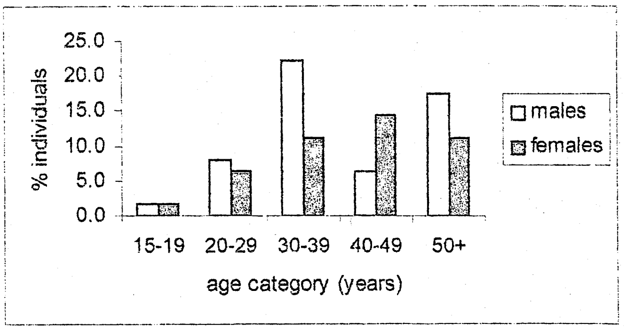

Figure 2a: Neolithic Period age and sex distribution: adults represented by gnathic remains.

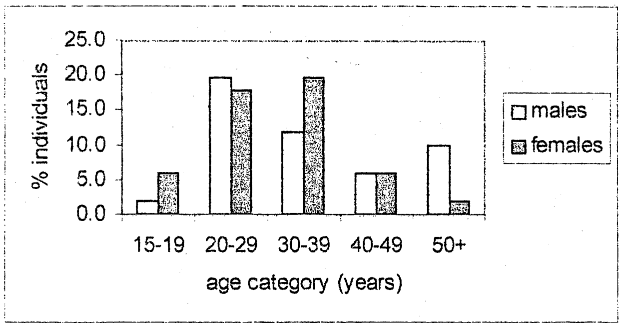

Figure 2b: Metal Period age and sex distribution: adults represented by gnathic remains.

A further category of unintentional dental alterations, termed task wear facets (TWF), were recorded. In this study they refer to teeth that are believed to have been altered through use as tools to perform particular tasks. TWF are recorded as distinct from IG as the aetiology of IG seems to suggest behaviour unrelated to use of teeth as tools.

Two reporting methods have been employed, being the individual count method and tooth count method. Both methods can give different results for the same trait analysed, and while individual count seems intuitively more meaningful, the chief advantages of the tooth count method are that it increases sample size and enables the generation of mean trait per individual if desired for comparison with other studies. It is important to note that for AMTL and ADP the tooth count sample size refers to intact and assessable alveoli, thus addressing the problem of post-mortem tooth loss. For example, while there are 947 permanent Neolithic period teeth there are 1432 assessable alveoli.

RESULTS

Intra Sample Sex Differences (by Individual)

There are no statistically significant (p>0.05) differences in the manifestation of dental traits by sex within each sample. A greater frequency of Neolithic period females exhibit carious lesions, relative to their male counterparts (Table 1, Figure 3a). On the other hand, more than twice the proportion of males display pulp exposure. Looking to the sex patterning in the Metal period (Table 1, Figure 3b), males show a greater disposition to calculus and pulp chamber exposure, while a greater proportion of females display caries, antemortem tooth loss and alveolar defects of pulpal origin.

Inter Sample Differences (by Individual)

While 41.6% of the Metal period sample displayed evidence for betel nut staining (BS), no individuals were so affected in the Neolithic sample (Table 1, Figure 3c). A higher frequency of task wear facets (Chi-sq 4.99, p=0.03) in the Metal period was the only other statistically significant inter-sample difference. The Metal period also displays a greater frequency of carious lesions and pulp chamber exposure, while the Neolithic sample has a greater frequency of individuals affected by calculus, antemortem tooth loss and alveolar defects of pulpal origin. Interestingly, levels of calculus are somewhat high for both samples.

Intra Sample Sex Differences (Tooth Count)

Table 2 and Figures 4a, b and c show the patterning of dental disease by tooth count. Little change is seen in the manifestation of dental traits by tooth count in the Neolithic sample. There is, however, a reversal whereby slightly more Neolithic female alveoli are affected by alveolar defects than male alveoli, albeit not a statistically significant difference (Chi-sq 0.09, p>0.7). Similarly, the patterning of dental traits is similar by tooth count and individual count in the Metal period. However, most of the differences between males and females are statistically significant using the tooth count reporting method. More male teeth are affected by calculus (Chi-sq 11.42, p<0.01), pulp exposure (Chi-sq 5.68, p<0.02) and task wear facets (Chi-sq 6.27, p<0.02). More female teeth are affected by carious lesions (Chi-sq 5.22, p<0.03), antemortem tooth loss (Chi-sq 5.42, p<0.03) and alveolar defects, albeit not significantly so in the test case (Chi-sq 2.34, p=0.13).

Inter Sample Differences (Tooth Count)

The patterns of dental disease when comparing the Neolithic and Metal periods are generally similar for the tooth count method as well (Figure 4c). Again it is more a change in degree than kind. There is a significantly greater frequency of alveolar defects (Chi-sq 3.86, p<0.05) in the Metal period. On the other hand, a greater frequency of Neolithic teeth are affected by calculus, and antemortem tooth loss (Chi-sq 6.33, p<0.02). While the frequency of carious lesions is higher in the Metal period by both reporting methods this difference is not statistically significant.

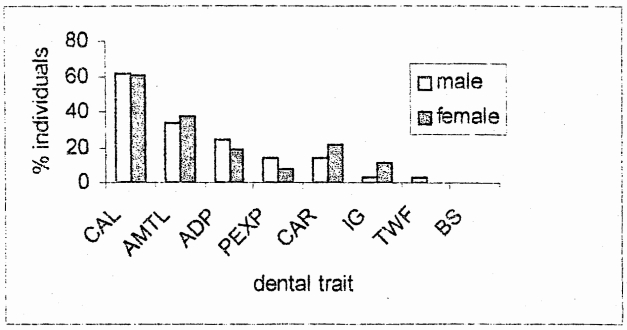

Figure 3a: Neolithic Period prevalence of dental conditions by individual.

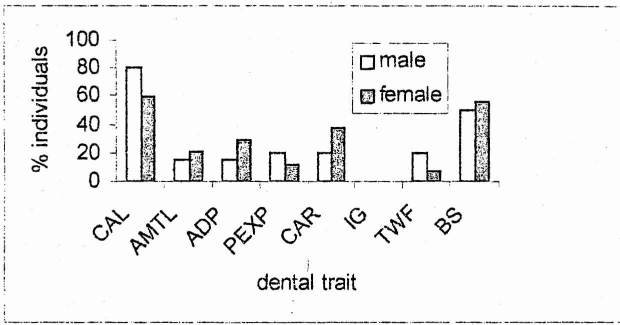

Figure 3b: Metal Period pevalence of dental conditions by individual.

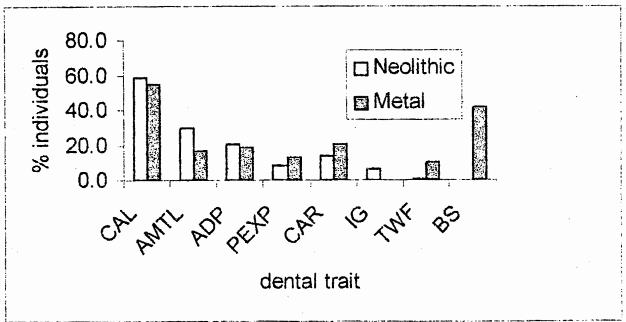

Figure 3c: Neolithic and Metal Period prevalence of dental conditions by individual.

Table 1. Prevalence of Dental Conditions by Individual

Neolithic Period	Male			Female			YA (unsexed)			Indeterminate			Total		
	obs	n	%	obs	n	%	obs	n	%	obs	n	%	obs	n	%
ADP	8	33	24.2	5	27	18.5	1	7	14.3	2	7	28.6	15	74	20.3
AMTL	11	33	33.3	10	27	37.0	0	7	0.0	1	7	14.3	22	74	29.7
CAL[1]	22	36	61.1	17	28	60.7	4	9	44.4	4	7	57.1	47	80	58.8
CAL[2]	33	36	91.7	26	28	92.9	6	9	66.7	7	7	100.0	72	80	90.0
CAR	5	36	13.9	6	28	21.4	0	9	0.0	0	7	0.0	11	80	13.8
PEXP	5	36	13.9	2	28	7.1	0	9	0.0	0	7	0.0	7	80	8.8
IG	1	36	2.8	3	28	10.7	0	9	0.0	1	7	14.3	5	80	6.3
TWF	1	36	2.8	0	28	0.0	0	9	0.0	0	7	0.0	1	80	1.3
Areca	0	36	0.0	0	28	0.0	0	9	0.0	0	7	0.0	0	80	0.0
Metal Period	Male			Female			YA (unsexed)			Indeterminate			Total		
	obs	n	%	obs	n	%	obs	n	%	obs	n	%	obs	n	%
ADP	4	26	15.4	8	28	28.6	0	9	0.0	2	13	15.4	14	76	18.4
AMTL	4	26	15.4	6	28	21.4	1	9	11.1	3	13	23.1	13	76	17.1
CAL[1]	21	26	80.8	16	27	59.3	1	10	10.0	5	14	35.7	42	77	54.6
CAL[2]	25	26	96.2	26	27	96.3	5	10	50.0	8	14	57.1	64	77	83.1
CAR	5	26	19.2	10	27	37.0	0	10	0.0	1	14	7.1	16	77	20.8
PEXP	5	26	19.2	3	27	11.1	0	10	0.0	2	14	14.3	10	77	13.0
IG	0	26	0.0	0	27	0.0	0	10	0.0	0	14	0.0	0	77	0.0
TWF	5	26	19.2	2	27	7.4	0	10	0.0	0	14	0.0	8	77	10.4
Areca	13	26	50.0	15	27	55.6	0	10	0.0	4	14	28.6	32	77	41.6

ADP	alveolar defect of pulpal origin	PEXP	pulp chamber exposure
AMTL	antemortem tooth loss	IG	interproximal groove
CAL	calculus	TWF	task wear facet
CAR	dental caries	Areca	betel nut staining

[1]medium and heavy calculus concentrations
[2]slight,medium and heavy concentrations

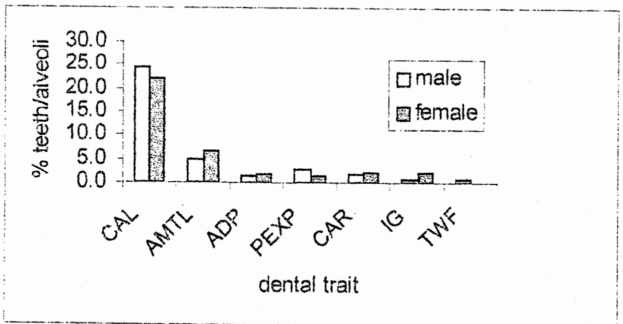

Figure 4a: Neolithic Period prevalence of dental conditions by tooth count.

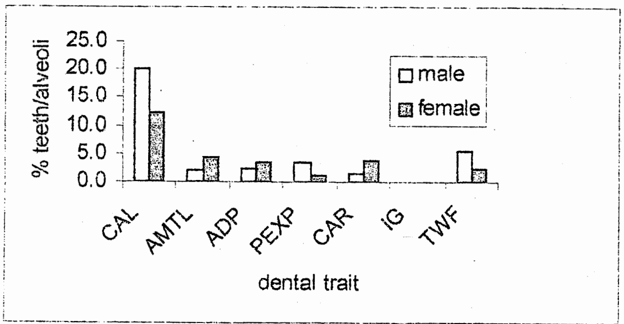

Figure 4b: Metal Period prevalence of dental conditions by tooth count.

Table 2. Prevalence of dental conditions by tooth count

Neolithic Period															
	Male			Female			YA (unsexed)			Indeterminate			Total		
	obs	n	%	obs	n	%	obs	n	%	obs	n	%	obs	n	%
ADP	10	688	1.5	9	540	1.7	1	119	0.8	2	83	2.4	22	1430	1.5
AMTL	33	688	4.8	35	540	6.5	0	119	0.0	1	83	1.2	69	1430	4.8
CAL[1]	109	445	24.5	73	333	21.9	6	89	6.7	24	84	28.6	211	951	22.2
CAL[2]	280	445	62.9	199	333	59.8	31	89	34.8	67	84	79.8	576	951	60.6
CAR	7	445	1.6	7	333	2.1	0	89	0.0	0	84	0.0	14	951	1.5
PEXP	12	445	2.7	5	333	1.5	0	89	0.0	0	84	0.0	17	951	1.8
IG[3]	3	351	0.9	5	261	1.9	0	69	0.0	1	63	1.6	9	744	1.2
TWF	3	445	0.7	0	333	0.0	0	89	0.0	0	84	0.0	3	951	0.3
Metal Period															
	Male			Female			YA (unsexed)			Indeterminate			Total		
	obs	n	%	obs	n	%	obs	n	%	obs	n	%	obs	n	%
ADP	15	693	2.2	21	586	3.6	0	84	0.0	3	155	1.9	39	1518	2.6
AMTL	14	693	2.0	25	586	4.3	0	84	0.0	7	155	4.5	46	1518	3.0
CAL[1]	102	506	20.2	56	462	12.1	0	80	0.0	10	104	9.6	168	1152	14.6
CAL[2]	321	506	63.4	254	462	55.0	15	80	18.8	40	104	38.5	627	1152	54.4
CAR	7	506	1.4	17	462	3.7	0	80	0.0	2	104	1.9	26	1152	2.3
PEXP	17	506	3.4	5	462	1.1	0	80	0.0	4	104	3.8	26	1152	2.3
IG[3]	0	355	0.0	0	328	0.0	0	49	0.0	0	83	0.0	0	815	0.0
TWF	28	506	5.5	11	462	2.4	0	80	0.0	0	104	0.0	39	1152	3.4

ADP	alveolar defect of pulpal origin	PEXP	pulp chamber exposure
AMTL	antemortem tooth loss	TW	taskwear facet
CAL	calculus	IG	interproximal groove
CAR	dental caries		

[1]medium and heavy calculus
[2]slight, medium and heavy calculus
[3]number of assessable premolars and molars

Prevalence of Dental Disease by Tooth Class (Tooth Count)

Plotting dental pathology occurrence across the mouth reveals further differences in disease patterns for both periods. With regard to alveolar defects of pulpal origin (ADP), it can be seen that in the Neolithic period (Figure 5a) this condition is concentrated on the posterior teeth, the molars in particular. In the Metal period, on the other hand, alveolar defects are more evenly distributed across the mouth (Figure 5b).

The results are also consistent with the observation that pulp chamber exposure (PEXP) concentrates in the anterior of the mouth in the Metal period, while the reverse is true for the for the Neolithic period. Molar pulp exposure in the Metal period accounts for only 15.4 % of all teeth so afflicted, while 88.2 % of teeth with pulp exposure are third molars in the Neolithic period sample.

The patterning of carious lesions across the mouth for both samples is quite similar, with the vast majority of caries concentrated in the molars. Antemortem tooth loss, on the other hand, is concentrated at the anterior of the mouth in the Neolithic period sample with the incisors recording the highest occurrence. The reverse trend is true for the Metal period, with the majority of cases affecting the posterior teeth, although there is a noticeable peak in incisor antemortem tooth loss.

INDIVIDUAL DENTAL PATHOLOGIES

Dental Caries

While the overall prevalence of carious lesions, by tooth count, for both periods is quite low, there are differences in the patterning of caries between each sample. During both the Neolithic and Metal periods the vast majority of lesions are manifested in the molars. Only 1/14 carious lesions in the Neolithic period and 4/26 in the Metal period did not occur in molars. Neither period exhibited statistically significant ($p < 0.05$) differences by jaw type for either sex.

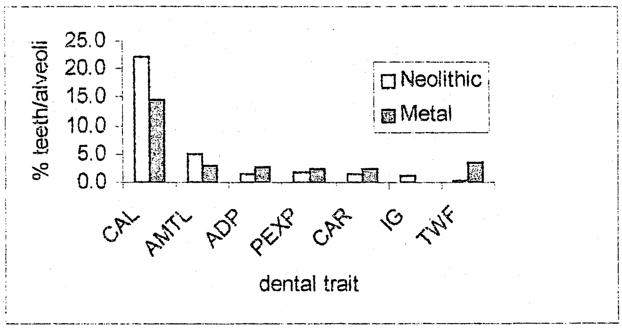

Figure 4c: Neolithic and Metal Period prevalence of dental conditions by tooth count.

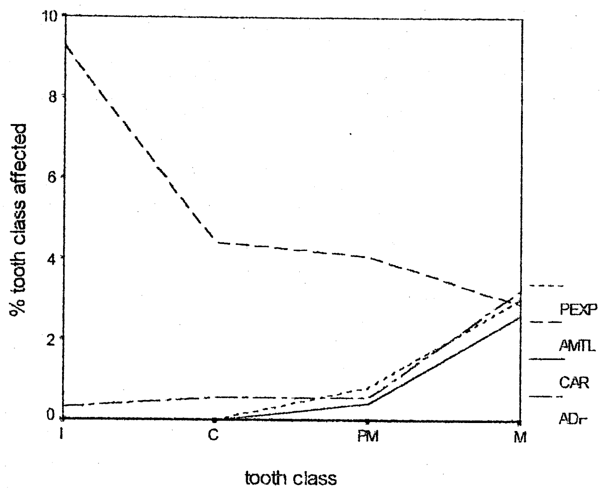

Figure 5a: Neolithic Period prevalence of dental traits by tooth class.

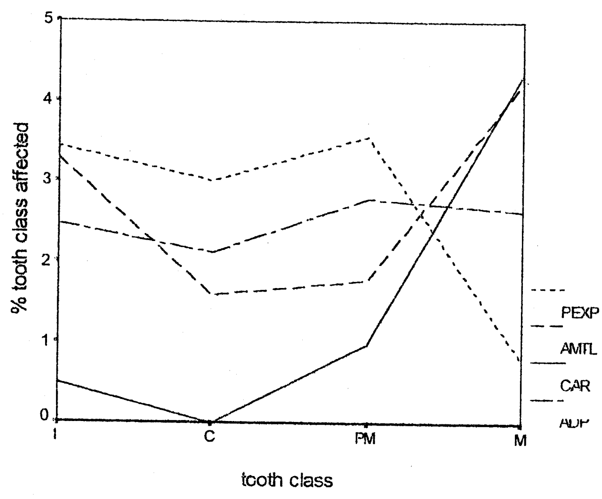

Figure 5b: Metal Period prevalence of dental traits by tooth class.

Further, as noted previously, neither period showed significant differences in caries frequency *per se*, although in the Metal period sample significantly ($p < 0.05$) more females have lesions than males.

Caries was also investigated with regard to its distribution by sex, jaw and lesion size. The majority of Neolithic period lesions are size 2 (57.1 %), tend to manifest themselves in the maxillary teeth (75 %) and are most frequently occlusal, distal or mesial respectively. With regard to the Metal period, there is an increase in the frequency of size 1 lesions, with size 1 (53.8 %) and 2 (38.5 %) caries accounting for the vast majority of all lesions. More than half the lesions in the Metal period sample are occlusal, with distal lesions being the next most important category.

Carious lesions were classified as root, cervical or simply crown. There is a similar pattern of lesion distribution for both periods. Root caries are rare in both samples, cervical caries are only a little better represented with the vast majority of lesions being confined to the crown.

Pulp Exposure

In the Neolithic period sample there are no statistically significant differences by sex or jaw type. However, mandibular teeth (2.4 %) were more affected by pulp exposure than maxillary (1.1 %) and no female teeth were affected by pulp exposure.

In the Metal period male teeth are significantly (Chi-sq 5.68, $p < 0.02$) more affected by pulp exposure than female teeth. With regard to jaw type, significantly more mandibular teeth (3.9 %) are affected than maxillary (0.7 %).

The greatest difference between the Neolithic and Metal periods is in the type of teeth affected. In the Metal period only 4/26 of all teeth displaying pulp exposure were molars with 11/26 affected teeth being incisors or canines and 11/26 being premolars. On the other hand, in the Neolithic period sample only premolars and molars were affected with the vast majority (15/17) being molars. When examining PEXP by aetiology it can be seen that, while PEXP is quite low overall, attrition induced pulp chamber exposure is by far the dominant causal agent for both periods.

Calculus

Because only a very slight deposit of calculus was needed for a positive score it was decided that it would be more meaningful to concentrate on examining only those individuals and teeth affected by moderate to large deposits. Looking at calculus distribution by tooth and jaw type in the Neolithic period sample, significantly (Chi-sq 17.77, $p < 0.001$) more mandibular teeth (27.5 %) are affected by calculus than maxillary (16.1 %). Similar frequencies of calculus are seen for each mandibular tooth class, whereas maxillary incisors are much less affected by calculus than other maxillary teeth.

In the Metal period there is no significant difference by jaw type, although it is the maxillary teeth (16.1%, compared to 13.1% for mandibular teeth) that show a slightly higher frequency of calculus. Overall, incisors, canines and premolars are similarly affected by calculus whereas the molars stand out as being the most affected. Interestingly, no mandibular incisors and very few canines exhibit calculus. On the other hand, maxillary incisors and canines exhibit the most calculus. Male teeth (20.2%) are significantly (Chi-sq 11.42, $p<0.01$) more affected than female teeth (12.1%).

Interproximal Grooves and Task Wear Facets

Interproximal grooves are absent from the Metal period sample but occur in five individuals from the Neolithic period. In two cases, representing two separate individuals, these grooves are associated with carious lesions. Figure 6 shows an association between an IG and a carious lesion in a 30-39 year old male. The left maxillary canine has erupted buccally to the left maxillary P3. The P3 has rotated 90^0 causing its buccal face to point mesially. An interproximal cervical cavity formed on the original distal face of P3, the discomfort of which presumably led to palliative probing and the subsequent development of an IG on the distal face. There is also an IG on the mesial face of P4, probably also associated with the probing. Alternatively, the probing caused or contributed to the formation of the lesion. The P3 cavity broached the pulp chamber and is highly likely the cause of the ADP. This ADP is a complex defect that likely originated at the tooth apex and then spread coronally and in the process destroyed a considerable amount of bone. The canine was not preserved. An IG is also present on the distal face of the RP4, while the RP3 has been lost post-mortem. Also associated with the RP4 is a large angular vertical defect and while the RP4 experienced more coronal wear, exposing a large area of secondary dentine, than the LP4, there is no clear breach of the pulp chamber. This individual is also the only one that displays clear evidence for TWF, on the occlusal surfaces of the maxillary and mandibular first molars, in the Neolithic period sample.

Task wear facets are much more common in the Metal period with 10.4% of individuals and 3.4% of all permanent teeth exhibiting these facets. Task wear facets occurred significantly (Chi-sq 6.9, $p<0.01$) more often in the maxillary dentition than the mandibular. Moreover, significantly (Chi-sq 6.27, $p<0.01$) more male maxillary teeth exhibit TWF than female maxillary teeth. Examined by tooth class, 61.5% of all observed facets occur in the incisors and canines. When TWF are examined by way of tooth surface affected, the lingual aspect of the incisors (30.8% of all observation) is the single most commonly affected area.

Figure 7 is a particularly clear example of lingual maxillary first incisor facets from a single 50+ year old Metal period female. A similar pattern of wear can be seen in Lukacs and Pastor (1988: Figure 12, 396), the cause of which is suggested to be due to the use of the teeth as some sort of clamp (see also Turner and Machado 1983:Figure 2). The particular wear reported for the Vietnamese Metal period is believed to be TWF rather than deliberate mutilation as their aesthetic, or otherwise, impact would have been unobservable.

Betel Nut

Evidence for betel nut staining is absent in the Neolithic period but affects 41.6% of all individuals in the Metal period, males and females equally. The general pattern of staining manifests as a concentration on the buccal aspect of the anterior teeth with a general marked lessening in density on the premolars and a general absence or only very slight staining of the molars. A study using scanning electron microscopy and gas chromatography coupled with mass spectrometry of one of these teeth indicates deliberate tooth staining by way of betel nut extracts, perhaps for aesthetic purposes (Oxenham *et al.* 2002).

THE VIETNAMESE SAMPLES IN COMPARISON WITH OTHER SOUTHEAST ASIAN SAMPLES

While there are no other studies of the oral health of ancient Vietnamese remains, there are a number of recent studies of ancient dental assemblages from Thailand. The results from seven of these sites, including Noen U-Loke (Nelson 1999), Ban Na Di (Domett 2001), Non Nok Ta and Ban Chiang (Douglas 1996), Khok Phanom Di (Tayles 1992; 1999), Nong Nor (Tayles *et al.* 1998), and Ban Lum Khao (Domett 2001 and this volume), are summarised for caries, antemortem tooth loss, alveolar defects of pulpal origin and calculus (Table 3). The assessment of subsistence economy at each site is based on each author's assessment of the archaeological and environmental evidence. The use of the term 'mixed' refers to the inference that both agriculture, to a generally unknown degree, and foraging contributed to the subsistence economies at these sites. No attempt is made to test the significance of observed differences among these assemblages due to differences in the age and sex structure of each sample. Further, these figures have been collated from the work of a number of authors and differences in the methods of data collection/recording cannot be controlled for. These comparisons are only meant as a gross analysis of these Southeast Asian dental series with respect to broad time and generalised subsistence considerations.

The ancient Southeast Asian oral response to subsistence/environment can be seen to be varied, even as assessed with the limited number of variables addressed in Table 3.

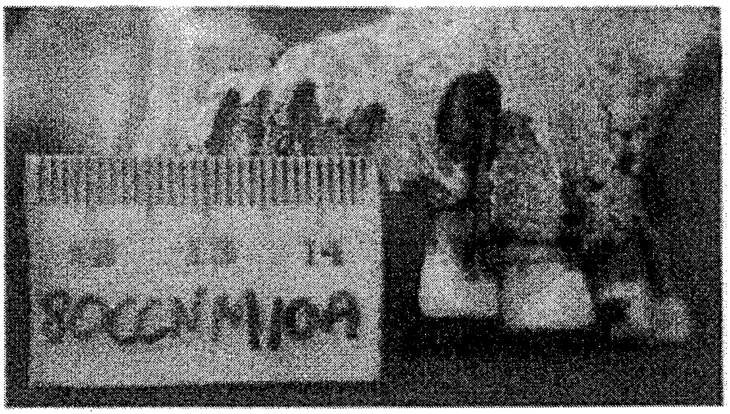

Figure 6. Neolithic Period male. Note interproximal grooves to premolars.

Figure 7: Metal Period female. Task wear facets on lingual aspect of both maxillary central incisors.

Nonetheless, the overall frequency of each trait is quite low on the world stage. The variation would be expected given the diversity and complexity of tropical regions themselves (Hutterer 1983). Further complications with generalising a Southeast Asian response centre on specifying in detail the subsistence strategies employed. The relative contributions of the components of the mixed subsistence economies, which are in the majority, are yet to be clearly elucidated for these sites from Thailand and Vietnam.

The Dental Pathology Profile (DPP) and Subsistence

Table 4 is a modification of Lukacs' (1989) DPP that only includes dental pathologies relevant to this study. The table has been expanded using data from Littleton and Frohlich (1993) to extend the range of identifiable subsistence strategies. Both Lukacs (1989) and Littleton and Frohlich (1993) provide various quantitative estimates to assist with classifying pathological manifestations as high or low. Table 5 summarises the DPPs for these two samples. At a gross level the DPPs for both the Vietnamese periods sampled are the same and both fit into the first three subsistence categories, i.e., hunter-gatherer, marine-dependent and 'transitional-mixed'.

DISCUSSION

Caries

The low prevalence of caries reported here would at face value indicate a low fermentable carbohydrate component in the diet of each period. However a range of complicating factors influence caries prevalence. One important factor that cannot be controlled for is geochemical, not the least of which includes ground water fluoride concentrations, information on which is not available for the study region. Given the archaeological evidence for a potentially significant rice component in the diet of the Metal period, the caries prevalence for this period might have been expected to have been greater than reported here. It needs to be noted again here that the Metal period sample is younger than the Neolithic period sample. The age dependent nature of dental pathologies means that the low frequency of carious lesions may be partly due to the more youthful age structure of the sample. Another factor to consider is that rice consumption, as opposed to wheat, does not appear to be correlated with caries prevalence *per se* (Sreebny 1983), although high levels of rice consumption may be correlated with relatively higher caries prevalence. Krasse (1985) also points out that the caries-inducing potential of rice is low. It would appear, then, that any marked increased reliance on rice may not leave the same general high caries rate signature that agricultural intensification has in general left in Europe and North America.

Archaeological evidence indicates a marine dietary component in both periods, although the relative contribution of marine resources to the diet is unknown. A number of studies have highlighted the cariostatic nature of marine diets (Walker and Erlandson 1986; Kelley *et al.* 1991; Larsen *et al.* 1991; Sealy *et al.* 1992). The Metal period is further distinctive in the large proportion of what is believed to be betel nut stained teeth, is believed to inhibit caries formation also (Moller *et al.* 1977; Schamschula *et al.* 1977; Nigam and Srivastava 1990). Attrition also reduces the incidence of occlusal caries (Meiklejohn *et al.* 1984) and is a factor to consider when looking at low occlusal caries rates. However, rates of tooth wear between the Neolithic and Metal period appear to be similar (Oxenham 2000). Notwithstanding these complicating factors however, the caries rate for the Metal period is very low by any standard and particularly so

Table 3: The prevalence of several oral pathologies (permanent teeth) from samples in Thailand and Vietnam

Site	date*	subsistence	Dental Pathology by Tooth Count % (rate in parentheses is individual count) caries	AMTL	ADP	CAL	source
Vietnam (Neolithic)	~ 6.0	foraging	1.5 (13.8)	4.8 (29.7)	1.5 (20.3)	22.2 (58.8)	6
Non Nok Tha (early)	5.5 - 4.5	mixed	1.7	5.0	1.4	28.8	4
Ban Chiang (early)	5.6 - 3.4	mixed	6.2	6.6	5.5	32.8	4
Non Nok Tha (late)	4.5 - 3.0	mixed	4.1	10.4	2.7	35.7	4
Khok Phanom Di	4.0 - 3.5	agriculture	10.8 (58.2)	8.9 (50.7)	6.0 (55.2)	n/a	3
Ban Chiang (late)	3.6 - 1.7	mixed	7.7	6.9	6.6	20.7	4
Ban Na Di	2.6 - 2.4	mixed	4.7	5.4	2.1	n/a	5
Vietnam (Metal)	3.3 - 1.7	mixed	2.3 (20.8)	3.0 (17.1)	2.6 (18.4)	14.6 (54.6%)	6
Noen U-Loke	2.3 - 1.7	agriculture	3.0 (29.6)	8.4 (55.6)	1.8 (17.9)	54.7 (90.6)	2
Ban Lum Khao	1.0 - 1.5	mixed	4.5	5.1	1.3	n/a	5
Nong Nor	3.1 - 2.7	mixed	6.0 (49.3)	4.1 (27.1)	0.8	n/a	1, 5

* date: 1000 years bp

mixed (subsistence): foraging and agriculture of indeterminate ratio

1 Tayles *et al.* (1998)	4 Douglas (1996)	AMTL ante-mortem tooth loss
2 Nelson (1999)	5 Domett (1999)	ADP alveolar defect of pulpal origin
3 Tayles (1992)	6 this study	CAL calculus (moderate and severe expression)

Table 4: Dental pathology profiles for various subsistence strategies

Dental Pathology	1.Hunter-Gatherer	2.Marine Dependent	3.Transitional-Mixed[1]	4.Mixed Farming[2]	5.Agriculture	6.Intensive Gardening[3]
attrition	high	high	moderate	low	low	low
caries	low	low	Moderate (low)	high	high	high
pulp exposure (caries)	low	(low)	moderate		high	
pulp exposure (attrition)	high	(high)	moderate	low	low	
AMTL		low	low	high		high
calculus	low[4]	low[4]	moderate	high	high	low

Table modified from Lukacs (1992) and Littleton and Frolich (1993).
[1]this category refers to strategies including various combinations of the following: pastoralism, marine, agriculture, horticulture, hunting, gathering.
[2]excludes hunter-gatherer and marine strategies as being significant contributors.
[3]diet high in carbohydrates (grain not significant component of diet) intensive agriculture/horticulture.
[4]moderate to high instances have been recorded for Marine dependent communities (Littleton and Frolich 1993).

Table 5: Summary of Vietnamese Neolithic and Metal Period DPPs

Dental Pathology	Neolithic	Metal	Strategy
caries	low	low	1, 2, 3
pulp exposure (caries)	low	Low	1, 2
pulp exposure (attrition)	high	high	1, 2
AMTL	low	low	2, 3
calculus	low	low	1, 2, 3

considering archaeological arguments (Higham 1996) for a transition to and intensification of agriculture in the Bronze Age of Northern Vietnam.

There is a significant sex difference in caries for the Metal period. Larsen *et al.* (1991) point out that numerous studies have reported a greater prevalence of female caries, but also note that this is not a universally observed pattern. Dietary differences and or snacking are commonly suggested as explanations for such differences (Larsen *et al.* 1991). Walker and Hewlett (1990), in an ethnographic study, suggested such a reason for the difference in caries prevalence between male and female African Pygmies. This particular example is important in highlighting that differences in caries prevalence by sex can exist in otherwise non-hierarchical or egalitarian societies. Other possible sex factors such as the effects of pregnancy are both difficult to assess and not necessarily influential in affecting dental health (Larsen *et al.* 1991).

Pulp Exposure

Attrition is by far the chief cause of pulp exposure for both time periods. The trend toward posterior tooth PEXP in the Neolithic period and anterior tooth concentration in the Metal period suggests either quite different masticatory patterns between both periods, or else that one or both communities were using their teeth for activities other than food processing. It is relevant that task wear facets are concentrated on the anterior teeth of the Metal period sample. This is also consistent with the evidence for high frequencies of anterior alveolar defects in the Metal period and suggests the causes of pulp exposure, alveolar defects and task wear facets are all related to using the teeth as tools.

The observation that more male Metal period teeth are affected by PEXP suggests that male teeth were under more stress than female. Given that the chief cause of PEXP is attrition of the anterior teeth in the Metal period, this may indicate a bias toward males using their teeth in non-masticatory tasks.

With regard to the Neolithic period, PEXP and alveolar defects are both concentrated in the posterior teeth and are likely interrelated. Note also that for neither sample was dental caries a significant contributor to PEXP and hence probably not to alveolar defects either.

Alveolar Defects of Pulpal Origin

In the Metal period ADP is greater by tooth count and affects a greater proportion of anterior teeth than is the case in the Neolithic period sample. This is also consistent with the view forwarded for a greater use of the anterior teeth in non-masticatory tasks in the Metal period.

Antemortem Tooth Loss

AMTL patterns are not obviously consistent with the patterning of alveolar defects, pulp exposure and task wear facets in the Metal period. However, the slight peaking of incisor AMTL at this time is consistent with the general pattern described for the Metal period proposed to be due to using the anterior teeth as tools.

With regard to the Neolithic period, the concentration of incisor AMTL is somewhat enigmatic. Given that the high frequency of incisor AMTL is unlikely to be due to attrition or caries induced pulp exposure and alveolar defects, which are concentrated in the posterior teeth, then some other causal factor must be sought. Deliberate tooth ablation could account for this pattern. Tooth ablation has been reported in prehistoric Thailand (Tayles 1997), but the clear patterning seen in that study is not apparent in the Neolithic period sample from Vietnam.

Calculus

In discussing calculus deposits it is preferable to place more weight on the evidence from the individual count analysis when making comparisons. The reason is that it is virtually impossible to control for the loss of calculus deposits on individual teeth during the period of curation. Some of the remains in this study have been stored and handled for over 30 years.

Males exhibit significantly more calculus, both by tooth count and individual count, in the Metal period. This pattern is not apparent in the Neolithic period where calculus frequency is similar by sex. The pattern seen in the Metal period may be due to under-representation of females in the older age classes both by tooth and individual count. However, it may also be due to differences in diet and/or oral hygiene. Given that both samples exhibit very high frequencies of some degree of calculus, over 80% of individuals in each sample, levels of oral hygiene might reasonably be considered to have been quite low. If the difference between the sexes is dietary, it could indicate that the composition of the male diet was different to that of females. However, given the findings of Lieverse (1999) that diets high in carbohydrates or protein can lead to high calculus levels, it is impossible to suggest what the dietary difference, if real, consisted of. Alternatively, the oral environment of males may be differentially predisposed to calculus formation due to non-dietary factors. Such factors are unlikely to include behaviour associated with betel nut staining, as the habit appears to have been practised equally by both sexes. It is therefore not clear what factor(s) predisposed males to greater levels of calculus formation.

Task Wear Facets and Interproximal Grooves

Where interproximal grooves are confined to the molars and premolars, there are persuasive arguments to believe that the most likely aetiology is dental probing (Frayer 1991; Bermudez de Castro *et al.* 1997). If they were caused by way of industrial activities, such as fibre processing, it would be expected that IG would be observed in the Metal period sample that displays a high frequency of teeth affected by task wear facets. That this is not seen tends to support the view that IG are caused by dental probing with some type of tooth pick.

The morphology and distribution of task wear facets in the Metal period sample is consistent with some type of fibre processing or use of the dentition in clamping activities. Further, it would seem that males were preferentially involved in these industrial activities.

Subsistence Strategies

The dental pathology profile (DPP) for the Neolithic period sample is consistent with Vietnamese work (Bui Vinh and Nguyen Van Hao 1980; Bui Vinh 1990; Nguyen Khac Su 1997) outlining the maritime nature of the Neolithic culture to which this sample belongs. One potential anomaly is the high degree of calculus. In fact calculus assessed by tooth count is significantly greater in the Neolithic period than the Metal period. This can perhaps be explained by the observation that marine dependent economies can evidence high levels of calculus (Perdersen 1947, cited in Littleton and Frohlich 1993).

The DPP for the Metal period, while not consistent with an agriculturally based economy, is certainly consistent with the transitional-mixed model. The degree to which hunting-gathering and/or aquatic strategies played a significant role in the subsistence economies of this period is difficult to assess, but it is not improbable that these strategies were important. Moreover, work by Vietnamese archaeologists (Nguyen Kach Su 1997) outlining the development of the Dong Son directly from previous maritime cultures is relevant in this context. It is also significant to note that evidence for sedentism in the Vietnamese Bronze Age is not inconsistent with a mixed economy model (Shoocongdej 1996).

Comparisons with other Southeast Asian Assemblages

The frequency of caries, antemortem tooth loss and alveolar defects of pulpal origin is relatively low for all sites examined here. In only one instance does one of these oral health measures exceed 10%, and that is caries in agriculturally oriented Khok Phanom Di. However, the other two sites identified as agriculturally oriented, Ban Na Di and Noen U-Loke, display quite low frequencies of caries. It is possible that Southeast Asian oral responses to agriculture are somewhat different to those observed in other regions of the globe. Alternatively, the role of agriculture in the economies of these sites sampled in Southeast Asia to date is in need of revision.

CONCLUSIONS

1. There is some evidence, albeit not overwhelming, for intra sample sex differences in diet and/or oral hygiene and/or food processing techniques for both time periods. Added to this is that higher rates of caries for females in both samples may be indicative of a higher carbohydrate content in the female diet.
2. The higher frequency of carious lesions in the Metal period is consistent with a modification of subsistence strategy away from a predominantly hunter-gatherer/aquatic based economy.
3. Pulp exposure for both samples is by and far attrition induced. This, and the observation that pulp exposure is concentrated on the anterior teeth in the Metal period, along with the evidence for task wear facets on the anterior teeth, suggest the use of teeth as tools at this time to a much greater extent than during the Neolithic period. Metal period incisor task wear facets are not inconsistent with some sort of fibre/sinew processing and/or using the dentition as some type of clamp.
4. Prehistoric assemblages in Thailand, with the possible exception of Ban Chiang, are similar to Vietnam in not providing dental evidence for an agricultural subsistence economy in the early Metal periods.
5. The Neolithic period dental pathology profile is consistent with Vietnamese evidence of an aquatic based economy. As for the Metal period sample, its dental pathology profile clearly mitigates against seeing agriculture playing a dominant role in its subsistence strategy. The situation of these sites adjacent to vast aquatic resources and the development of the Northern Vietnamese Bronze Age from a maritime economy base poses the question: "to what extent were the Metal period cultures in Northern Vietnam reliant on aquatic resources for their subsistence?"

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REFERENCES

Bermudez de Castro, J.M.B., J.L. Arsuaga and P.L. Perez. 1997. Interproximal grooving in the Atapuerca-SH hominid dentitions. *American Journal of Physical Anthropology* 102:369-76.

Brothwell, D.R. 1981. *Digging up Bones*. Ithaca: Cornell University Press.

Bui Vinh. 1980. Bao Cao Khai Quat, Di Tich Van Hoa Da But, Dia Diem Khao Co Hoc: Con Co Ngua (Thanh-Hoa). [Cultural

Vestiges at Da But Archaeological Site at Con Co Ngua (Thanh Hoa)]. Unpublished Excavation Report, Institute of Archaeology, Hanoi, Vietnam.

Bui Vinh. 1990. The Da But Culture in the Stone Age of Viet Nam. *BIPPA* 10:127-30.

Bui Vinh and Nguyen Van Hao. 1980. *Bao Cao Khai Quat Di Chi Con Co Ngua (Thanh Hoa)*. Hanoi.

Clarke, N.G. 1990. Periodontal defects of pulpal origin: evidence in early man. *American Journal of Physical Anthropology* 82:371-6.

Clarke, N.G. and R.S. Hirsch. 1991. Physiological, pulpal, and periodontal factors influencing alveolar bone. In M.A. Kelley and C.S. Larsen (eds), *Advances in Dental Anthropology*, pp. 241-66. New York: Wiley-Liss.

Domett, K.M. 2001. *Health in Late Prehistoric Thailand*. Oxford: Archaeopress. BAR *International Series* 946.

Domett, K.M. 2002. The prehistoric people of Ban Lum Khao, Central Thailand. BIPPA 22(6):111-9.

Douglas, M.T. 1996. Paleopathology in Human Skeletal Remains from the Pre-Metal, Bronze and Iron Ages, Northeastern Thailand. PhD dissertation, University of Hawai'i, Honolulu.

Frayer, D.W. 1991. On the etiology of interproximal grooves. *American Journal of Physical Anthropology* 85:299-304.

Frayer, D.W. and M.D. Russell. 1987. Artificial grooves on the Krapina Neanderthal teeth. *American Journal of Physical Anthropology* 74:393-405.

Ha Van Tan. 1985. Prehistoric pottery in Viet Nam and its relationships with Southeast Asia. *Asian Perspectives* 26(1): 135-46.

Higham, C.F.W. 1989. *The Archaeology of Mainland Southeast Asia*. Cambridge: Cambridge University Press.

Higham, C. 1996. *The Bronze Age of Southeast Asia*. Cambridge: Cambridge University Press.

Hutterer, K.L. 1983. The natural and cultural history of Southeast Asian agriculture: ecological and evolutionary considerations. *Anthropos* 78:169-212.

Kelley, M.A., D.R. Levesque and E. Weidl. 1991. Contrasting patterns of dental disease in five early northern Chilean groups. In M.A. Kelley and C.S. Larsen (eds), *Advances in Dental Anthropology*, pp. 203-13. New York: Wiley-Liss.

Krasse, B. 1985. The cariogenic potential of foods - a critical review of current methods. *International Dental Journal* 35:36-42.

Larsen, C.S., R. Shavit and M.C. Griffin. 1991. Dental caries evidence for dietary change: an archaeological context. In M.A. Kelley and C.S. Larsen (eds), *Advances in Dental Anthropology*, pp. 179-202. New York: Wiley-Liss.

Lieverse, A.R. 1999. Diet and the aetiology of dental calculus. *International Journal of Osteoarchaeology* 9:219-32.

Littleton, J. and B. Frohlich. 1993. Fish-eaters and farmers: dental pathology in the Arabian Gulf. *American Journal of Physical Anthropology* 92:427-47.

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. 261-86. New York: Wiley-Liss.

Lukacs, J.R. 1992. Dental paleopathology and agricultural intensification in South Asia: new evidence from Bronze Age Harappa. *American Journal of Physical Anthropology* 87:133-150.

Lukacs, J.R. and R.F. Pastor. 1988. Activity-induced patterns of dental abrasion in prehistoric Pakistan: evidence from Mehrgarh and Harappa. *American Journal of Physical Anthropology* 76:377-98.

Matsumura, H., L.C. Nguyen, K.T. Nguyen and T. Anezaki. 2000. Dental morphology of the Early Hoabinian, the Neolithic Da But and the metal Age Dong Son cultural people in Vietnam. *Zeitschrift fur Morphologie und Anthropologie* 83:59-73.

Meiklejohn, C., C. Schentag, A. Venema and P. Key. 1984. Socioeconomic change and patterns of pathology and variation in the Mesolithic and Neolithic of Western Europe: some suggestions. In M.N. Cohen and G.J. Armelagos (eds), *Paleopathology at the Origins of Agriculture*, pp. 75-100. Orlando: Academic Press.

Moller, I.J., J.J. Pindborg and I. Effrendi. 1977. The relation between betel chewing and dental caries. *Scandinavian Journal of Dental Research*. 85(1):64-70.

Nelsen, K.M. 1999. The Dental Health of the People from Noen U-Loke. A Prehistoric Iron Age Site in Northeast Thailand. MA dissertation, University of Otago, New Zealand.

Nigam, P. and A.B. Srivastava. 1990. Betel chewing and dental decay. *Federation of Operative Dentistry* 1(1):36-8.

Nguyen Khac Su. 1997. In the framework of the maritime culture of Vietnam: the prehistoric maritime culture of the northeast. *Vietnamese Studies* 53(123), No. 1:87-116.

Oxenham, M.F. 2000. Health and Behaviour During the Mid-Holocene and Metal Period of Northern Viet Nam. PhD dissertation, Northern Territory University, Australia.

Oxenham, M.F., C. Locher, Nguyen Lan Cuong and Nguyen Kim Thuy. 2002. Identification of *Areca catechu* (betel nut) residues on the dentitions of Bronze Age inhabitants of Nui Nap, Northern Vietnam. *Journal of Archaeological Science* 29(9):909-15.

Parker, K. 1998. The Early Neolithic Cemetery of Con Co Ngua, Northern Vietnam: Non Metric Cranial Variation and Relationships. BSc (Hons) dissertation, Northern Territory University, Australia.

Schamchula, R.G., B.L. Adkins, D.E. Barmes and G. Charlton. 1977. Betel chewing and caries experience in New Guinea. *Community Dentistry and Oral Epidemiology* 5 (6):284-6.

Sealy, J.C., M.K. Patrick, A.G. Morris and D. Adler. 1992. Diet and dental caries among Later Stone Age inhabitants of the Cape Province, South Africa. *American Journal of Physical Anthropology* 88:123-34.

Shoocongdej, R. 1996. Rethinking the development of sedentary villages in western Thailand. *BIPPA* 14:203-15.

Sreebny, L.M. 1983. Cereal availability and dental caries. *Community Dentistry and Oral Epidemiology* 11(3):148-55.

Tayles, N. 1992. The people of Khok Phanom Di: Health as Evidence of Adaptation in a Prehistoric Southeast Asian Population. PhD dissertation, University of Otago, New Zealand.

Tayles, N. 1997. Tooth ablation in prehistoric Southeast Asia. *International Journal of Osteoarchaeology* 6:333-45.

Tayles, N. 1999. *The Excavation of Khok Phanom Di: A Prehistoric Site in Central Thailand. Volume IV: The People.* The Society of Antiquaries of London: Oxbow Books.

Tayles, N., K. Domett and V. Hunt 1998. The people of Nong Nor. In C. Higham and R. Thosarat (eds), *The Excavation of Nong Nor: A Prehistoric Site in Central Thailand,* pp: 321-368. Dunedin: Department of Anthropology, University of Otago.

Turner, C.G. II and L.M.C. Machado 1983. A new dental wear pattern and evidence for high carbohydrate consumption in a Brazilian Archaic skeletal population. *American Journal of Physical Anthropology* 61: 125-30.

Turner, C.G. II, C.R. Nichol and G.R. Scott 1991. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In M.A. Kelley and C.S. Larsen (eds), *Advances in Dental Anthropology,* pp. 13-31. New York: Wiley-Liss.

Walker, P.L. and J.M. Erlandson 1986. Dental evidence for prehistoric dietary change on the northern Channel Islands, California. *American Antiquity* 51 (2): 375-83.

Walker, P.L. and B.S. Hewlett 1990. Dental health, diet and social status among central African foragers and farmers. *American Anthropologist* 92 (2): 383-98.