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The Pathology and Dental Morphology of Neolithic Burials from the Wu-Shan-Tou Site, Southwestern Taiwan

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ABSTRACT

Wu-Shan-Tou (WST) is a Neolithic site dated to approximately 2700 B.P. in southwestern Taiwan, where excavation in 1999 revealed 35 human burials and four dog burials. The goal of this paper is to give a preliminary report of ten reconstructed[1] WST human skeletons, based on morphological studies that began in 2009. Generally speaking osteoarthritis was a common disease amongst WST individuals who had reached the age of 20. The presence of osteoarthritis is not surprising as the disease has been noted to afflict a large number of individuals in contemporary sites. However, the identification of osteomyelitis and tuberculosis (TB) is extremely surprising as such diseases have never been identified in Neolithic sites before. Periodontal disease, fracture, and degenerative joint disease were observed among the ten individuals. However, the incidence of these diseases is comparatively low (20%, 20%, and 10%, respectively). In terms of dental morphology, most of the individuals studied have with shoveling, double shoveling and enamel extension. Curiously, Carabelli's cusp is observed in one of the individuals.

Keywords: Wu-Shan-Tou, osteoarthritis, osteomyelitis, tuberculosis

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烏山頭遺址出土人骨病理學與牙齒形態學之初步分析

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摘　要

新石器時代的烏山頭遺址位於西南臺灣、距今約 2700 年。該遺址於 1999 年搶救發掘時，出土了 35 具人骨與 4 具狗墓葬。而本文的目的即在於初步分析自 2009 年起，對於當時出土的 10 具人骨的形態學研究。關節炎乃此 10 具人骨中，20 歲以上個體常見的一種病理現象，而這種情形也多見於其他當代的史前遺址之中。然而，骨髓炎與肺結核的發現則為臺灣新石器時代出土人骨之首例。另外，牙周病、骨折與退化性關節炎也可見於此批出土人骨之中，只是比例皆不高（依次為 20%、20%與 10%）。於牙齒形態上，大多數的個體可見箕形門齒（含 shoveling 與 double shoveling）及琺瑯質延展（enamel extension）。同時，也可見其中一個體出現 Carabelli's cusp（一種多出現於歐洲人的牙齒特徵，於太平洋島群民族出現的比例僅有 35-45%）。

關鍵字：烏山頭、關節炎、骨髓炎、肺結核

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INTRODUCTION

The multi-disciplinary nature of bioarchaeology allows the field to approach any given topic from multiple viewpoints. For instance, in the past (especially during the 1970s), the term bioarchaeology referred to the study of faunal remains. More recently its definition has been extended to include biological materials, specifically flora and fauna, from archaeological contexts. It is clearly defined as the "reconstruction of human activity, health, and disease" by Bradford University in the UK.

The changing scope of bioarchaeology in the last few decades reflects how it draws from a variety of fields such as biology, geology, physics, engineering, as well as the social and behavioral sciences (Larsen 2006). For instance, different definitions have been applied for the study of osteoarthritis (OA) between clinicians and anthropologists. The latter further emphasizes the development of osteophytes around the joint capsule (Jurmain 1999), whereas the former focuses on the impacts of joint injures in the development of OA later in adulthood (Jurmain 1999; Micheli and Klein 1991).

Currently, one of the objectives of bioarchaeology is to reconstruct the behavior and lifestyle of a given group through a combination of biomechanical analyses, genetic analyses, the study of pathologies, and other observations. Based on these ideas, this paper aims to conduct a pathological and dental morphological analysis of ten reconstructed WST human skeletons.

BRIEF REVIEWS OF BIOARCHAEOLOGICAL STUDIES IN PREHISTORIC TAIWAN

Studies in the field of biological anthropology began in Taiwan during the period of Japanese colonization. This early research predominantly emphasized the collection of body measurements and descriptions of living aborigines. However, a subsequent shift in focus later in the period saw attention move onto the study of skeletal remains from Neolithic sites (e.g., Buntaro 1907a, 1907b, 1907c; Kanaseki 1952, 1978; Torii 1898). Few bio-anthropological studies were conducted by Taiwanese post 1945; those studies that did occur continued to focus upon Neolithic human skeletons, with a specific emphasis upon burial practices such as

the presence of stone coffins (e.g., Chen 1994; Chu 1990; Liu 1999; Song and Lien 1985) or associated goods (e.g., Shi and Song 1956; Song and Lien 1985; Zheng 1998).

Few studies have been done after 1990. One major work which was completed is a master thesis by Ching-fang Chang in 1993 titled "The morphological and pathological analyses and their comparisons of the human skeletons from the Shih-San-Hang site (SSH)." Salvage archaeology at SSH has involved several excavations, which discovered 291 human burials, mostly in excellent to good preservational condition.

Chang conducted a study upon 17 adult males and 15 adult females (Chang 1993). According to Chang, ratios of caries and abscesses in the SSH people are low. However, she also suggests they may have developed the habit of chewing betel nuts as evidenced by their dental attrition. Additionally, Chang suggests that they may have used their teeth as a tool as indicated by the abnormal dental-wear patterns (Chang 1993). Furthermore, the presence of enamel hypoplasia in some individuals indicates the potential for dystrophy to be present in this society (Chang 1993). Besides dental pathology, Chang notes that degenerative joint disease was the most common disease; trauma such as fractures was unusual (Chang 1993).

In 2005, another master thesis "Childhood Stress of an Iron Age Population from Taiwan: Using Linear Enamel Hypoplasia and Porotic Hyperostosis as Stress Indicators" by Chin-hsin (Kathy) Liu once again analyzed the SSH people. Liu found that two- to five-year-old children were the peak age group for enamel hypoplasia, which she argues that enamel hypoplasia in children may have resulted from contaminated food, water, elongated lactation, or low-quality food for weaning. Furthermore, Liu identified that enamel hypoplasia was differentially distributed according to sex, as it was more severe in females than males, signifying differential weaning practices between the sexes (Liu 2005). Finally, the presence of porotic hyperostosis, an iron-deficiency indicator, most commonly present in the sub-adult and young adult skeletons, raises the possibility that the SSH people practiced an ocean-oriented subsistence strategy. There may have been a lack of knowledge with concerns to sanitary practices to avoid parasitic infections.

Finally, a brief pathological introduction of the San-Pau-Chu (SPC), Wu-Chen-Tsu South (WCTS), and Nan-Kuan-Li East (NKLE) sites was presented in the dissertation titled "The

Biological Evidence of the San-Pau-Chu People and Their Affinities" (Lin 2009). In this volume, Lin states that (quote):

> *Pathological conditions such as osteoarthritis, fractures, and variations such as the presence of a squatting facet on tibiae were observed in many of these individuals. Vertebral osteophytosis is the most common pathology. Eleven out of forty-five (24.44%) SPC people have osteophytic lipping on their epiphyseal rings of lumbar vertebrae (L2-5). Additionally, there are a number of traumatic lesions that suggest inter-individual conflicts. Two individuals had stone spears in their rib cages: one from SPC G16 II B1, approximately 30 years old, probably male), the other is from NKLE (F5 B11, 25-35 years old, undetermined sex). Clear cuts from cervical to lumbar vertebrae in one (K17 II B1, 23-35 years old, probably male) of the SPC people also suggest the presence of violence. K17 II B1 bears one cut from C6-7 to T1-4 and another from T11-12 to L1-5, and likely extending to sacrum- S1-2. Unlike a potential case of head-hunting in the Wu-Chen-Tsu Site (B3, age and sex are not determined), which belongs to a Niao-Sung Culture dated to 1400-1000 before present (Tsang et al. 2004, 2006; Tsang et al. 2007), neither an unusual burial position nor pathological condition was found in these individuals from SPC.*

In terms of anterior teeth, all examined SPC individuals had shoveling whilst 93.1% of them had double-shoveling (Lin 2009). In addition, with regards to the first premolar, a quarter of the SPC individuals had two roots (Lin 2009). Three of the SPC individuals presented Carabelli's trait. Finally, 84% of the SPC people had an enamel extension or enamel pearl on one or more maxillary and mandibular molars (Lin 2009).

MATERIALS AND METHODS

The Wu-Shan-Tou (WST) Site

The WST site is within the area occupied by the Ta-Hu culture in southern Taiwan during the Late Neolithic Period. At that time, Taiwan was occupied by cultural groups in different

regions, including the Botanical Garden culture in the north, the Ying-Pu culture in west-central, the Ta-Hu culture in the south, and Pei-Nan and Chi-Lin cultures in the east. Of these, the Ta-Hu culture in the south (e.g., Chen 1980) is characterized by very fine quality grayish-black pottery which is typically thin, highly polished, and decorated with wavy patterns.

Two different types of burials have been identified in the WST site of the Ta-Hu culture (Tsang et al. 2006). The first type of burial has complete pots being interred with the deceased as grave goods, whereas the second type has children or infants being interred within larger pottery vessels (Tsang et al. 2006). These burial practices can be clearly observed within the San-Pau-Chu site from the Southern Taiwan Science Park (STSP) in southwest Taiwan (Tsang et al. 2006).

The Wu-Shan-Tou site is a Neolithic site on the plains between the Wu-Shan-Tou Reservoir and the Wu-Shan-Tou community, located at Jia-Nan Village in Tainan city, Taiwan. It was discovered during the reconstruction of the Chia-Nan Irrigation System in 1920. Since then, human bones and a great amount of potsherds have been found due to irrigation construction. Previous reports about the site have been published by Yukichi Sayama (1923), Isamu Kono (1929), and Naoichi Kokubu (1959); however, further investigation did not begin until an Environmental Impact Assessment for the construction of the second national highway was requested by the National Expressway Engineering Bureau in 1996.

The WST site can be dated back to approximately 2700 years ago. Artifacts from this culture include pottery, and stone tools; ecofacts include fauna, bone and antler tools, human remains, and plant seeds. Amongst these, the most interesting phenomena are Features 1 (F1) and 14 (F14). Cranial fragments (F1) were observed around the fireplace (F2); human bones were also piled within black pottery in F14 (Lee 1999).

A total of 35 human skeletons were discovered during the salvage archaeology (Figure 1) as a result of the highway construction in 1999 (Lee 1999). Following the excavation these human remains were stored in the National Museum of Prehistory and were not reconstructed until 2009. No preserved coffins were observed for the WST burials, but infants buried inside ceramic jars (one person per jar) were observed in some cases. Other than human burials, four dog burials were discovered in this site (Lee 1999).

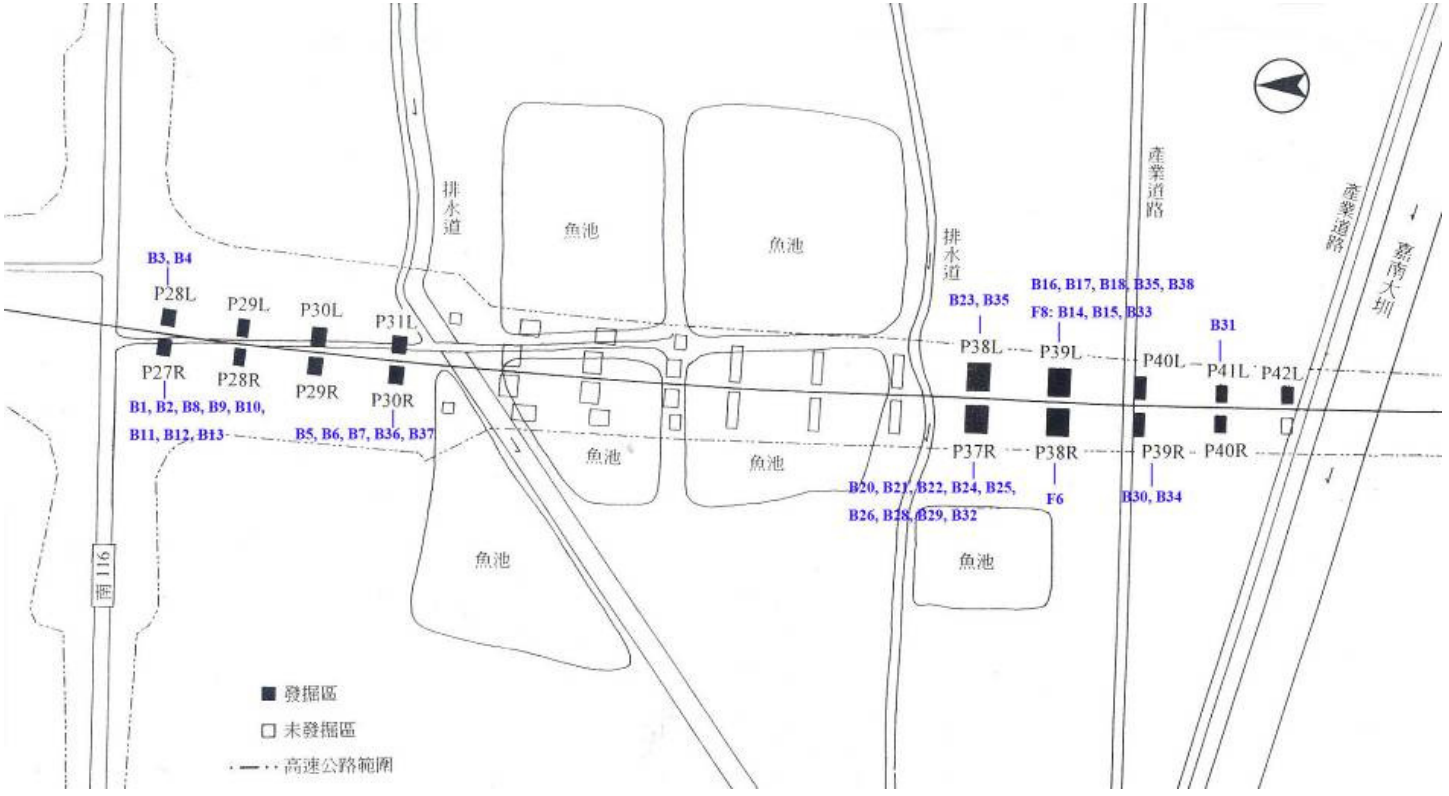

Figure 1 Excavated pits and discovered burials (modified from Lee 1999).

Methods

Sexing, aging, paleopathology, and observation of non-metric traits as well as measurements of metric traits, including dentition, were applied according to *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994). Determination of age and sex is mostly based on skulls (Acsádi and Nemeskéri 1970; Ubelaker 1989) and pelvises (Brook and Suchey 1990; Buikstra and Mielke 1985; Suchey and Katz 1986; Todd 1920, 1921; Phenice 1969). In addition, long bone lengths for children (Ubelaker 1989), as well as diameters for humeral and femoral heads, can be supplementary tools for aging. However, bone preservation and completeness was not perfect for each site (see Pietrusewsky and Douglas 2002), which increases the difficulty of identification.

Because of distortion on cranial morphology, measurements for each cranial trait were not always possible, so dental morphological studies were applied. In this regard, 15 non-metric traits were observed according to Arizona State University (ASU) dental anthropology system (Turner et al. 1991) (Dental Visual Recoding Forms from Buikstra and Ubelaker 1994). For dental measurement, it included crown width (buccolingual diameters), crown length (or mesiodistal diameter), and crown height. However, only comparisons between crown width were applied due to dental attrition (e.g., Buikstra and Ubelaker 1994; Hillson 1996; Mayhall 2000) and dental pathology (e.g., Buikstra and Ubelaker 1994; Hillson 1996), such as caries.

Depending on preservation, either the left or right side of the maxillary and mandibular teeth was used. Measurements for all of the samples were made twice at different times in order to test intra-observer errors.

RESULTS

Diagnosis of WST Burials

Ten reconstructed WST human skeletons were studied including Burial 2 (B2), B5, B7, B12, B14, B19, B24, B25, B26, and B28. The following are preliminary reports of each individual (Table 1):

Table 1 age, sex, dental morphology, and pathology among 10 reconstructed WST skeletons.

	age	Sex	dental morphology	pathology
B2	18-19 years old	possible male	potential tooth use as tool	—
B5	30 years old	male	congenital tooth loss for I_2, impacted M_3, and periodontal disease	potential osteophytes
B7	30-34 years old	male	—	osteophytes, compressed thoracic vertebral bodies (a sign for TB), potential infection on rib heads, abnormal bony growth on the right femoral neck
B12	early 20s	likely female	tooth crowding and enamel hypoplasia	potential fracture on the distal end of the right radius, abnormal bony growth on femoral necks
B14	7.5-8.5 years old	N/A	—	—
B19	40-44 years old	male	potential tooth use as tool	Osteophytes, healed fractures on left ribs 8-9
B24	around 45 years old	likely female	one extra cusp on the buccal side of the left M2	dislocation on both shoulder (much severe on left shoulder), severe inflammation on cervical vertebral bodies and drainage canals for femoral necks (potential osteomyelitis), osteoporoses for patellae, osteophytes, potential healed marks on the right 1st rib, potential eburnation on the right 10th rib, (potential degenerative joint disease)
B25	38-39 years old	likely male	periodontal disease	osteophytes
B26	9 years old	N/A	—	potential healing cut mark on endo-cranium
B28	2.5 years old	N/A	—	—

B2 was a possible male aged around 18-19 years old. Bones of skull and long bones are present; however, preservation of the remainder of the skeleton is relatively poor (less than 25% of the bones were available for observation). In addition, severe enamel hypoplasia or a potential use of teeth as a tool was identified (relative deep grooves can be observed on the incisors and canines along with a particular wear pattern on the right mandibular premolars) (Figure 2). No pathological conditions were observed.

B5 was a male aged 30 year years old. Bone preservation is good except a partial cranium, squama of scapulae, and small sections of the vertebral column and ribs which are in comparatively poor condition. Various pathological conditions were observed for B5, including an impacted mandibular third molar (Figure 3), congenital tooth loss for mandibular lateral incisors (Figure 3), and periodontal disease around the right maxillary central incisors. Potential osteophytes were also observed. A personal character trait, spina bifida (un-fusion between S3 and S5) (Figure 4), also was observed for this individual.

B7 was another male aged around 30-34 years old. Bone preservation is similar to B5. Pathological conditions including, periodontal disease, osteophytes on ulnae, right patella, thoracic and lumbar vertebrae, compressed thoracic vertebral bodies (Figures 5-1, 5-2) and potential infection into adjacent rib heads, and abnormal bony growth (most likely drainage canals) on the right femoral neck, were identified.

B12 was most likely a female in her early 20s. Bone preservation is good except damage to the bodies of the scapulae, sternum, and parts of the cervical and thoracic vertebrae. Pathological conditions included tooth crowding (especially for left third molar and right second premolar), enamel hypoplasia (left central incisor), potential fracture on the distal end of the right radius, and abnormal bony growth (including potential canal drainages) on femoral necks. Finally, a trait useful for personal identification was identified: partial spina bifida (ossification failure up to S4: code number according to Standard = 7.4.1) (Buikstra and Ubelaker 1994).

B14 was a child aged around 7.5-8.5 years old. Bone preservation is relatively good except for damage to the extremities of the long bones, vertebral column, and ribs. Partial

preservation was observed for the cranium. No pathological condition was available for observation.

Figure 2 B2, Unusual marks on buccal sides of mandibular teeth from left 1st premolar to right 1st premolar (the curvature is too deep to be as enamel hypoplasia)

Figure 3 B5, Congenital loss of left mandibular lateral incisor as well as impacted 3rd molars

Figure 4 B5, Spina bifida (unfusion between S3 and S5)

Figure 5-1 B7, Compressed vertebral column (T7) as symbol of Tuberculosis

Figure 5-2 B7, Compressed vertebral column (T11) as symbol of Tuberculosis

B19 was a male aged around 40-44 years old. Bone preservation is good except for damage to the sphenoid, palatine, and the body of the scapulae, and the presence of partial cervical and thoracic vertebrae as well as partial ribs. Osteophytes were observed upon various locations of the vertebrae and ribs (Figure 6). Relatively severe lipping (sharp ridge, sometimes curled with spicules) was identified on the upper rings of C6-7, T2, T8-10, and L2. Healed fractures were observed on the left ribs 8-9 (the former is still with evidence of inflammation on the fracture site) (Figures 7-1, 7-2). Finally, severe dental wear on left mandibular, central incisor and canine was observed as well as a special wear pattern upon the maxillary anterior teeth, which may indicate tool use of the teeth (Figure 8).

Figure 6 B19, Osteophytes (slightly spicules)

Figure 7-1 B19, Healed fracture rib (left rib 8, ventral view)

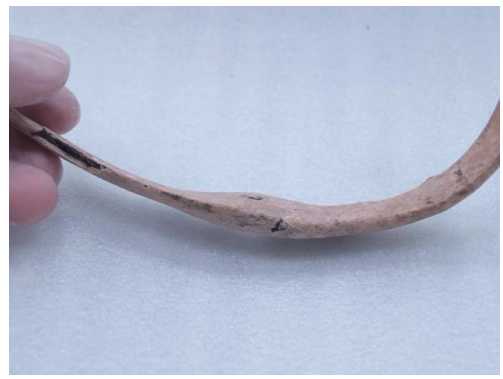

Figure 7-2 B19, Healed fracture rib (left rib 8, superior view)

Figure 8 B19, Unique wear patterns (tool use?)

B24 was most likely a female at age around 45 years old. Bone preservation is excellent except for damage to the right sphenoid, sternum, neural arches of the cervical and thoracic vertebrae, and the foot bones. Both personal identifiers and pathological conditions were observed, including formina for basi-vertebral veins on the fifth cervical vertebra and the first thoracic vertebra, spina bifida for sacrum (unfused between S4-S5), and one extra cusp on the buccal side of the left maxillary second molar, which is a rarely reported dental non-metric trait. Major pathologies include three parts: shoulder girdles, chest, and lower limbs. For

shoulder girdles, severe surface osteophytes and periarticular resorption were observed on the surface above the conoid tubercle of the left clavicle and the left humeral head (Figures 9). Potential inflammation marks were also observed on the inferior surface of glenoid fossa of right scapula, right humeral neck, and left clavicle. For the chest, the following were observed: severe inflammation on bodies of the third-sixth cervical vertebrae (Figure 10), osteophytes between the 7th thoracic vertebra and the fifth lumbar vertebra, a potential healed cut mark on the superior surface of the right first rib, eburnation on the right tenth rib, and lipping on the proximal tip of the left tenth rib. For the lower limbs, drainage canals for femoral necks and osteoporoses for patellae were observed. In addition to the afore-mentioned pathology, a curved wear pattern on the mandibular incisors was observed.

Figure 9-1 B24, Severe, long-term dislocation (both shoulder)

Figure 9-2 B24, Severe, long-term dislocation (both scapulae)

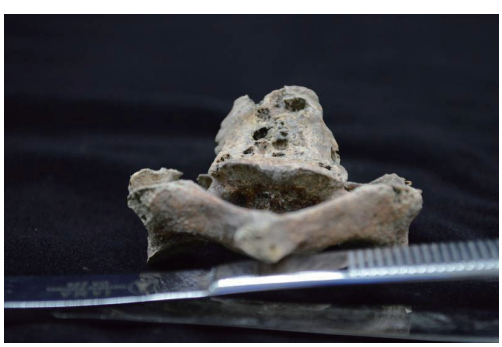

Figure 10-1 B24, Canal drainages appear on vertebral body

Figure 10-2 B24, Canal drainages appear on femoral neck.

B25 was most likely a male aged around 38-39 years old. Except severe bone loss on sphenoid, right zygomatic bone, and patellae, bone preservation in B25 is excellent. Periodontal disease was observed on left maxillary canine, right maxillary central incisor and mandibular first molar. Osteophytes were observed on various parts of the body, including vertebrae, humeri, and ulnae. As a personal identifier, septal aperture was observed on the right humerus.

B26 was a 9 year-old child. Except for the bodies of the scapulae, fibulae, patellae, and pedal phalanges, bone preservation is excellent. Incomplete metopic suture was still observable. Additionally, potential cranium healing marks were observed on endocranium of the parietal and occipital bones.

B28 was a child at least 2.5 years old. Inconsistency between dental development and bony growth was observed. [2] Bone preservation is relatively poor in this individual, which may also result from immature state (various developmental stages of second ossification centers) of bone in this individual.

Dental Morphology

Dental non-metric traits among these ten WST skeletal series are as shown on the Table 2. For winging on the maxillary central incisors, two cases are not straight: one is B5 with a bilateral rotation, and the other is B26 with a unilateral rotation on the left incisor.

Table 2 numbers and percentages of individuals among ten reconstructed WST samples for 15 different non-metric dental traits.

Non-metric Trait	**N**	**n**	**%**	**Non-metric Trait**	**N**	**n**	**%**
winging	9	2	22.2	peg-shaped	9	2	22.2
Shoveling UI1	7	7	100	Double Shoveling	8	6	75
2-rooted UP1	9	0	0	Carabelli's cusp	9	1	11.1
Hypocone	10	1	10	Metacoule	7	1	14.3
Cusp 5 UM1	7	1	14.3	3-cusped UM2	6	2	33.3
4-cusped LM1	8	5	62.5	4-cusped LM2	7	4	57.1
Cusp 6 LM1	7	0	0	Cusp 7 LM1	7	0	0
Enamel Extension	9	9	100				

(N = number of individuals among 10 reconstructed WST samples; n = total individuals with the observed trait among reconstructed WST samples; % = percentage of observed individuals among ten reconstructed WST samples)

Traits on incisors such as shoveling and double shoveling are common (both with a frequency of occurrence of 75%). Carabelli's cusp - a trait that is present in the highest frequencies in European populations (75-85% of individuals), followed by African, Asian, Native American, and rarest in Pacific Island populations (35-45%) (Kolakowski et al. 1980; Scott 1980) - also is present, identified on one out of nine individuals (with a frequency of occurrence of 11.1%).

Cusp 5 on the maxillary first molar has an occurrence-rate of 14.3%. Three-cusped maxillary second molar has a 33.3% incidence of occurrence, which is only slightly higher than the 10% amongst Southeast Asians and East Asians (Scott and Turner 1997). Other traits identified upon molars are a high occurrence of hypocones (six out of seven individuals or 85.7%) and low presence rate of metacoules (one out of seven individuals or 14.3%). However, the incidence rate for two-rooted maxillary first premolar is 0.

In terms of mandibular dental non-metric traits, four-cusp first and second molars both have incidences of occurrence of 42.9%. Neither cusp six nor cusp seven is present on the first molar. Additionally, all of the ten reconstructed skeletons have more than one tooth (amongst all their teeth) with enamel extension.

Pathological Comparisons

There are a few comparable pathological conditions between the SSH and the WST people. For instance, incidences of caries and abscesses are both low in SSH, which is also true in WST (two out of the ten individuals with periodontal disease: B5 and B25). Additionally, the incidences of trauma particularly fractures are comparable between the two peoples. Incidences of trauma are unusual in both the SSH and WST populations. In this regard, only two out of ten individuals studied from the WST site were observed with fractures (B12 for potential fracture on radius and B19 for healed rib fractures). Use of tooth as a tool - largely identified via the identification of special dental wear patterns - can be seen in both the SSH and WST peoples.

Vertebral osteophytes identified on the skeletal remains of the WST people are consistent with those in SPC, WCTS, and NKLE peoples. Finally, trauma, specifically trauma related to inter-individual violence (even wars), which has been identified in at least two cases from the SPC site (G16 II B1 & K17 II B1) and one case from the NKLE site (F5 B11), is not common in the WST site.

DISCUSSION

Based upon the ten reconstructed WST skeletons in this study, three children under the age of ten, two young adults at around age 20, three adults in their 30s, and two mid-age adults, were observed. The three children included in the study were too young to identify their sex. The remaining seven individuals include three males, two probable males, and two probable females.

Three geographical clusters were shown amongst these individuals (as shown in Figure 1).

Cluster 1: B2 and B12 were buried in P27R. They represent a male and a female potentially in their early 20s. No apparent pathological conditions were identified.

Cluster 2: B5 and B7 were buried in P30R. They represent males in their 30s. Apparent dental pathology was shown in B5, and potential TB[3] was shown on B7.

Cluster 3: B24, B25, B26, and B28 were buried in P37R. They represent a female, a male, and two children, aged in their 40s, a nine years old and a 2.5 years old, respectively. Dislocation, osteomyelitis, and degenerative joint disease were shown on B24. Periodontal disease was shown on B25. No observable pathology was shown on B26 and B28.

None of these clusters were close to each other, so it is unlikely that any relationship will be identified with the current archaeological data. However, it is possible that B24 B25, B26, and B28 form a nuclear family (with two parents and two children).

In terms of pathological conditions in general, osteophytes were not present for individuals younger than 30 years old at this site. Although still in its initial developmental stage, there are slight traces of osteophytes on ulnae of B12. Additionally, one case of degenerative joint disease was observed as indicated by the osteoporoses of B24's patellae.

Surprisingly, osteomyelitis and tuberculosis (TB) may have been present among two of these individuals. In this regard, severe dislocation was observed on left shoulder of B24. As it is known, osteomyelitis is the result of the introduction of pyogenic bacteria such as *Staphylococcus aureus* and *Streptococcus* into bone (Ortner and Putschar 1981). Direct infection from traumatic or surgical wounds, direct extension from adjacent soft tissue infections, [4] and hematogenous route from a remote septic focus are the three predominant infection routes for osteomyelitis (Ortner and Putschar 1981). Since severe dislocation was observed on her left shoulder, this is most likely the origin of infection for the pathological conditions seen in her vertebral column, femoral heads and necks.

In terms of the presence of TB, it is likely to be present on B7. Overall, the most noteworthy pathology regarding this person is the collapses of thoracic vertebral bodies.

Because of the combination of collapsed thoracic vertebral bodies, the lack of any indication of involvement or destruction of vertebral arches, inter-vertebral joint, and spinous process (Grange 1999; Oehlecker 1924; Ortner and Putschar 1981; Sorrel and Mme 1932), it is clear that TB is the most likely cause. However, neither ancient DNA analysis nor X-ray photography have been done in this study. If they had, they would have helped verify alternatives.

Trauma was not common in the WST site, although one case has a potential fracture on the right radius (B12), and a second case has healed fracture marks on ribs (B19). However, cases of disturbances in dental development and dental modification were more commonly observed. For example, on B5 an impacted mandibular third molar and congenital tooth-loss for mandibular lateral incisors, and on B12 tooth crowding (especially for left third molar and right second premolar). Furthermore, tooth ablation was observed on B24, and "pressure--chipping" teeth were observed on B2, B19, and B24. This type of "pressure-chipping" [5] is likely to be the result of external sources such as fiber-making processes. [6] Additionally, two cases of periodontal disease were observed (B2 and B25).

In addition to pathological conditions, several individuals from this site are with one or more personal identifiers such as spina bifida, foramina for basi-vertebral veins, septal aperture, and incomplete metopic suture. Among these personal characters, spina bifida had the highest incidence rate (approximately 42.86%). In this count, individuals under age 10 were not included because the fusion of S3-S5 will not begin until approximately 17 years of age.

Although tooth ablation was common among Taiwanese aborigines according to ethnographic records (e.g. Liu et al. 2003; Suzuki 1991), it was uncommon for the WST people (only seen on B12 and B24). Abnormalities on dental morphology include potential tooth use on B19 and B24, periodontal disease on B25, and tooth crowding on B12 (especially for left third molar and right second premolar). Traits predominant in Sinodont populations such as shoveling were common in WST people (75%). However, the European trait Carabelli's cusp also was present in the WST people (11.1%). In this regard, it is suggested that genes are a major controlling factor in tooth development and dental morphology (e.g.,

Biggerstaff 1979; Garn 1977; Kraus 1957; Kraus and Furr 1953; Krogman 1960; Moorrees 1962; Osborne 1963, 1967; Tobias 1955; Townsend et al. 1994; Witkop 1960), while environmental factors influence trait expression to some extent (Scott and Turner 1997). The latter is especially true for traits expressed within the same field, such as shoveling of the maxillary lateral incisors (Scott and Turner 1997).

CONCLUSION

Based on the current results of pathological and dental wear patterns of the WST people, it is easy to conclude that individuals in this site were likely to get osteophytes at early ages. However, it is very clear that this is a society with a system of social support for those with disabilities, such as B7 (a person with Tuberculosis) and B24 (a person with severe dislocation and may have developed towards osteomyelitis).

Because the limited number of measured teeth for each individual (each trait has measured between three and seven individuals, but most of the traits are with five individuals), there is not enough data to yield statistical power. No further analyses on metric or non-metric traits have been applied in this study. However, future analyses upon this population (WST people) or population comparisons with Austronesian-speaking populations and other Asian populations will be conducted when the number of skeletal remains studied has surpassed 15 (or more preferably 25).

None of the human burials in Taiwanese archaeological sites have been fully studied, including the aforementioned SSH site. The SSH site is another site that has been scientifically studied. The number of studied individuals only accounts for a very small number of the individuals excavated from the SSH site. The studies conducted upon SSH can be divided into three different analytical stages: first, morphological comparison (by Ms Ching-fang Chang), second, facial reconstruction (by Dr. Michal Pietrusezsky and colleagues), and the third, morphology (enamel hypoplysia) and isotopic analyses (by Dr. Kathy Liu).

There will be great improvement in terms of Taiwanese biological anthropology, bioarchaeology, and archaeology, if the human skeletons from the WST site are completely

studied using scientific methods as shown in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994) and subsequently the data are used to indicate specific phenomena. Additionally, results from the study of the WST people will shed light on health conditions in prehistoric Taiwan.

AVENUES FOR FUTURE RESEARCH

It is our goal to fully understand this group of prehistoric people who lived during the Neolithic in southwest Taiwan. In this regard, isotopic and residue analyses as well as ancient DNA studies should help us to understand the biological and ecological aspects of the WST people. Results from the preliminary isotopic analyses conducted between October 2012 and May 2013 suggest that further study will not be worthwhile because of the fragmentary nature of the WST bones. Starting October 2012, a preliminary study of the 10 reconstructed WST people using residue analysis of calculus (conducted by Dr Carol Joy Lentfer) is still being undertaken.

Although there is much literature studying TB and osteomyelitis - such as Buikstra and Ubelaker (1994) and Ortner and Putschar (1981) - it is still a surprise to observe them within bone remains of the WST people. However, single line evidence may not be sufficient to negate errors that could result from intra-observer error of these diseases. The next stage of this research will see testing of the ancient DNA of these diseases (at least TB) and, if possible, will see research being conducted into the biological relationships of the WST people, modern Taiwan aborigines, and other Austronesian-speaking populations.

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NOTES

1. Ten Wu-Shan-Tou (WST) individual discussed in this paper were cleaned and "reconstructed" (as 3D puzzle) from September 2009 to December 2011. They were either washed with water but still fragmentary or in their original buried position with gypsum or silicon.

2. 6 yrs + 24 months for dental development because of the presence of all permanent 1st molar; long bone length indicate a range of 1.5-2.5 yr; development of vertebrae: approximately 4 yrs (not for L4-L5) for na-na of vertebrae but < 3 yrs (none was fused) for na-centrum of vertebrae; presence of partial metopic suture indicates a younger age than 6 years old.

3. Tuberculosis (TB) is one of the members of the Mycobacterium tuberculosis complex, which is comprised of M. tuberculosis, Mycobacterium bovis, Mycobacterium africanum, and Mycobacterium microti. The earliest evidence of unambiguous detection of M. tuberculosis is from the metacarpal of an extinct long-horned bison dated at 17,870 ± 230 years (Rothschild et al. 2001). Additionally, tubercular decay of skeletal prehistoric humans has been found in Egyptian mummies dating from 3000-2400 BC (Crubézy et al. 1998)

4. The involved bone shows an irregular surface with pitting and cavities that correspond with abscess formation in the living tissues.

5. "The wear is characterized by severe crushing and/or flaking of the crown surface of one or more teeth" (Turner and Cadien 1969).

6. Grains of stone mixed with foods during grinding may also cause this type of "pressure chipping" tooth.

REFERENCES

Acsádi, György, and János Nemeskéri

1970 History of Human Life Span and Mortality. Budapest: Akadémiai Kiadó.

Biggerstaff, Robert H.

1979 The Biology of Dental Genetics. Yearbook of Physical Anthropology 22: 215-227.

Brooks, Sheilagh T., and Judy M. Suchey

1990 Skeletal Age Determination Based on the Os Pubis: A Comparison of the Acsadi–Nemeskeri and Suchey–Brooks Methods. Human Evolution 5: 227-238. DOI: 10.1007/BF02437238.

Buikstra, Jane E., and James H. Mielke

1985 Demography, Diet, and Health. *In* The Analysis of Prehistoric Diets. Robert I. Gilbert, Jr. and James H. Mielke, eds. Pp. 359-422. Orlando: Academic Press.

Buikstra, Jand E., and Douglas H. Ubelaker, eds.

1994 Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History. Arkansas Archaeological Survey Research Series, 44. Fayetteville, Arkansas: Arkansas Archeological Survey.

Buntaro, Adachi (足立文太郎)

1907a Tai wan ban jin tou gai (〈臺灣蕃人頭蓋 〉)[Skulls of Taiwan Aborigines]. Tokyo Anthropology 22(252): 219-233(東京人類学雜誌 22(252)：219-233).

1907b Tai wan ban jin tou gai(〈臺灣蕃人頭蓋〉)[Skulls of Taiwan Aborigines]. Tokyo Anthropology 22(254): 311-334(東京人類学雜誌 22(254)：311-334).

1907c Tai wan ban jin tou gai(〈臺灣蕃人頭蓋〉)[Skulls of Taiwan Aborigines]. Tokyo Anthropology 22(255): 361-374(東京人類学雜誌 22(255)：361-374).

Chang, Ching-fang (張菁芳)

1993 Shih-San-Hang yi zhi chu tu ren gu zhi xing tai xue yu bing li xue fen xi gi qi bi jiao yan jiu(《十三行遺址出土人骨之形態學與病理學分析及其比較研究》)[Metric

and Non-metric Analyses of Human Skeleton from the Shih-San-Hang Site]. M.A. thesis, Department of Anthropology, National Taiwan University(國立臺灣大學人類學系碩士論文).

Chen, Yu-may (陳玉美)

1980 Kaohsiung xuan do hu shi qian yi zhi(《高雄縣大湖史前遺址》)[The Ta-Hu Prehistoric Site in the Kaohsiung County]. M.A. thesis, Department of Anthropology, National Taiwan University(國立臺灣大學人類學系碩士論文).

Chen, Zhong-yu (陳仲玉)

1994 Qu bing(《曲冰》)[The Qu-Bing Site]. Institute of History and Philology Academia Sinica Field Work Report, 2(中央研究院歷史語言研究所田野工作報告 2). Taipei: Institute of History and Philology, Academia Sinica(台北：中央研究院歷史語言研究所).

Chu, Zheng-yi (朱正宜)

1990 Taitung xuan ma wu ku xi kou xin shi qi shi dai yi zhi zhi diao cha yan jiu(《台東縣馬武窟溪口新石器時代遺址之調查研究》)[Research of New Neolithic Sites along the Ma-Wu-Ku River, Taitung]. M.A. thesis, Department of Anthropology, National Taiwan University (國立臺灣大學人類學系碩士論文).

Crubézy, Eric, Bertrand Ludes, Jean-Dominique Poveda, John Clayton, Brigitte Crouau-Roy, and Daniel Montagnon

1998 Identification of Mycobacterium DNA in an Egyptian Pott's Disease of 5400 Years Old. Comptes rendus de l'Acadᵉmie des Sciences-Série III-Sciences de la vie 321(11): 941-951. DOI : 10.1016/S0764-4469(99)80009-2.

Garn, Stanley Marison

1977 Genetics of Dental Development. *In* The Biology of Occlusal Development. James A. McNamara, ed. Pp. 61-88. Michigan: Ann Arbor.

Grange, John M.

1999 The Global Burden of Tuberculosis. *In* Tuberculosis: An Interdisciplinary Perspective. John D. H. Porter and John M. Grange, eds. Pp. 3-31. London: Imperial College Press.

Hillson, Simon

1996 Dental Anthropology. Cambridge: Cambridge University Press.

Jurmain, Robert D.

1999 Stories from the Skeleton: Behavioral Reconstruction in Human Osteology. Interpreting the remains of the Past, volume 1. Greensboro: Gordon and Breach Publishers.

Kanaseki, Takeo

1952 Anthropological studies of Far Eastern people: Taiwan Aborigines as Center. Fukouka Medical 43(2): 1-13.

1978 Review of Physical Anthropology in Taiwan. Tokyo: Hosei University Press.

Kokubu, Naoichi (國分直一)

1959 Tai wan sen shi zi dai seki tou－ishi bou tyou、ishi kama o yo bi yuu hei seki tou ni tsu i te (〈台灣先史時代石刀－石庖丁、石鎌および有柄石刀について〉)[Stone knives in Taiwan prehistory]. Ethnographic Study 23(4): 261-298(《民族學研究》23 (4)：261-298).

Kolakowski, Donald E., Edward F. Harris, and Howard L. Bailit

1980 Complex Segregation Analysis of Carabelli's Trait in a Melanesian Population. American Journal of Physical Anthropology 53: 301-308.

DOI: 10.1002/ajpa.1330530215.

Kono, Isamu (甲野勇)

1929 Tai wan u san tou hakken no do sei dou butsu gan men (〈台灣烏山頭発見の土製動物顔面〉)[Earthen animal head in the Wu-Shan-Tou site, Taiwan]. Prehistory 1 (4): 63(《史前學雜誌》1(4)：63).

Kraus, Bertram Shirley

1957 The Genetics of the Human Dentition. Journal of Forensic Science 2: 419-427.

Kraus, Bertram Shirley, and Montie L. Furr

1953 Lower First Premolars. Part I. A Definition and Classification of Discrete Morphologic Traits. Journal of Dental Research 32: 554-564.

DOI: 10.1177/00220345530320041701.

Krogman, Wilton Marion

1960 Oral Structures Genetically and Anthropologically Considered. Annals of the New York Academy of Sciences 85: 17-41. DOI: 10.1111/j.1749-6632.1960.tb49946.x.

Larsen, Clark Spencer

2006 The Changing Face of Bioarchaeology: An Interdisciplinary Science. *In* Bioarchaeology: The Contextual Analysis of Human Remains. Jane E. Buikstra and Lane A. Beck, eds. Pp. 359-374. Oxford: Elsevier Inc.

Lee, Kun-xiu (李坤修)

1999 Er gao lu quan fan wei Wu-Shan-Tou yi zhi qiang jiu fa jue bao gao(《二高路權範圍烏山頭遺址搶救發掘報告》)[*Salvage Archaeology in the Wu-Shan-Tou Site*]. Taitung: National Museum of Prehistory Planning Bureau (台東：國立台灣史前文化博物館籌備處).

Lin, Hsiu-man

2009 The Biological Evidence of the San-Pau-Chu People and Their Affinities. Ph.D. dissertation, Department of Anthropology, University of New Mexico.

Liu, Chin-hsin

2005 Childhood Stress of an Iron Age Population from Taiwan: Using Linear Enamel Hypoplasia and Porotic Hyperostosis as Stress Indicator. M.A. thesis, Department of Anthropology, University of Florida.

Liu, Huan-yue, A-zhao Chen, and Jing-fang Chen (劉還月、陳阿昭、陳靜芳)

2003 Taiwan dao min de sheng ming li su(《臺灣島民的生命禮俗》)[Life Rituals of Taiwan Aborigines]. Taipei: Chang-Ming Culture Press (臺北：常民文化).

Liu, Yi-chang (劉益昌)

1999 Qi jia gwan yi zhi de nei han ji fan wei yan jiu (《七家灣遺址的內涵及範圍研究》)[Content and Studies of the Chi-Gia-Wan Site]. Taichung: Veterans Affairs Commission at Wuling Farm (臺中：行政院退輔員會武陵農場).

Mayhall, John T.

2000 Dental Morphology: Techniques and Strategies. *In* Biological Anthropology of the Human Skeleton. M. Anne Katzenberg and Shelley R. Saunders, eds. Pp. 103-134. Toronto: Wiley-Liss, Inc.

Micheli, Lyle J., and Justin D. Klein

1991 Sports Injuries in Children and Adolescents. British Journal of Sports Medicine 25(1): 6-9.

Moorrees, Coenraad F. A.

1962 Genetic Considerations in Dental Anthropology. *In* Genetics and Dental Health. Carl J. Witkop, ed. Pp. 101-112. New York: McGraw-Hill.

Oehlecker, Franz

1924 Tuberculosis der Knochen und Gelenke. Berlin: Urban und Schwarzenberg.

Ortner, Donald J., and Walter G. J. Putschar

1981 Identification of Pathological Conditions in Human Skeletal Remains. Washington and London: Smithsonian Institution Press.

Osborne, Richard H.

1963 Respective Roles of Twin, Sibling, Family, and Population Methods in Dentistry and Medicine. Journal of Dental Research 42(6): 1267-1287. DOI: 10.1177/00220345630420060401.

1967 Some Genetic Problems in Interpreting the Evolution of the Human Dentition. Journal of Dental Research 46(5): 945-948. DOI: 10.1177/00220345670460055501.

Phenice, Terrell W.

1969 A Newly Developed Visual Method of Sexing in the Os Pubis. American Journal of Physical Anthropology 30: 297-301. DOI: 10.1002/ajpa.1330300214.

Pietrusewsky, Michael, and Michele T. Douglas

2002 Ban Chiang, a Prehistoric Village Site in Northeast Thailand. I, the Human Skeleton Remains. Thai Archaeology Monograph Series, 1. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.

Rothschild, Bruce M., Larry D. Martin, Galit Lev, Helen Bercovier, Gila Kahila Bar-Gal, Charles Greenblatt, Helen Donoghue, Mark Spigelman, and David Brittain

2001 Mycobacterium Tuberculosis Complex DNA from an Extinct Bison Dated 17,000 Years Before the Present. Clinical Infectious Diseases 33: 305-311. DOI: 10.1086/321886.

Sayama, Yukishi (佐山融吉)

1923 Sayama Yukichi shi yo ri tsuu shin(〈佐山融吉氏よリ通信〉)[Communications of Yukichi Sayama]. Anthropology 38(3): 130-131(《人類学雑誌》38(3)：130-131).

Scott, George R.

1980 Population Variation of Carabelli's Trait. Human Biology 52l: 63-78.

Scott, George R., and Christy G. Turner II

1997 The Anthropology of Modern Human Teeth: Dental Morphology and its Variation in Recent Human Populations. Cambridge Studies in Biological and Evolutionary Anthropology, 20. Cambridge: Cambridge University Press.

Shi, Zhang-ru, and S. Wen-xun (石璋如、宋文薰)

1956 Tie zhen shan shi qian yi zhi shi jue bao gao (《鐵砧山史前遺址試掘報告》)[Excavation at the Te-Zhe-Shan Site]. Journal of Archaeology and Anthropology 8: 35-50 (《臺灣大學考古人類學刊》8：35-50).

Song, Wen-xun, and Zhao-mei Lien (宋文薰、連照美)

1985 Pei-Nan yi zhi fa jue zi liao zheng li di er juan: Mu zang fen xi(《卑南遺址發掘資

料整理第二卷：墓葬分析》)[Excavation Report of the Pei-Nan Site II: Burial Analyses]. Taipei: Ministry of Education (台北：教育部).

Sorrel, Étienne, Chirurgien de l'Hŏpital Trousseau, and Mme. Sorrel-Dejerine

1932 Tuberculose Osseuse et Osteo-Articulaire. Parris: Masson.

Suchey, Judy M., and Darryl Katz

1986 Skeletal Age Standards Derived from an Extensive Multiracial Sample of Modern Americans. American Journal of Physical Anthropology 69: 269.

Suzuki, Shitsu (鈴木質)

1991 Taiwan fan ren feng su zhi: Tan suo yuan zhu min de li shi(《臺灣番人風俗誌：探索原住民的歷史》)[Taiwan Aborigines-Social Life and Customs]. Taipei: Wu-Ling Press (臺北：武陵出版公司).

Tobias, Phillip Vallentine

1955 Teeth, Jaws and Genes. Journal of the Dental Association of South Africa 18: 88-104.

Todd, Thomas Wingate

1920 Age Changes in the Pubic Bone, I: The Male White Pubis. American Journal of Physical Anthropology 3 (3): 285-334. DOI: 10.1002/ajpa.133003030.

1921 Age Changes in the Pubic Bone: II. The Pubis of the Male Negro-White Hybrid. III. The Pubis of the White Female. IV. The Pubis of the Female Negro-White Hybrid. American Journal of Physical Anthropology 4 (1): 1-70. DOI: 10.1002/ajpa.1330040102.

Torii, Ryuzo

1898 Physique of the Peng-Pu Tribe in Taiwan. Tokyo Anthropology 14(153): 112-118.

Townsend, Grant C., Paula Dempsey, Tasman Brown, John Kaidonis, and Lilidsay Richards

1994 Teeth, Genes and the Environment. Perspectives in Human Biology 4: 35-46.

Tsang, Cheng-hwa, Kung-ti Li, and Zheng-yi Chu (臧振華、李匡悌、朱正宜）

2006 Xian min lu ji(《先民履跡》)[Footprint of the Prehistoric Men at the Southern Taiwan Science Park (STSP)]. Tainan: Tainan City Government (台南：台南市政府).

Tsang, Cheng-hwa, Kung-ti Li, Zheng-Yi Chu, Shu-fen Lin, Ren-chuan Wang, Rui-ying Lu, Jun-xiong Chen, Rui-ming Weng, Jun-yuan Wang, Yu-shan Chen, Wen-fen Lu, Ji-rong Chen, Min-qing Li, Jun-fa Li, Feng-ping Yang, Cui-ping Weng, and Qin-hui Tu (臧振華、李匡悌、朱正宜、林淑芬、王仁川、盧瑞櫻、陳俊雄、翁瑞明、王俊元、陳玉珊、盧文菜、陳紀融、李敏青、李俊發、楊鳳屏、翁萃苹、涂勤慧)

2004 Tainan ke xue gong ye yuan qu dao ye yi zhi wei hua ru bao cun qu bu fen qiang jiu kao gu gi hua qi mo bao gao(臺南科學工業園區道爺遺址未劃入保存區部份搶救考古計畫期末報告)[Salvage Archaeology of the Tao-Te Site in the Tainan Science-Based Park].Taipei: Institute of History and Philology, Academia Sinica(臺北：中央研究院).

Tsang, Cheng-hwa, Kung-ti Li, De-ren Li, and Zheng-yi Chu (臧振華、李匡悌、李德仁、朱正宜)

2007 Tainan ke xue gong ye yuan qu kao gu yi zhi qiang jiu jian ce hou xu gi hua qi mo bao gao(《臺南科學工業園區考古遺址搶救監測後續計畫期末報告》)[Final Report for Salvage Archaeology: Southern Tainan Science Park]. Taitung: National Museum of Prehistory (臺東：國立臺灣史前文化博物館).

Turner, Christy G. II, and James D. Cadien

1969 Dental Chipping in Aleuts, Eskimo and Indians. American Journal of Physical Anthropology 31: 303-310. DOI: 10.1002/ajpa.1330310305.

Turner, Christy G. II, Christian Robert Nichol, and George Scott

1991 Scoring Procedures for Key Morphological Traits of the Permanent Dentition: The Arizona State University Dental Anthropology System. *In* Advances in Dental Anthropology. Mark Kelley and Clark Spencer Larsen, eds. Pp. 13-31. New York: Wiley-Liss.

Ubelaker, Douglas H.

1989 The Estimation of Age at Death from Immature Human Bone. *In* Age Markers in the Human Skeleton. Mehmet Yasar Iscan, ed. Pp. 55-70. Springfield, Illinois: Charles C. Thomas Publisher.

Witkop, Carl J.

1960 Dental Genetics. Journal of the Dental Association of South Africa 60: 564-577.

Zheng, Jian-wen (鄭建文)

1998 Shui wa ku yi zhi ji qi xiang guan wen ti zhi yan jiu(《水娃窟遺址及其相關問題之研究》)[The Shui-Wa-Ku Site and Its Research Questions]. M.A. thesis, Department of Anthropology, National Taiwan University (國立臺灣大學人類學系碩士論文).