Brief Communication: Two-Rooted Lower Canines—A European Trait and Sensitive Indicator of Admixture Across Eurasia

Christine Lee[1]* and G. Richard Scott[2]

[1]*Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing China 100044*
[2]*Department of Anthropology, University of Nevada Reno, Reno, NV 89557*

KEY WORDS dental morphology; two-rooted lower canines; East Asia; migration

ABSTRACT With the exception of Carabelli's trait, the European dentition is better known for the morphological traits that it does not exhibit rather than the ones that it does. One root trait, however, runs counter to the characterization of reduced and simplified European crowns and roots. Although a rare trait in general, two-rooted lower canines are much more common in Europeans than in any other regional grouping and, given adequate sample sizes, can be useful in evaluating gene flow between Europeans and neighboring groups. In European samples, two-rooted lower canines consistently exhibit frequencies of 5–8%. In our sample from northern Spain, the trait attains a frequency of almost 10%. In contrast, in Sub-Saharan Africans the trait is virtually unknown while in Asian and Asian-derived populations, it varies between 0.0 and 1.0%. Here we show that two-rooted canine frequencies for new migrants along the western frontiers of China and Mongolia ranged from 0–4%. These data suggest European-derived populations migrated into western China (Xinjiang Province) and Mongolia (Bayan Olgii Aimag) sometime during the late Bronze age (1000–400 BCE). Am J Phys Anthropol 146:481–485, 2011. © 2011 Wiley-Liss, Inc.

The European dental morphological pattern is better characterized by trait absence rather than trait presence. Classic crown traits like upper central incisor winging, shovel-shaped incisors, upper molar cusp 5, lower molar cusps 6 and 7, the deflecting wrinkle and the protostylid are infrequent in number and modest in expression when present. Although Europeans exhibit a high incidence of Carabelli's trait, with pronounced cusp forms not uncommon, this feature is not as typically European as originally thought (Scott and Turner, 1997; Turner and Hawkey, 1998). Even traits that distinguish the European dentition, notably the hypocone of the upper molars and hypoconulid of the lower molars, are known for a high frequency of absence rather than a high frequency of presence (Mayhall et al., 1982).

Most root traits also fail to set Europeans apart as they rarely express the accessory distolingual root of the lower first molars (3RM1) that is a feature of North Asian and derived populations or Tomes' root of the lower first premolar that is most common in Australian and African populations (Irish, 1993; Scott and Turner, 1997). Europeans exhibit less root fusion than North Asians as two-rooted upper first premolars, two to three-rooted upper second molars, and two-rooted lower molars are all in frequencies around 60–70%, in the middle of the range for world wide variation.

Overall, the dental pattern of Europeans is characterized by morphological reduction and simplification. Accessory cusps and roots tend to be infrequent and major molar cusps tend to be reduced in size or lost altogether. There is, however, an interesting and notable exception to this generalization. Europeans exhibit the highest frequencies in the world of two-rooted lower canines.

Almost 50 years ago, Alexandersen (1963) noted two-rooted lower canines were more common in Europeans than in African or New World populations. However, his extensive data from mostly central Europeans could only be compared to a handful of samples from other geographic regions. At that time, the surface of world variation in crown and root trait frequencies had barely been scratched. The past 40 years has seen explosive growth in dental morphological studies, and we now have a much firmer grasp on the variation of two-rooted lower canines. In Table 1, the population variation of two-rooted lower canines is shown for major populations of the world. To emphasize the point that this is a European trait, of the 12,128 individuals included in the table, only 306 express two-rooted lower canines (2.5%) but of these 83% (254) were Europeans. If you include related Asiatic Indian, Middle Eastern, and North African populations, this number increases to 89% (272/306).

Rare traits can be useful indicators of population movement, gene flow, or some combination thereof (cf. Delgado-Burbano et al., 2010). The relatively high frequency of two-rooted lower canines in Europeans is in contrast to the rarity of this trait in North and South-

Grant sponsor: Wenner-Gren; Grant number: dissertation fieldwork grant #7263; Grant sponsor: Chinese Academy of Sciences, Fellowship for young international scientists; Grant number: #2010Y1ZA3.

*Correspondence to: Christine Lee, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PO Box 643, 142 Xizhimenwai Street, Beijing, China 100044.
E-mail: Christinelee70@gmail.com

Received 3 February 2011; accepted 14 June 2011

DOI 10.1002/ajpa.21585
Published online 24 August 2011 in Wiley Online Library (wileyonlinelibrary.com).

TABLE 1. World variation in two-rooted lower canines

Geographic region	Affected	*n*	Percent	References
Sub-Saharan Africa	1	311	0.3	Irish, 1993; Shaw, 1931
Austral-Melanesia	0	709	0	Scott and Turner, 1997
Southeast Asia and Pacific	11	1496	0.7	Scott and Turner, 1997
East Asia	6	1143	0.5	Scott and Turner, 1997
North and South America	16	3297	0.4	Scott and Turner, 1997
Europe	254	4426	5.7	Kuba, 2006; Adler, 2005; Alexandersen, 1963; Scott and Alexandersen, 1992
India, Middle East and North Africa	18	746	2.4	Hawkey, 2002; Irish, 1993

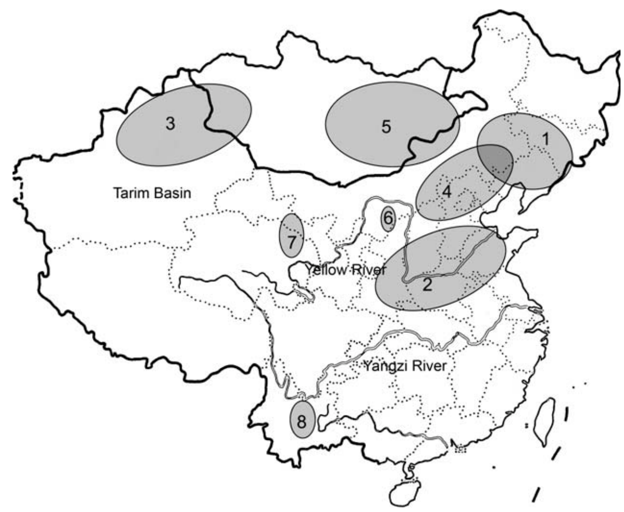

Fig. 1. Map of Asia showing regional divisions: (1) Northeastern China, (2) Central Plains China, (3) Western China and Mongolia, (4) Northern China, (5) Mongolia, (6) Ordos China, (7) Northwestern China, and (8) Southern China.

east Asians. Recently, skeletal and mummified remains from the Tarim Basin in Xinjiang Province, China suggest an early movement of a new population with European features into what is now northwestern China (Han, 1994; Mallory and Mair, 2000; Cui et al., 2010; Zhang, 2010). If skeletal remains from this region are European in origin, this should be expressed in elevated frequencies of two-rooted lower canines. It is our hypothesis that the genetic traces of early European colonizers in northern Asia can be identified and verified by two-rooted lower canine frequencies.

MATERIALS AND METHODS

To test the proposition that a particular dental trait can be used to support European colonization in Asia, the authors collected data on a Spanish sample from Vitoria, Spain ($n = 295$) and a series of Asian samples from 74 sites in China and Mongolia ($n = 970$). The sample from Spain is comprised primarily of Basques. The burials cover the temporal span from the 11th to 19th centuries. Data on Asian populations were collected from archaeological and anatomical samples housed at the National University of Mongolia (Ulaan Baatar), National Museum of Mongolian History (Ulaan Baatar), Mongolian Archaeology Institute (Ulaan Baatar), Center for Chinese Frontier Archaeology, Jilin University (Changchun), the Chinese Institute of Archaeology (Beijing), and the Institute of Vertebrate Paleontology and Paleoanthropology (Beijing). These samples, dating from the Neolithic Period (3800 BCE) to the Republican Period (1949 CE), were divided into eight regions based on geographical zone and archaeological culture (Chang, 1986; Debaine-Francfort, 1995; Higham, 1996; Honeychurch and Amarvtushin, 2006) (see Fig. 1). Northeastern China is represented by samples from the Lower Xiajiadian, Upper Xiajiadian, and Koguryo archaeological cultures (Shenyang Cultural Relic Bureau, 2008). The Central Plains China region is the heartland of Chinese culture. The archaeological samples include the Neolithic Yangshao and Dawenkou, and the Bronze age Zhou and Qin (Chinese Archaeological Institute et al., 2002; Inner Mongolia Archaeological Institute, 2006; Suo, 2005). The western China and Mongolia region includes the Bronze age kurgan burials from the Altai and Tianshan mountain ranges, the oasis states of the Tarim Basin, and the Uyghur Empire (Volkov and Dorjsuren, 1963; Novgorodova et al., 1982; Liu, 2002). Northern China includes samples from the Xianbei and Qidan nomadic tribes (Wei, 2004; Chen, 2009). Mongolia represents the Xiongnu and Mongol Empires based north of the Great Wall (Torbat, 2004; Miller et al., 2006; Lkhagvasuren, 2007). The Ordos region includes archaeological sites which were traditionally the buffer zone between the Chinese and Mongolian empires (Inner Mongolia Archaeological Institute, 1982, 1989; Yang, 2004). Northwestern China includes archaeological samples from along the Silk Road (Qinghai Archaeological Institute, 2007). Finally, the Southern China region includes archaeological samples along the southern frontier of the Chinese Empire (Jiang, 2011). More details on the Asian samples can be found in Lee (2007).

There are both positives and negatives to scoring root traits. On the positive side, they are relatively easy to score and, compared to crown traits, their presence is not impacted by dental wear. Moreover, the trait can often be scored when there are no teeth present, as two-rooted forms are clearly evident even in empty tooth sockets (Fig. 2A). On the negative side, the curation of skulls often involves gluing teeth into their sockets. In such instances, individuals cannot be scored and overall sample size is reduced.

We follow the principle of Turner et al. (1991) that to be scored as a two-rooted lower canine, the inter-radicular bifurcation between the buccal and lingual roots (radicals) should be at least 1/4th to 1/3rd of total root length (Fig. 2B). To derive total frequencies, the individual count method was used. That is, if either the left or right canine was two-rooted, the individual was scored as affected. Although there are several methods of tabulating crown and root traits, Scott (1980) demonstrated that scoring expression on all teeth (total tooth count), only left or only right teeth (side count), or the most pronounced expression on either antimere (individual count), yielded similar frequencies for Carabelli's trait.

RESULTS

For rare traits like two-rooted lower canines, it is often difficult to test for sex differences because of low expected values. For the Asian samples, only 13 of 970 individuals exhibited the trait so it would not be statistically feasible to test sex dimorphism in this sample. For the Spanish sample, however, there was an incidence of 10.0% for males (11/110), 7.7% for females (10/130), and 10.9% for individuals of unknown sex (6/55). With expected values at or above 10, the χ^2 for sex dimorphism was 0.412 ($0.70 > P > 0.50$). In terms of mesiodistal and buccolingual diameters, the lower canine is the most sexually dimorphic tooth in humans (Garn et al., 1967). This dimorphism does not appear to extend to root number although small sample size precludes a definitive conclusion.

It is not possible in every instance to examine the roots of both antimeres, but in cases where both left and right canines could be scored, asymmetry was more common than symmetry. Of the 27 Spanish individuals who exhibited two-rooted lower canines, 19 were scored on both sides. In 13 instances, only one side expressed the trait. Of the 13, 6 were on the right side and 7 were on the left so there is no directional asymmetry. Only 6 of 19 individuals (31.6%) exhibited the trait on both sides of the jaw. With this degree of asymmetry, the individual count method would maximize trait frequencies. Given the overall rarity of the trait, however, this would not impact the relative frequencies of two-rooted lower canines among world populations.

In Table 2, the frequency variation of two-rooted canines is shown for the Spanish sample and the North Asian samples. Medieval and post-medieval populations in northern Spain (primarily Basque) revealed a two-rooted lower canine frequency of 9.2%, at or near the upper end of the range of variation for this trait. The populations of Northeastern China, Mongolia, and Northwestern China all have a frequency of 0.0%. Central Plains China, Southern China, and Northern China have frequencies of 1.0, 1.1, and 1.9%, respectively. The European-derived populations of Western China and Mongolia exhibit a frequency of 2.8%. The highest regional frequency of two-rooted lower canines among the Asian samples is from Ordos China at 4.0%.

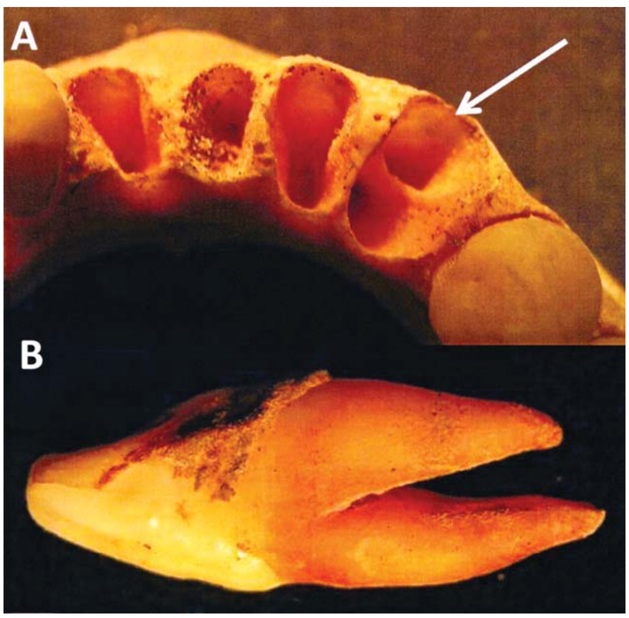

Fig. 2. Two-rooted lower canines. (A) Lower anterior teeth with postmortem loss of right canine, where two roots are easily visible in empty socket (arrow). (B) Two-rooted lower canine with inter-radicular projection extending about 2/3rd of total root length. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

DISCUSSION

One of the major concerns of Alexandersen (1963) regarding two-rooted lower canines revolved around the issue of “atavism.” This term, rarely used today, begs the question of whether or not this double rooted form was common at one time, then disappeared, only to reappear sometime later. Swindler (1995) notes that “the deciduous and permanent canines in the majority of living primates have a single root.” This suggests that two-rooted lower canines are not the ancestral condition in anthropoids or hominoids. Rather, the phenotype is a derived condition, found primarily in recent human populations distributed across Western Eurasia.

The presence of the two-rooted canines in East Asia may provide some clue as to the eastward migration of new populations into China and Mongolia. The largest numbers of individuals with this trait are concentrated along the western and northern frontiers of China and Mongolia. Archaeological excavations support the large scale movement of people into this area during the Bronze age (ca. 2200 BCE–400 BCE). Burial artifacts and settlement patterns suggest cultural and technological ties to the Afanasevo culture in Siberia, which in turn is linked archaeologically, linguistically, and genetically with the Indo-European Tocharian populations that appear to have migrated to the Tarim Basin ca. 4,000 years ago (Ma and Sun, 1992; Ma and Wang, 1992; Mallory and Mair, 2000; Romgard, 2008; Keyser et al., 2009; Li et al., 2010).

TABLE 2. Two-rooted lower canine variation in the study sample

Sample(s)	Culture	Affected	*n*	%
Spain	Basque	27	295	9.2
Northeastern China	Lower Xijaiadian, Upper Xiajiadian, Koguryo	0	63	0.0
Central Plains China	Yangshao, Dawenkou, Zhou, Qin, Modern Han Chinese	3	292	1.0
Western China and Mongolia	Afanasevo, Scythian, Uighur	5	181	2.8
Northern China	Xianbei, Qidan	2	108	1.9
Mongolia	Xiongnu, Mongol	0	104	0.0
Ordos Region China	Ordos, Daihai	2	50	4.0
Northwestern China	Qijia, Qiang	0	80	0.0
Southern China	Dian, non-Han Chinese	1	92	1.1
Asian Total		13	907	1.4

The appearance of a new population on the western frontier also supports the findings of previous research in cranial metrics, dental nonmetrics, and DNA. Using cranial metrics and archaeological dating, Han (1994) hypothesized the earliest large-scale migration into western China occurred during the early Bronze age (2000 BCE) from Central Asia or southern Siberia. Dental nonmetric data also support multiple migrations into western China (Xinjiang Province) from Central Asia during the Bronze age to Iron age (Lee, 2007; Zhang, 2010). mtDNA studies on archaeological and modern population samples from Xinjiang Province show heterogeneous Asian and European genetic signatures dating from the Bronze age to the present (Yao et al., 2004; Cui et al., 2010; Zhang et al., 2010; Li et al., 2010).

As the frequency of two-rooted canines is highest in European samples and low to nonexistent in Asians, we propose this trait was introduced into East Asia by Indo-European speaking groups or their affines crossing the western frontier of China and Mongolia. Further data are needed to clarify aspects of these population movements, including the identity of the migrants, along with the number, routes, and timing of the migrations.

Although two-rooted lower canines cannot offer the precision of DNA in evaluating the ancestry in individual skulls, this trait is a sensitive indicator of admixture wherever Europeans come in contact with Asian or African populations. As this distinctive trait can be scored with relative ease in large samples, it provides a useful supplemental tool in discerning gene flow between distantly related populations going back many millennia.

LITERATURE CITED

Adler AJ. 2005. Dental anthropology in Scotland: morphological comparisons of Whithorn, St. Andrews and the Carmelite Friaries. PhD Dissertation, Arizona State University, Tempe.

Alexandersen V. 1963. Double-rooted human lower canine teeth. In: Brothwell D, editor. Dental anthropology. New York: Pergamon Press. p235–244.

Chang KC. 1986. The archaeology of China, 4th ed. New Haven: Yale University Press.

Chen S. 2009. Lamadong cemetery, Sanyan culture, osteological research. PhD Dissertation, Jilin University, Changchun.

Chinese Institute of Archaeology, Inner Mongolia Archaeology Institute, Jilin University, Chifeng Archaeological Station. 2002. The middle reaches of Banzhijian River during the pre-Qin era. Beijing: Scientific Publishing.

Cui Y, Li C, Gao S, Xie C, Zhou H. 2010. Early Eurasian migration traces in the Tarim Basin revealed by mtDNA polymorphisms. Am J Phys Anthropol 142:558–564.

Debaine-Francfort C. 1995. Du neolithique a l'age du bronze en Chine du nord-ouest: La culture de Qijia et ses connexions. Paris: Editions Recherche sur les Civilizations.

Delgado-Burbano ME, Scott GR, Turner CG II. 2010. The Uto-Aztecan premolar among North and South Amerindians: geographic variation and genetics. Am J Phys Anthropol 143:570–578.

Garn SM, Lewis AB, Swindler DR, Kerewsky RS. 1967. Genetic control of sexual dimorphism in tooth size. J Dent Res 46:963–972.

Han K. 1994. The study of ancient human skeletons from Xinjiang, China. Sino-Platonic papers no. 51. Philadelphia: Department of Asian and Middle Eastern Studies, University of Philadelphia.

Hawkey D. 2002. The peopling of South Asia: evidence for affinities and microevolution of prehistoric populations of India and Sri Lanka. Spolia Zeylanica Bull Natl Mus Sri Lanka 39:1–315.

Higham C. 1996. The Bronze age of Southeast Asia. Cambridge: Cambridge University Press.

Honeychurch W, Amartuvshin C. 2006. States on horseback: The rise of Inner Asian confederations and empires. In: Stark MT, editor. Archaeology of Asia. Malden: Blackwell Publishing. p 255–278.

Inner Mongolia Archaeological Institute. 1982. Liangcheng county, Yinniugou cemetery archaeological report. Neimenggu Wenwu Kaogu 3:26–32.

Inner Mongolia Archaeology Institute. 1989. Liangcheng county, Guoxian Yaozi cemetery. Kaogu Xuebao 1:57–81.

Inner Mongolia Archaeological Institute. 2006. Inner Mongolia, Helingger county, Tuchengzi city archaeological report. Neimenggu Wenwu Kaogu 1:9–16.

Irish JD. 1993. Biological affinities of late Pleistocene through modern African aboriginal populations: the dental evidence. PhD Dissertation, Arizona State University, Tempe.

Jiang Z. 2011. The excavation to Jinlianshan cemetery in Chengjiang county. Yunnan Kaogu 1:71076.

Keyser C, Bouakaze C, Crubézy E, Nikolaev VG, Montagnon D, Reis T, Ludes B. 2009. Ancient DNA provides new insights into the history of south Siberian Kurgan people. Hum Genet 126:395–410.

Kuba C. 2006. Nonmetric traits and the detection of family groups in archaeological remains. PhD Dissertation, Arizona State University, Tempe.

Lkhagvasuren Kh. 2007. Mongoliin arkheologi. Ulaan Baatar: Chingis Khan University.

Lee C. 2007. The biological affinities of Neolithic through modern period populations from China and Mongolia: the cranial and dental nonmetric trait evidence. PhD Dissertation, Arizona State University, Tempe.

Li C, Li H, Cui Y, Xie C, Cai D, Li W, Mair VH, Xu Z, Zhang Q, Abuduresule I, Jin L, Zhu H, Zhou H. 2010. Evidence that a west-east admixed population lived in the Tarim Basin as early as the early Bronze age. BMC Biol 8:15.

Liu X. 2002. Xinjiang Province. Yili River valley new archaeological discoveries. Xiyu Yanjiu 1:109–110.

Ma Y, Sun Y. 1992. Western regions under the Xiongnu and the Han. In: Hamatta J, editor. History of civilizations of Central Asia, Vol. 2. The development of sedentary and nomadic civilizations 700 BC to 250 AD. Paris: UNESCO Publishing. p 277–246.

Ma Y Wang B. 1992. The culture of the Xinjiang region. In: Hamatta J, editor. History of civilizations of Central Asia, Vol. 2. The development of sedentary and nomadic civilizations 700 BC to 250 AD. Paris: UNESCO Publishing. p 209–225.

Mallory JP, Mair VH. 2000. The Tarim mummies. London: Thames and Hudson.

Mayhall JT, Saunders SR, Belier PL. 1982. The dental morphology of North American whites: a reappraisal. In: Kurten B, editor. Teeth: form, function, and evolution. New York: Columbia University Press. p 245–258.

Miller BK, Allard F, Erdenebaatar D, Lee C. 2006. A Xiongnu tomb complex: excavations at Gol Mod 2 cemetery, Mongolia. Mongolian J Anthropol Archaeol Ethnol 2:1–21.

Novgorodova EA, Volkov VV, Korenevsko SN, Mamonova NN. 1982. Ulangom: Ein skythenzeitliches Grabergeld in der Mongolei. Weisbaden: Harrassowitz.

Qinghai Archaeological Institute. 2007. Qinghai Province, Xijing city, Taojiazhai Han Dynasty tombs 2002 archaeological report. Dongya Kaowu B:67–80.

Romgard J. 2008. Questions of ancient human settlements in Xinjiang and the early Silk Road trade, with an overview of the Silk Road research institutions and scholars in Beijing, Gansu, and Xinjiang. Sino-Platonic papers no. 185. Philadelphia: Department of Asian and Middle Eastern Studies, University of Philadelphia.

Scott GR. 1980. Population variation of Carabelli's trait. Hum Biol 52:63–78.

Scott GR, Alexandersen V. 1992. Dental morphological variation among medieval Greenlanders, Icelanders, and Norwegians. In: Smith P, Tchernov E, editors. Structure, function and evolution of teeth. London: Freund Publishing House. p 467–490.

Scott GR, Turner CG II. 1997. The anthropology of modern human teeth. Cambridge: Cambridge University Press.

Shaw JCM. 1931. The teeth, the bony palate and the mandible in Bantu races of South Africa. London: Bale and Danielsson.

Shenyang Cultural Relics Bureau. 2008. Sixty years of archaeological discoveries in the areas of Shenyang. Shenyang: Liaohai Publishing.

Suo X. 2005. Inner Mongolia. Linxian county, Shuiquan site archaeological report. Kaogu 11:19–29.

Swindler DR. 1995. Canine root development and morphology in *Macaca nemistrina*. Primates 36:583–589.

Torbat TS. 2004. Hunnugin jiriin irgediin bulsh. Ulaan Baatar: National University Press.

Turner CG II, Hawkey DE. 1998. Whose teeth are these? Carabelli's trait. In: Lukacs JR, editor. Human dental development, morphology, and pathology: a tribute to Albert A. Dahlberg. Eugene, OR: University of Oregon. Anthropology Papers No. 54. p 41–50.

Turner CG II, Nichol Cr, Scott GR. 1991. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In: Kelly MA, Larson CS, editors. Advances in Dental Anthropology. New York: Wiley-Liss. p 13–31.

Volkov VV, Dorjsuren TS. 1963. Hovd aimagiin Manhan sumin nutagt ertiin sudalin maltaga haiguul hiisen tuhai. Arheologiin Sudal 2:51–68.

Wei J. 2004. Inner Mongolia Xianbei cemeteries archaeological reports. Beijing: Scientific Publishing.

Yang J. 2004. The formation of the Northern zone during the spring and autumn and warring states periods. Beijing: Cultural Press.

Yao Y, Kong Q, Wang C, Zhu C, Zhang Y. 2004. Different matrilineal contributions to genetic structure of ethnic groups in the Silk Road region in China. Mol Biol Evol 21:2265–2280.

Zhang L. 2010. The skeletal research of Jilintai reservoir cemeteries, Yili County, Xinjiang province. PhD Dissertation, Jilin University, Changchun.

Zhang F, Xu Z, Tan J, Sun Y, Xu B, Li S, Zhao X, Zhou H, Gong G, Zhang J, Jin L. 2010. Prehistorical east-west admixture of maternal lineages in a 2500-year-old population in Xinjiang. Am J Phys Anthropol 142:314–320.