



Dental health, diet, and social transformations in the Bronze Age: Comparative analysis of pastoral populations in northern Kazakhstan



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ABSTRACT

Comparative analyses of human health and diet are often undertaken for consecutive periods of time which exhibit different social formations or material culture. The aim of this research was to test the link between social transformations and corollary shifts in health or diet. Therefore, oral health and dietary intake were examined in successive Bronze Age periods in central Eurasia with very different patterns of settlement and scales of interaction. Researchers have posited that these periods are evidence of an economic shift from agro-pastoral to pastoral patterns of subsistence. Populations from two sites in northern Kazakhstan (52°10'N, 64°32'E; 52°32'N, 62°23'E) were investigated in terms of dental caries, calculus, abscesses, ante-mortem tooth loss and periodontal disease. The results of this study indicate that the types of dental pathological conditions present stayed relatively uniform over time, suggesting similarities in dietary intake for populations at the sites of Bestamak (2032–1639 cal BC) and Lisakovsk (1860–1680 cal BC). The dietary intake of these communities is indicative of a noncariogenic diet with a high protein content and lack of carbohydrates. These findings conform to general patterns for pastoral societies and are consistent with stable carbon and nitrogen isotopic data. While they types of pathological conditions were similar, the severity of these lesions decreased in the later period. Comparatively more pronounced frequencies of pathological conditions during the earlier period are attributed to multiple etiologies including different patterns of consumption, dental cleaning behaviors, or stress. While the archaeological record indicates broad shifts in settlement patterns, demography, and mortuary rituals from the Middle to Late Bronze Ages, there was only a slight shift in dental health.

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1. Introduction

Discussions of prehistoric health and subsistence based on skeletal remains can be problematic, as there are recognized limitations of archaeological datasets (Wood et al., 1992). However, comparative research of dental pathological conditions in prehistoric populations may provide crucial understandings of diet and health, especially when interdisciplinary techniques are employed. Numerous studies have established the link between dental

paleopathological conditions and prehistoric diet (Lillie, 1996; Kaus and Tam, 2009; Šlaus et al., 2011; Murphy et al., 2013). Correlations between diet and oral health are poorly understood for the Eurasian steppe, as analyses of dental lesions are rarely undertaken on pastoral populations (for exceptions see Eng, 2007; Zubova, 2008a, 2008b; Machicek, 2011; Murphy et al., 2013) (Fig. 1). Comparative bioarchaeological projects which investigate dental health and diet often juxtapose consecutive periods of time when significant social change has occurred (Lillie, 1996; Kaus and Tam, 2009; Šlaus et al., 2011). These studies highlight that at times of social transformation there is periodically an associated shift in diet and health. Therefore, this paper investigates possible correlations between transitions in social and ritual landscapes with dental

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Fig. 1. Location of Bestamak and Lisakovsk study sites and other Eurasian steppe sites discussed in this paper: 1 – Kamennyi Ambar; 2 – Bol'shcheykaraganskogo/Arkaim; 3 – Yelovsky; 4 – Chernoozerye; 5 – Aymyrlyg; 6 – Ai-Dai.

health data through the examination of two consecutive periods of the Bronze Age in the central Eurasian steppe. Marked changes occurred in north central Kazakhstan at the transition from the Middle (2130–1630 cal BC) to Late Bronze Age (1700–1400 cal BC) (Fig. 2) (Hanks et al., 2007; Panyushkina et al., 2008; Logvin and Sevina, 2013). These contiguous periods reflect an important transition in patterns of settlement, the demographic size of settlements, and mortuary rituals within the broader region. It has also been proposed that these periods reflect a shift in subsistence practices from a focus on agro-pastoral to pastoral consumption patterns, which can be investigated through the examination and interpretation of dental pathological conditions.

The Middle Bronze Age (2130–1630 cal BC) in central Eurasia (southern Urals Russia and north central Kazakhstan), is dominated by two archaeological cultures, the Sintashta and Petrovka. In terms of material culture, these groups differ only slightly and are presented together as they overlap at many sites (even

though in some locations the Sintashta development begins 100 years earlier). The Middle Bronze Age (MBA) is characterized by large aggregated settlements at sites such as Arkaim and Andreevskoye (Fig. 3) (Zdanovich and Batanina, 2002; Batanina and Hanks, 2013). Settlements have exterior enclosures and ditches, sometimes discussed as fortifications, and estimates of population size range from 200 to 700 individuals (Gening et al., 1992; Grigor'yev, 2000:258; Anthony, 2007; Kohl, 2007; Koryakova and Epimakhov, 2007). Cemeteries are often initially identified and delineated based on the presence of kurgan (mound) burials visible on the surface. Kurgan construction consists of planned circular mounds of either dirt or stone surrounded by a circular ditch that can contain from a single to multiple burials (Fig. 4). While kurgan burials dominate discussions of mortuary practices during the MBA, there is also evidence of unmarked, or flat, burials that are located outside of mounded structures at many cemeteries (Fig. 5). An estimated

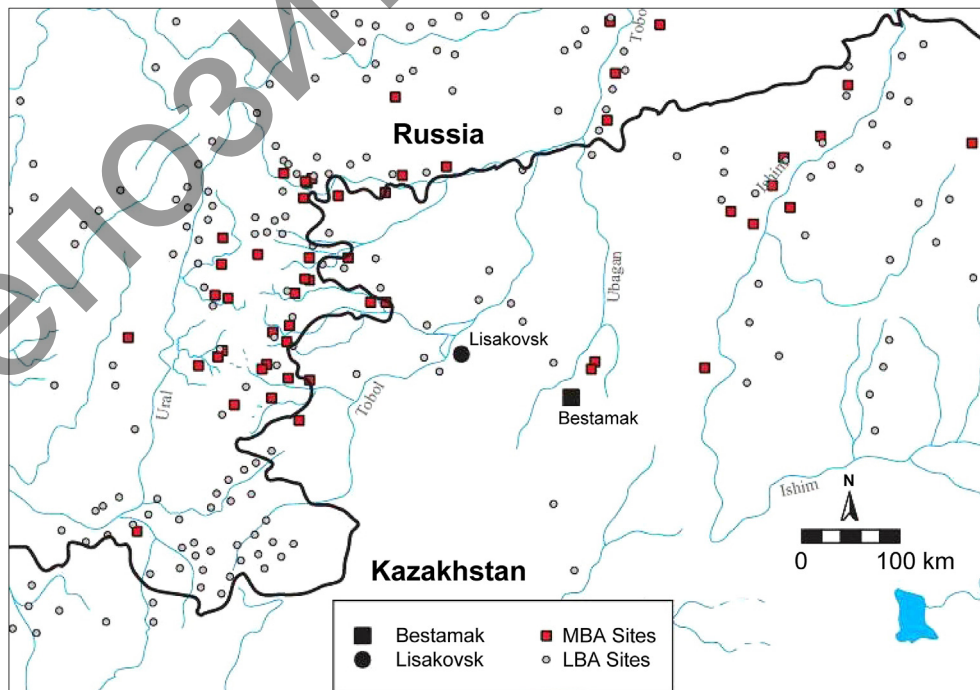


Fig. 2. Middle Bronze Age (MBA) to Late Bronze Age (LBA) settlement transition in central Eurasia.

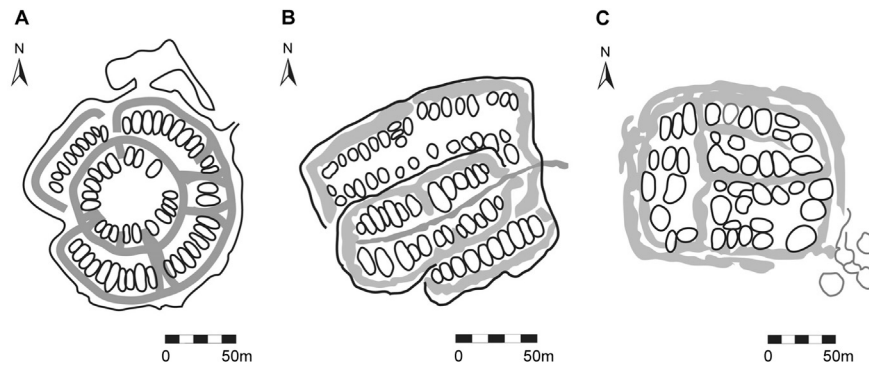


Fig. 3. MBA settlements (clockwise) of (A) Arkaim, (B) Rodniki, and (C) Andreevskoe (redrawn by A. Ventresca Miller based on Zdanovich and Batanina, 2002: 130,134).

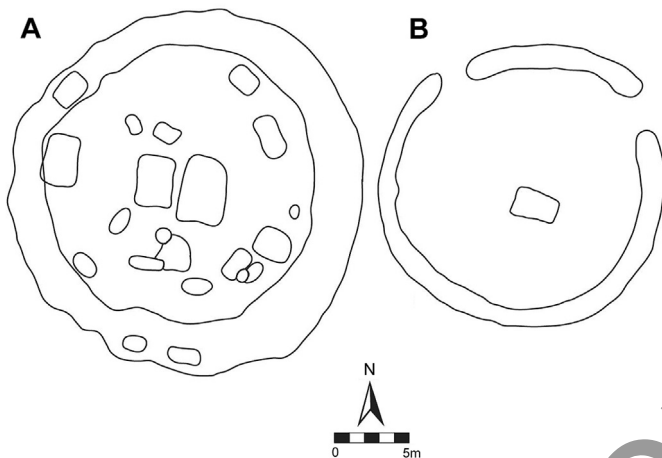


Fig. 4. Examples of MBA kurgan burials with surrounding ditches: multiple burials (A) Bol'shchekaraganskogo mogil'nik, kurgan 25 (redrawn by A. Ventresca Miller based on Zdanovich, 2002b:127) and a single burial (B) mogil'nik Aleksandrovskii IV, kurgan 2 (redrawn by A. Ventresca Miller based on Malyutina et al., 2010:186).

16 spoke-wheeled vehicles have been identified as part of the burial retinue at Sintashta and Petrovka sites (Gening et al., 1992; Vinogradov, 2003; Koryakova and Epimakhov, 2007). While radiocarbon dates relevant to Sintashta and Petrovka

developments are few (Hanks et al., 2007; Logvin and Ševnina, 2013), the majority of mortuary contexts are dated relative to associated ceramics recovered.

The majority of faunal remains recovered from MBA settlements indicate a primary use of cattle, sheep, and goat, with somewhat lesser use of horse (Kosintsev 2000; Gayduchenko, 2002, 2005, 2010; Bachura, 2009; Kosintsev and Gasilin, 2009; Kosintsev, 2010). However, the aggregated, and apparently settled nature, of MBA communities in conjunction with the recovery of sickles has led some scholars to suggest that horticultural or agricultural subsistence practices were part of a mixed agro-pastoral lifeway (Zdanovich, 1997:15; Zdanovich and Zdanovich, 2002). While the recovery of wild cereals, sickles, mortars, and pestles at nearby sites have been used as evidence for horticultural or agricultural activities, these items may have had other functional or ritual uses related to animal foddering, metals processing, or medicinal plant use (Epimakhov, 2010) (Fig. 6). Recent understandings of the subsistence regimes of Bronze Age groups in this region highlight the more pastoral nature of local economies. While pastoralists are often defined as those who undertake animal herding as their primary form of subsistence procurement, a number of other strategies linked to variability in mobility and agro-pastoralist orientations have been identified (Khazanov, 1978; Barfield, 1981, 1993; Cribb, 1991; Chang and Koster, 1994; Frachetti, 2008). As our understandings of subsistence economies for central Eurasian groups begin to change, there is a renewed focus on direct sources of data regarding consumption practices in local communities.

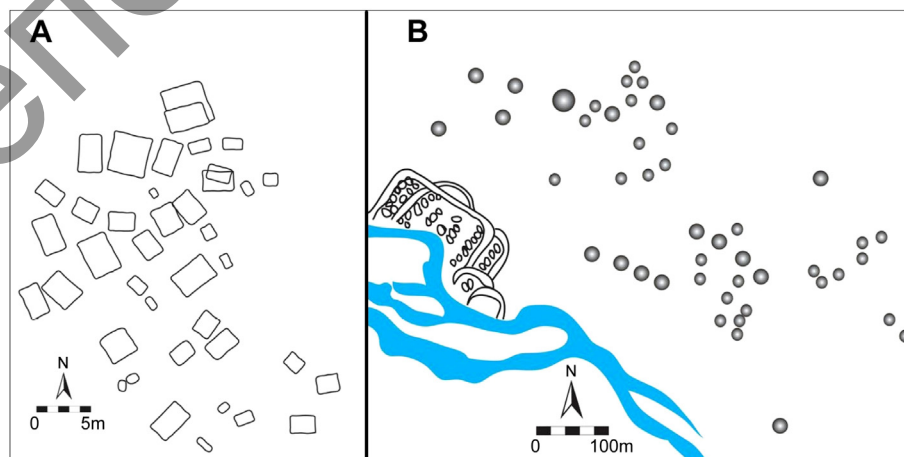


Fig. 5. Examples of MBA cemeteries: flat cemetery of (A) SM (Sintashta) and (B) Stepnoye kurgan cemetery (redrawn by A. Ventresca Miller based on Gening et al., 1992:112 and Hanks and Doonan, 2009:346).



Fig. 6. Mongolian pastoralists using sickles to cut fodder for animals (Photo courtesy of Jörg Janzen).

Late Bronze Age (LBA) cultural developments have been referred to as the 'Andronovo culture' or 'Andronovo family of cultures' based on the recovery of analogous archaeological material over a vast area. The Andronovo development is split into numerous sub-cultures, but most agree that the Alakul' and Fedorovo sub-culture designations are appropriate for northern Kazakhstan (Matveev et al., 2002:444; Koryakova and Epimakhov, 2007:126–7). These two sub-cultures are in general geographically separated with Alakul' in the north and west, and Fedorovo in the east, but they are also intermixed at numerous sites in the broader region. Settlements during the LBA reveal an increase in the number of residential sites combined with a decrease in the size of settlements (Evdokimov, 1983; Potemkina, 1983; Khabdulina and Zdanovich, 1984; Tkacheva, 1999; Kuz'mina, 2007; Koryakova and Epimakhov, 2007). Few LBA settlements have been fully excavated, yet. Those investigated reveal that houses were semi-subterranean and were often arranged in a single row or a set of parallel rows with entrances facing the river (Fig. 7) (Kuz'mina, 1994:403; Maljutina, 1994; Kuz'mina, 2007:39). The majority of LBA cemeteries have above ground kurgan burial constructions, which makes them easier to identify (Koryakova and Epimakhov,

2007:130–1). Circular kurgans often have a central area located underneath mounded soil, which is outlined by a ring of stones and a ditch (Fig. 8). The stone ring and ditch encapsulate a central area below the mound that can contain from one to several burials. Unmarked or flat burials are also found inside of kurgan zones (in ditch, under stone ring) as well as outside the confines of kurgan constructions (Fig. 9).

As communities became smaller and more dispersed during the LBA, scholars have hypothesized that there was a switch to increasingly mobile forms of pastoralism (Tkacheva 1999). The relationship between dispersed communities and increased mobility, changing herd sizes, and herd composition is another branch of the prehistoric economy that is not well understood (Morales-Muniz and Antipina, 2003; Bendrey, 2011). Nearly all scholars agree that Bronze Age societies in the central Eurasian steppe maintained livestock and that meat and milk products formed a major component of their subsistence economy (Khazanov, 1984; Cribb, 1991; Kosintsev, 2000, 2003; Frachetti, 2002; Outram et al., 2009). Improved comprehension of individual and community dietary intake is critical to a better understanding of the broader social and economic processes within

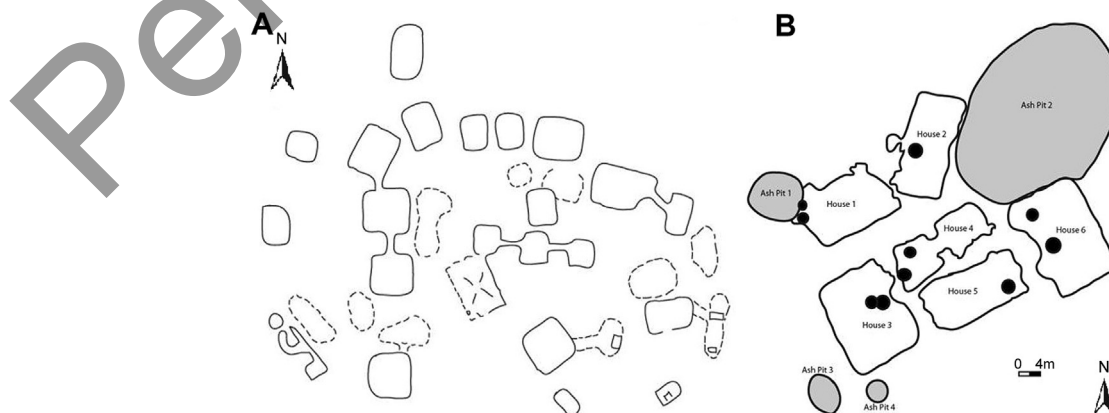


Fig. 7. Examples of LBA settlements: sites of (A) Atasu (Kuz'mina, 1994:403) and (B) Cheremukhovyi Kust (Zakh and Ilyushina, 2010:42).

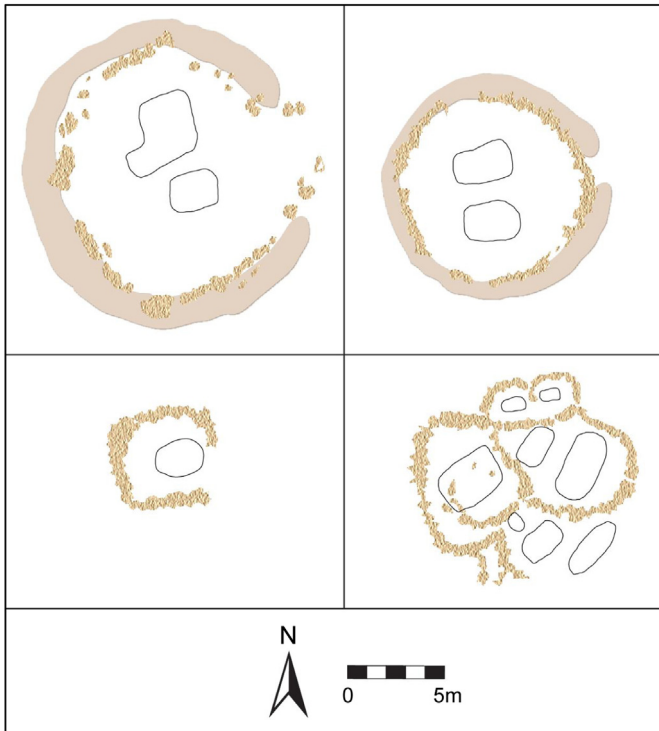


Fig. 8. Examples of LBA kurgan burials from the Lisakovsk cemetery.

central Eurasia. Zooarchaeological research at the LBA site of Lisakovsk indicates that the dominant faunal remains were cattle, sheep, and goat, with only a few horses present (Outram et al., 2010). As soil flotation has not been used as a recovery method at this site, the remains of grains, cereals, and fish have not been identified. While a shift to pastoral lifeways have been posited, new techniques need to be used to examine pastoralism as a subsistence strategy that included supplementation of the diet with a range of alternate foods including fish and wild plants.

Developments in social, economic and political complexity seemingly reached an important apex during the Middle Bronze Age in the central Eurasian steppe. Sintashta and Petrovka (MBA) communities had elaborate mortuary practices and aggregated populations (Sal'nikov, 1967; Gening et al., 1992; Anthony, 2007). Settlements were concentrated in several neighboring micro-regions in the southern Urals and consisted of nucleated house structures within an enclosure (Gening et al., 1992; Grigor'yev, 2000; Anthony, 2007; Kohl, 2007; Koryakova and Epimakhov, 2007; Hanks, 2009). The subsequent LBA is marked by the dispersal of small settlements and similar material culture on a vast regional scale and is interpreted as a period of increased interaction and mobility (Koryakova and Epimakhov, 2007). A transition is seen in settlement patterns which reveal an increase in the number of residential sites combined with a decrease in the size of settlements (Evdokimov, 1983; Potemkina, 1983; Khabdulina and Zdanovich, 1984; Kuz'mina, 2007; Koryakova and Epimakhov, 2007). This shift from aggregated to dispersed communities is often interpreted as a result of a transition in the economy and mobility of local groups, from settled or semi-settled agro-pastoralists to more nomadic forms of pastoralism. Furthermore, the shift to smaller communities that lacked planned construction may offer support for hypotheses that imply increased interaction and mobility during the LBA. However, the actual subsistence economies of local communities are understudied and recent research has demonstrated that pastoralism is a highly variable strategy of consumption patterns and herding techniques (Khazanov, 1978; Cribb, 1991; Chang and Koster, 1994; Leonard and Crawford, 2002; Frachetti, 2008). Furthermore, the mobility of pastoral groups is still very much an open question, as there is little direct evidence related to human migration or movement, animal herding strategies, or animal circulation. While there were clear shifts in settlement patterns between these two periods, we have no datasets that clarify how mobility occurred at local or regional scales.

This shift in patterns of settlement from the MBA to LBA needs to be tested against possible shifts in mobility, herding strategies, and consumption patterns. However, the case study presented here examines only a small portion of the data necessary to investigate this transition. This research combines detailed assessments of

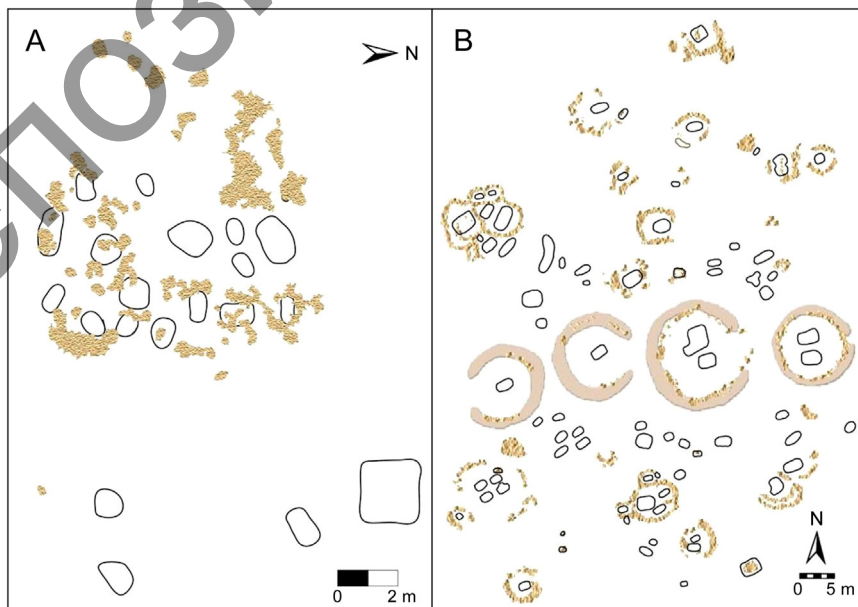


Fig. 9. Examples of LBA cemeteries at (A) Urefti (Stefanov and Korochkova, 2006:75) and (B) Lisakovsk 1 (Ventresca Miller, 2013).

dental pathological lesions from human skeletal remains to comparatively investigate dietary intake and oral health diachronically at this broad transition. This paper presents a bioarchaeological approach to Eurasian prehistory through comparative analyses of dental lesions that have the potential to provide information on the consumption practices of individuals and local communities. While this article focuses specifically on dental disease, this interdisciplinary approach also reflects on parallel isotopic analyses undertaken at these sites (Ventresca Miller et al., 2014).

There is a long-recognized link between insights from dental pathological lesion studies and dietary reconstructions (Powell, 1985; Larsen et al., 1991). Investigations of dental caries, antemortem tooth loss, dental calculus, abscesses, and periodontal disease in the context of archaeological datasets have explored correlations between diet and economy, diachronic dietary change, and diet and status (Powell, 1985; Lukacs, 1989; Larsen et al., 1991; Nelson et al., 1999). While dental pathological lesions are an indirect source of information on consumption practices, it can be combined with other forms of information including stable carbon and nitrogen analyses (e.g. Lillie and Richards, 2000; Murphy et al., 2013; Ventresca Miller et al., 2014) to provide increased support for the reconstruction of dietary trends. This paper presents an unusual case where the types of dental lesions present are relatively uniform in two communities located in concurrent periods of time. However, overall dental health shifted slightly, with slightly better oral health in the later period. While significant social transformations occurred in central Eurasia at the MBA to LBA transition, there seems to be little effect on subsistence regimes. This may be particularly important in regard to our understandings of mobility and interaction which are posited to have greatly increased during the later period.

2. Data and methods

2.1. Regional settings

The Bestamak and Lisakovsk sites are located in northern Kazakhstan, within Kostanay oblast' (administrative region) (Fig. 2). The Bestamak cemetery and settlement (ca. 52°10'N, 64°32'E) are located on the right bank of the Buruktal River (Fig. 10), while the Lisakovsk site consists of seven cemeteries and a settlement (ca. 52°32'N, 62°23'E) along the Tobol River (Fig. 11). The topography, climate, soils, and vegetation cover for these sites varies slightly, which may have affected the subsistence regimes evident during the Middle and Late Bronze Ages. As the available datasets regarding these topics are not very detailed for prehistory, researchers have attempted reconstructions based on small datasets and materials collected in modern conditions.

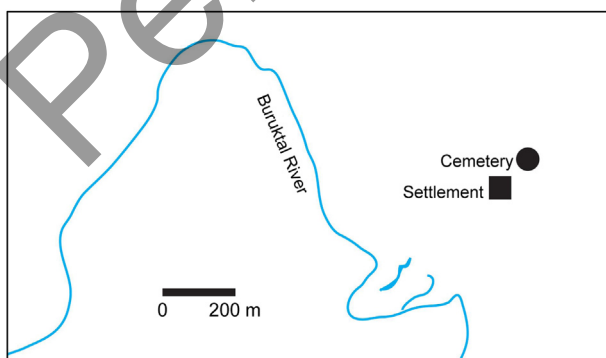


Fig. 10. Location of Bestamak settlement and cemetery (ca. 52°10'N, 64°32'E) on the right bank of the Buruktal River.

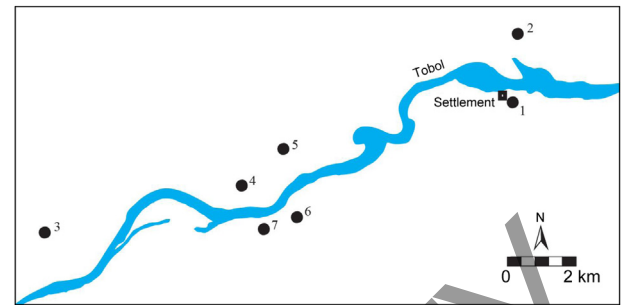


Fig. 11. Location of Lisakovsk settlement and cemeteries 1 through 7 (ca. 52°32'N, 62°23'E) along the Tobol River.

Prehistoric climate is not well understood for the central Eurasian steppe during the Bronze Age, as few detailed studies have been undertaken. Research into climatic change in the region has ranged in focus from general studies of a small number of sites over a broad area to the examination of a single location. The former includes the investigation of 8 lakes across northern Kazakhstan (Kremenetski et al., 1997), while the latter includes detailed information from a single site, for example a peat bog (e.g. Lopez et al., 2003). An overall lack of knowledge of regional ecological conditions parallels a paucity of data available for local zones surrounding archaeological sites. The steppe and forest-steppe regions are affected by continental climate which causes drastic spatial variation in seasonal conditions (Coupland, 1992). Today, this region has ten year alternating wet and dry cycles, along with recurring droughts (approximately every 8–12 years) (Koryakova and Epimakhov, 2007:5–6). Scholars disagree on the climatic conditions during the Bronze Age with differing theories on whether the climate has been stable, become more arid, or increased in humidity (Demkin and Demkina, 2002; Matveev et al., 2002; Anthony et al., 2005; Anthony, 2007; Koryakova and Epimakhov, 2007). However, research programs have begun to focus on regional and micro-regional approaches to determine temperature fluctuations (Demkin and Demkina, 2002). Matveev et al. (2002:474) note that between the cemetery and settlement of Chistolobzhasky in the southern Urals, which are only 50 km apart, there is a significant difference in the vegetation recovered from cultural layers. Based on this difference, the authors posit that the climate shifted from one that was extremely arid to one that was less arid. However, this shift is not correlated to any radiocarbon dates to support this data (Matveev et al., 2002). Until climatic data is collected and analyzed for many local communities, it should not be used as a basis for making claims about Bronze Age groups.

While very little climate change research has been published for central Eurasia, several broad trends in vegetation history are evident based on lake cores collected at Mokhovoe Lake within Kostanay oblast' (Kremenetski et al., 1997). This lake is located between the Tobol and Ubagan Rivers and therefore is relatively close to the archaeological sites under study. Sedimentation at the lake started circa 6000 BP, with a suggested hiatus between 4500/4000 and 3000/2900 BP (Kremenetski et al., 1997). Between 6000 and 4500 BP the vegetation in this region was forest-steppe and grass steppe with some patches of Birch forest. These findings are interpreted as a long period of wet climatic conditions when vegetation groups expanded and the herb cover of the steppe was more mesophytic, containing plants that needed a regular source of water (Kremenetski et al., 1997:403). The hiatus in sediment covers the time from 4500 to 2900 BP, which encompasses the Bronze Age, and was characterized by a drier and more continental climate with decreased forest area. However, while this gap is construed as a

period of drier climate, the reality is that gaps are an absence of data and therefore cannot be used to indicate climate change. Therefore, the extent of variation in climate and local environment during the Bronze Age continue to be unclear for northern Kazakhstan and portions of the southern Urals region.

The Kostanay oblast' (administrative region) located in northern Kazakhstan consists of two broadly defined vegetation sub-provinces, the Northern Kazakhstan forest-steppe and the Trans-Urals – Turgay (Rachkovskaya and Bragina, 2012:124–5). The forest-steppe encompasses only a small section of the northeastern part of the Kostanay oblast' and includes *Betula* and *Populus-Betula* forests interspersed with meadow steppes and rich forb – feather grass steppes (Rachkovskaya and Bragina, 2012:126). Small sections of vegetation can also include sedge marshes and willow brushwoods, especially in depressions. In comparison, the majority of the oblast' is considered part of the Trans-Ural – Turgay subprovince which contains a full range of steppe vegetation communities. These include steppes of rich-forb – feather grass and forb – feather grass in the north, with fescue – feather grass steppes on the slopes on low hills near rivers (Rachkovskaya and Bragina, 2012:126–7). Furthermore, small vegetation communities are present including sagebrush, bunch grass and other xerophytic forb – fescue – feather grasses. Several areas also have relic pine forests interspersed with meadow communities and complex steppes on lake terraces (Rachkovskaya and Bragina, 2012:127). Modern land use within the oblast' reveals that 64% of the land surface in the oblast' is arable, while natural pastures have productivity levels ranging from 500 to 1500 kg/ha in steppe meadows (Rachkovskaya and Bragina, 2012:129–133). While vegetation communities in Kostanay oblast' are categorized as two subprovinces, there are also many smaller vegetation communities in the region. Both archaeological sites are located within areas of open steppe, however they differ because Bestamak is found in an area dotted with small salt marsh ponds while Lisakovsk is located on the high banks of the Tobol River. Further research on the local vegetation surrounding each site needs to be undertaken to understand the possible biological diversity present in each micro-region.

2.2. Archaeological context and data

2.2.1. Bestamak site

Bestamak has recently been dated to the Middle Bronze Age through the analysis of three separate burials with radiocarbon dates ranging from 2032 to 1639 cal BC (Logvin and Ševnina, 2013). In total, 60 burials were excavated at the cemetery that can be linked to the MBA through pottery typologies, but only 35 individuals had adult dentition that could be used for analyses of dental pathological lesions. The Bestamak site consists of a cemetery and a settlement that span several periods (Figs. 2 and 10). Only burials corresponding to the MBA were used in this analysis, which includes both kurgan (mound) and unmarked flat burials (Logvin, 2002; Ševnina, 2003; Logvin and Ševnina, 2004, 2008; Kalieva and Logvin, 2009; Logvin et al., 2009; Ševnina and Boroshilova, 2009).

2.2.2. Lisakovsk site

The Lisakovsk site consists of seven cemeteries and a settlement along the Tobol River (Figs. 2 and 11). Radiocarbon dating and dendrochronological analysis of timbers from the site indicate a range of dates from 1860 to 1680 cal BC (Panyushkina et al., 2008). In total, of 88 individuals that were available for physical analysis from Lisakovsk only 42 individuals had adult dentition available for analyses of dental pathology. The cemeteries at Lisakovsk are composed of several burial types including kurgans surrounded by ditches, stone-covered burials, stone-enclosed burials, and

unmarked or flat burials (Usmanova and Logvin, 1998; Usmanova, 2005; Usmanova et al., 2005; Usmanova, 2010). The Bestamak and Lisakovsk sites were chosen for research because they contain two of the most fully excavated cemeteries in northern Kazakhstan. Furthermore, they contain multiple types of burials, including those that are unmarked and therefore more likely to be useful in analyses where comparative studies of individuals are undertaken (e.g. Ventresca Miller, 2013).

The dentition of a total of 35 individuals from Bestamak and 42 individuals from Lisakovsk was analyzed as part of this research. Furthermore, full skeletal analysis was undertaken to determine the biological sex and age of each individual. Sex determination of the skeletons was done using standard morphological and metric criteria based on the pelvic and cranial indicators (Phenice, 1969; Acsádi and Nemeskéri, 1970; Ubelaker, 1989). Human age estimates were based on epiphyseal union, primary ossification centers, dental eruption patterns, dental wear, suture closure, epiphyseal union, pubic symphysis, auricular surface, degenerative joint disease (Scott, 1979; Powell, 1985; Ubelaker, 1989; Buikstra and Ubelaker, 1994). Individuals were assigned to several age categories: Infant (0–2 y), Child (2–12 y), Adolescent (12–18 y), Younger Adult (18–35 y), Older Adult (35–50 y), and Eldest Adult (50+). The final dental inventory and pathological lesion assessment included only permanent teeth. Several types of pathological lesions were recorded as part of this research, including caries, calculus, abscesses, antemortem tooth loss (AMTL) and alveolar bone resorption using well established methods (Hillson, 1979, 1996, 2001; Buikstra and Ubelaker, 1994; Lukacs, 1995; Ortner, 2003). Pathological lesions were recorded on Arizona State Museum recording forms. Of the total 77 individuals represented by the two sites investigated, 1173 teeth and 309 tooth sockets were examined and considered in these analyses. Dental health data were only documented for permanent dentition and their alveoli. Preservation was considered adequate for each tooth if the crown was represented by at least its cervical two thirds and surface features were visible macroscopically (not obscured by extensive calculus deposition, severe attrition, or postmortem breakage). Sufficient tooth socket preservation was characterized by the visibility of surface features and the presence of two thirds of surrounding alveolar bone.

2.3. Methods

Dental caries is defined as structural damage to the teeth, often the “chemical dissolution of the tooth surface caused by metabolic events taking place in the biofilm (dental plaque) covering” (Fejerskov et al., 2008:4). Carious lesions develop at sites in the dentition where biofilms are allowed to accumulate over time, including pits, fissures and grooves in occlusal surfaces (Fejerskov et al., 2008). While biofilm does not necessarily result in the development of clinically visible carious lesions, it is a prerequisite for the occurrence of these lesions. Dietary shifts affect oral pH and biofilm formation, and the result of imbalance between tooth mineral and biofilm fluid is dental caries (Fejerskov et al., 2008). There is a clear relationship between diet and dental decay in both clinical and anthropological studies (Lukacs, 1992; Beighton et al., 1995; Hillson, 1996; Walker et al., 1998; Ortner, 2003). In modern populations, three main variables can be positively and independently correlated to caries: gingival index (periodontal disease), dietary intake, and salivary concentration of lactobacilli (Beighton et al., 1995). In a similar vein, this paper explores the correlation between prehistoric dental pathological lesions, oral health, and diet. Carious lesions were identified in terms of location (Buikstra and Ubelaker, 1994) and extent (Hillson, 2001) based on examination with a magnifying glass and dental probe.

Dental calculus is mineralized microbial biofilm (plaque) which forms on the tooth surface. Studies indicate that calculus formation

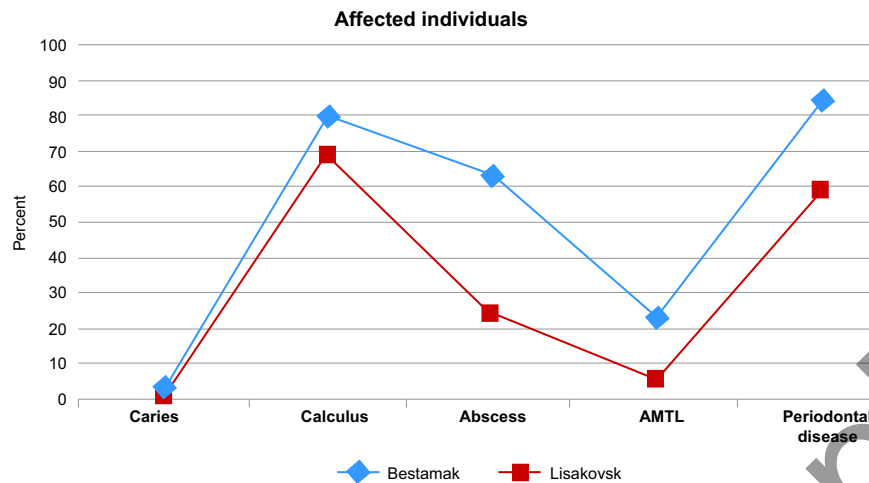


Fig. 12. Frequencies of affected individuals at Bestamak and Lisakovsk.

is progressive over time as individuals' age (Dumitrescu and Kawamura, 2010). Levels of calculus and location of formation are affected by oral hygiene, diet, age, systemic disease and ethnic origin (White, 1997). There is an inverse relationship between calculus and dental caries for subjects of a similar age (Duckworth and Huntington, 2006). Furthermore, a high amount of calcium and high pH in saliva correlates with increased formation of calculus, and an inhibition of caries (Duckworth and Huntington, 2006:14–22). Supragingival dental calculus deposits were recorded using a three-stage scoring system (Brothwell, 1981; Buikstra and Ubelaker, 1994).

Dental abscesses are caused by inflammation and infection of the root canal, leading to the accumulation of pus which drains through the alveolar bone. Dental abscesses were identified by the presence and location (buccal or lingual) of a drainage channel in the alveolar bone at the apex of the tooth root (Buikstra and Ubelaker, 1994; Ortner, 2003). Abscesses were recorded in terms of location, size (in mm), and degree of alveolar resorption surrounding the drainage channel. Abscesses were visually identified for individuals who had intact alveolar bone, which means that the true presence of abscessing is underestimated for all of the samples (Lukacs, 1989). Abscess formation arises as a consequence of inflammatory processes related to the development of caries, calculus formation and attrition, and therefore is a secondary indicator related to dietary intake (Lukacs, 1989).

Antemortem tooth loss (AMTL) can be caused by multiple factors including advanced dental caries, dental wear, nutritional deficiencies, and culturally induced avulsion or trauma (Ortner, 2003). AMTL was scored by the tooth location and the degree of alveolar resorption as part of the dental inventory. The calculation of caries rates can be greatly affected by AMTL, therefore several methods have been developed to examine this intersection in a comprehensive manner (e.g. Kelley et al., 1991; Lukacs, 1995). AMTL was quantified by dividing the number of teeth lost antemortem by the number of tooth sockets present. In addition, the Diseased Missing Index (DMI) was used to score AMTL and caries together (Kelley et al., 1991). The calculation for DMI is expressed by adding the total number of carious teeth and teeth lost antemortem and expressing this number as a percentage of the total number of teeth and sockets observed. DMI was calculated for each site separately in terms of observable dentition and alveolar bone in locations of tooth sockets.

Periodontal disease (periodontitis) is caused by inflammation and destruction of the gum tissue, periodontal ligaments, and alveolar bone. This condition is closely linked to dental calculus and tooth loss (AMTL), and can also be associated with increased risk for a variety of other diseases (for discussion Dewitte, 2012). Periodontal disease was recorded only when the alveolar bone showed changes in the cortical surface, revealing either porous cancellous spaces or an altered alveolar crest (Clarke et al., 1986:175). This

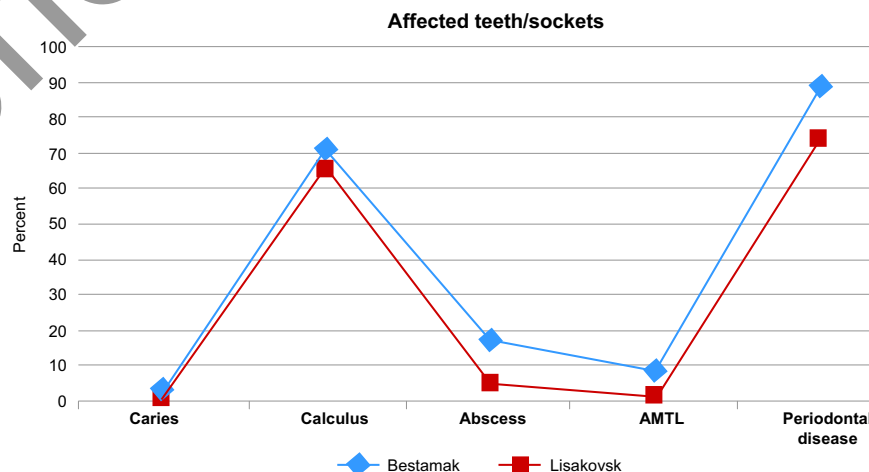


Fig. 13. Frequencies of affected teeth/sockets at Bestamak and Lisakovsk.

disease was recorded based on a five category scale that included the degree of alveolar resorption near the tooth socket and degree of root exposure of teeth in occlusion.

3. Results

A total of 1173 teeth were observable for dental caries from the sites of Bestamak ($n = 691$) and Lisakovsk ($n = 482$). The location and severity of each carious lesion was recorded (Buikstra and Ubelaker, 1994). The observed number of caries are based on the minimum prevalence, as some lesions may be obscured by dental wear or may only be observed radiographically (Hillson, 2001; Fejerskov et al., 2008). The rate of dental caries was defined in two ways: as the number of carious teeth divided by the number of observable teeth; and the number of individuals with a carious lesion divided by the number of individuals with dentition (Tables 1–4; Figs. 12 and 13). The rate of dental caries was very low for both sites analyzed in this study. At Bestamak, only a single carious lesion was identified out of 35 individuals examined (2.9%). This carious lesion was recorded on one tooth from a total of 619 teeth (0.1%). The carious lesion was identified on the mandibular right second molar of an adolescent and characterized by a deep pit in the tooth. Comparatively, there was a lack of caries evident for the 42 individuals (482 teeth) examined from the Lisakovsk site. A Fischer's exact test of independence (2-Tail) compared the presence or absence of caries by tooth and revealed that the difference between the two sites not significant ($p = 1$). There were also no significant differences between individuals in the proportions of caries based on age or sex categories.

A total of 1170 teeth were observable for dental calculus from the sites of Bestamak ($n = 687$) and Lisakovsk ($n = 483$). Calculus deposits were compared in two ways: the number of teeth affected divided by the number of observable teeth and the number of individuals with calculus divided by the number of individuals with dentition (Tables 1–4; Figs. 12 and 13). There was a high degree of dental calculus deposition at the two sites, which is often associated with high protein diets that lack carbohydrates and sugars (Hillson, 1979). At Bestamak, 80% (28 of 35) individuals examined had evidence of dental calculus, while the presence of calculus on dentition at Lisakovsk was also high with 69.0% (29 of 42) individuals having evidence of the disease. A total of 687 teeth were examined for calculus from the site of Bestamak, and the majority had only slight calculus deposits (65.1%). Very few teeth had moderate (5.7%) or heavy deposits (0.1%) of calculus present, although a good number of teeth lacked calculus altogether (29.1%). At Lisakovsk a total of 483 teeth were examined for calculus with the majority having slight (54.6%) or moderate (11.6%) calculus deposits, and a good number of teeth lacking calculus deposits altogether (33.8%). When compared with Bestamak, the site of Lisakovsk had a slightly smaller proportion of individuals with calculus, although similar proportions of teeth with calculus deposits. A Fischer's exact test of independence (2-Tail) compared the presence or absence of calculus by tooth and revealed that the difference between the two sites not significant ($p = 0.084$).

Intra-site differences were identified at the site of Bestamak, where older adults (35–50) had a higher frequency of dental calculus than younger adults (18–35). A Fischer's exact test of

Table 1
Dental pathological lesions (absolute numbers and percentages) at Bestamak (number of affected individuals versus total number of individuals with dentition).

Dental lesion	Age group	Male		Female		Indet.		Subadult		Total	
		abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
Caries	2–12							0/6	0.0	0/6	0.0
	12–18							1/4	25.0	1/4	25.0
	18–35	0/2	0.0	0/5	0.0	0/7	0.0			0/14	0.0
	35–50	0/3	0.0	0/3	0.0	0/2	0.0			0/8	0.0
	50+	0/1	0.0			0/1	0.0			0/2	0.0
	Indet.			0/1	0.0					0/1	0.0
Total		0/6	0.0	0/9	0.0	0/10	0.0	1/10	10.0	1/35	2.9
Calculus	2–12							2/6	33.3	2/6	33.3
	12–18							4/4	100.0	4/4	100.0
	18–35	2/2	100.0	4/5	80.0	6/7	85.7			12/14	85.7
	35–50	3/3	100.0	3/3	100.0	2/2	100.0			8/8	100.0
	50+	1/1	100.0			0/1	0.0			1/2	50.0
	Indet.			1/1	100.0					1/1	100.0
Total		6/6	100.0	7/8	87.5	8/10	80.0	6/10	60.0	28/35	80.0
Abscess	2–12							1/2	50.0	1/2	50.0
	12–18							0/1	0.0	0/1	0.0
	18–35	1/2	50.0	2/4	50.0					3/6	50.0
	35–50	2/3	66.7	2/3	66.7	2/2	100.0			6/8	75.0
	50+	1/1	100.0							1/1	100.0
	Indet.			1/1	100.0					1/1	100.0
Total		4/6	66.7	5/8	62.5	2/2	100.0	1/3	33.3	12/19	63.2
AMTL	2–12							0/2	0.0	0/2	0.0
	12–18							0/1	0.0	0/1	0.0
	18–35	0/2	0.0	0/2	0.0					0/4	0.0
	35–50	1/2	50.0	1/2	50.0	1/1	100.0			3/5	60.0
	Indet.			0/1	0.0					0/1	0.0
Total		1/4	25.0	1/5	20.0	1/1	100.0	0/3	0.0	3/13	23.1
Periodontal disease	2–12							1/2	50.0	1/2	50.0
	12–18							1/1	100.0	1/1	100.0
	18–35	1/2	50.0	3/4	75.0					4/6	66.7
	35–50	3/3	100.0	3/3	100.0	2/2	100.0			8/8	100.0
	50+	1/1	100.0							1/1	100.0
	Indet.			1/1	100.0					1/1	100.0
Total		5/6	83.3	7/8	87.5	2/2	100.0	2/3	66.7	16/19	84.2

Table 2

Dental pathological lesions (absolute numbers and percentages) at Bestamak (number of affected teeth/sockets versus total number of observable teeth/sockets).

Dental lesion	Age group	Male		Female		Indet.		Subadult		Total	
		abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
Caries	2–12							0/69	0.0	0/69	0.0
	12–18							1/107	0.9	1/107	0.9
	18–35	0/48	0.0	0/98	0.0	0/174	0.0			0/293	0.0
	35–50	0/41	0.0	0/84	0.0	0/42	0.0			0/167	0.0
	50+	0/12	0.0			0/12	0.0			0/24	0.0
	Indet.			0/31	0.0					0/31	0.0
Total		0/101	0.0	0/213	0.0	0/228	0.0	1/176	0.6	1/691	0.1
Calculus	2–12							22/69	31.9	22/69	31.9
	12–18							88/107	82.2	88/107	82.2
	18–35	48/49	97.9	48/98	49.0	96/174	55.2			192/321	59.8
	35–50	39/40	97.5	77/77	100.0	27/30	90.0			143/147	97.3
	50+	11/11	100.0			0/1	0.0			11/12	91.7
	Indet.			31/31	100.0					31/31	100.0
Total		98/100	98.0	125/175	71.4	123/205	60.0	110/176	62.5	487/687	70.9
Abscess	2–12							1/17	5.9	1/17	5.9
	12–18							0/7	0.0	0/7	0.0
	18–35	4/43	9.3	9/58	15.5					13/101	12.9
	35–50	14/43	32.6	10/73	13.7	7/35	20.0			31/151	20.5
	50+	2/8	25.0							2/8	25.0
	Indet.			5/25	20.0					5/25	20.0
Total		20/94	21.3	24/156	15.4	7/35	20.0	1/14	7.1	52/309	16.8
AMTL	2–12							0/22	0.0	0/22	0.0
	12–18							0/10	0.0	0/10	0.0
	18–35	0/45	0.0	0/29	0.0					0/74	0.0
	35–50	18/64	28.1	5/53	9.4	1/38	2.6			24/155	15.5
	Indet.			0/30	0.0					0/30	0.0
Total		18/109	16.5	5/112	6.1	1/38	2.6	0/32	0.0	24/291	8.2
Periodontal disease	2–12							1/16	6.3	1/16	6.3
	12–18							10/10	100.0	10/10	100.0
	18–35	29/45	64.4	50/58	86.2					79/103	76.7
	35–50	67/67	100.0	82/82	100.0	37/37	100.0			186/186	100.0
	50+	9/9	100.0							9/9	100.0
	Indet.			30/30	100.0					30/30	100.0
Total		105/121	86.8	162/170	95.3	37/37	100.0	11/17	64.7	315/354	89.0

Table 3

Dental pathological lesions (absolute numbers and percentages) at Lisakovsk (number of affected individuals versus total number of individuals with dentition).

Dental lesion	Age group	Male		Female		Indet.		Subadult		Total	
		abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
Caries	0–2							0/1	0.0	0/1	0.0
	2–12							0/15	0.0	0/15	0.0
	12–18							0/6	0.0	0/6	0.0
	18–35	0/1	0.0	0/2	0.0	0/9	0.0			0/12	0.0
	35–50	0/3	0.0	0/1	0.0	0/2	0.0			0/5	0.0
	50+					0/1	0.0			0/1	0.0
Indet.					0/2	0.0			0/2	0.0	
Total		0/4	0.0	0/3	0.0	0/14	0.0	0/22	0.0	0/42	0.0
Calculus	0–2							0/1	0.0	0/1	0.0
	2–12							8/15	53.3	8/15	53.3
	12–18							5/6	83.3	5/6	83.3
	18–35	1/1	100.0	2/2	100.0	6/9	66.7			9/12	75.0
	35–50	3/3	100.0	1/1	100.0	1/2	50.0			5/6	83.3
	50+					1/1	100.0			1/1	100.0
Indet.					1/1	100.0			1/1	100.0	
Total		4/4	100.0	3/3	100.0	9/13	69.2	13/22	59.1	29/42	69.0
Abscess	0–2							0/2	0.0	0/2	0.0
	2–12							0/6	0.0	0/6	0.0
	12–18							1/3	33.3	1/3	33.3
	18–35			1/2	50.0	1/4	25.0			2/6	33.3
	35–50	2/2	100.0	0/0	–	0/0	–			2/2	100.0
	50+					0/1	0.0			0/1	0.0
Indet.					0/1	0.0			0/1	0.0	
Total		2/2	100.0	1/2	50.0	1/6	16.7	1/11	9.1	5/21	23.8

(continued on next page)

Table 3 (continued)

Dental lesion	Age group	Male		Female		Indet.		Subadult		Total	
		abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
AMTL	0–2							0/2	0.0	0/2	0.0
	2–12							0/5	0.0	0/5	0.0
	12–18							1/3	33.3	1/3	33.3
	18–35			0/2	0.0	0/2	0.0			0/4	0.0
	35–50	0/2	0.0							0/2	0.0
	50+					0/1	0.0			0/1	0.0
Total	Indet.					0/1	0.0			0/1	0.0
Total		0/2	0.0	0/2	0.0	0/4	0.0	1/10	10.0	1/18	5.6
Periodontal disease	0–2									0/5	0.0
	2–12							0/5	0.0	0/5	0.0
	12–18							2/3	66.7	2/3	66.7
	18–35			2/2	100.0	2/2	100.0	3/3	100.0	5/5	100.0
	35–50	2/2	100.0							2/2	100.0
	50+					1/1	100.0			1/1	100.0
Total	Indet.					0/1	0.0			0/1	0.0
Total		2/2	100.0	2/2	100.0	4/5	80.0	2/8	25.0	10/17	58.8

Table 4

Dental pathological lesions (absolute numbers and percentages) at Lisakovsk (number of affected teeth/sockets versus total number of observable teeth/sockets).

Dental lesion	Age group	Male		Female		Indet.		Subadult		Total	
		abs.	%	abs.	%	abs.	%	abs.	%	abs.	%
Caries	0–2							0/1	0.0	0/1	0.0
	2–12							0/164	0.0	0/164	0.0
	12–18							0/88	0.0	0/88	0.0
	18–35	0/8	0.0	0/43	0.0	0/122	0.0			0/130	0.0
	35–50	0/38	0.0	0/11	0.0	0/3	0.0			0/41	0.0
	50+					0/2	0.0			0/2	0.0
Total	Indet.					0/2	0.0			0/2	0.0
Total		0/46	0.0	0/54	0.0	0/129	0.0	0/253	0.0	0/482	0.0
Calculus	0–2							0/1	0.0	0/1	0.0
	2–12							40/164	24.4	40/164	24.4
	12–18							76/88	86.4	76/88	86.4
	18–35	8/8	100.0	39/43	90.7	111/124	89.5			158/175	90.3
	35–50	38/38	100.0	4/11	36.4	1/3	33.3			43/52	82.7
	50+					1/2	50.0			1/2	50.0
Total	Indet.					1/1	100.0			1/1	100.0
Total		46/46	100.0	43/54	79.6	114/130	87.7	116/253	45.8	319/483	66.0
Abscess	0–2							0/3	0.0	0/3	0.0
	2–12							0/40	0.0	0/40	0.0
	12–18							2/30	6.7	2/30	6.7
	18–35			1/27	3.7	1/27	3.7			2/54	3.7
	35–50	3/30	10.0	0/0	–	0/0	–			3/30	10.0
	50+					0/2	0.0			0/2	0.0
Total	Indet.					0/3	0.0			0/3	0.0
Total		3/30	10.0	1/27	3.7	1/32	3.1	2/73	2.7	7/162	4.3
AMTL	0–2							0/4	0.0	0/4	0.0
	2–12							0/22	0.0	0/22	0.0
	12–18							1/31	3.2	1/31	3.2
	18–35		–	0/30	0.0	0/10	0.0			0/40	0.0
	35–50	0/44	0.0							0/44	0.0
	50+					0/2	0.0			0/2	0.0
Total	Indet.					0/4	0.0			0/4	0.0
Total		0/44	0.0	0/30	0.0	0/16	0.0	1/57	1.8	1/147	0.7
Periodontal disease	0–2									0/23	0.0
	2–12							0/23	0.0	0/23	0.0
	12–18							20/31	64.5	20/31	64.5
	18–35			28/29	96.6					28/29	96.6
	35–50	38/38	100.0							38/38	100.0
	50+					1/2	50.0			1/2	50.0
Total	Indet.					0/1	0.0			0/1	0.0
Total		38/38	100.0	28/29	96.6	1/3	33.3	20/54	37.0	87/124	70.2

independence (2-Tail) compared the presence of calculus on observable teeth and indicates that the difference between older and younger adults was significant ($p = 0.00136$). More specifically, younger women had significantly less dental calculus than older

women ($p = 0.00335$), older men ($p = 0.02145$), as well as younger men ($p = 0.01105$). At Lisakovsk there was a significant difference between subadults and adults in terms of dental calculus ($p = 0.00001$), with no differences within the subadult or adult

categories based on age or sex. No other significant differences in the proportions of calculus were identified at the sites of Bestamak or Lisakovsk based on sex and age categories. However, analyses of dental calculus that divide the teeth by upper and lower jaw show a clear pattern within the Bestamak samples which have similar proportions of calculus present in each tooth class. There is a clear pattern of increased calculus on first and second molars and premolars with somewhat less calculus on third molars, canines and incisors. In contrast, at Lisakovsk the only consistent pattern is that there is a difference in the proportion of calculus on premolars, with the right maxillary and left mandibular premolars having very little calculus present. However, there was no statistical difference between the premolars in terms of presence of calculus by tooth.

When broader tooth classes were examined at Lisakovsk, high proportions of calculus were found on the molars (average of 86%) and the canines (81%), with somewhat lower proportions for the premolars (average of 43%) and second incisor (52%). While these latter findings fit with general trends, there are significant differences between tooth classes in terms of the presence of calculus. A Fischer's exact test of independence (2-Tail) compared the presence of calculus on observable teeth and indicates that there are significant differences between incisors and canines ($p = 0.01991$), canines and premolars ($p = 0.00809$), as well as premolars and molars ($p = 0.00020$). It is currently unclear why dental calculus patterns at Lisakovsk vary so widely.

Dental abscesses were identifiable at Bestamak for a total of 19 individuals and 309 tooth sockets, while at Lisakovsk dental abscesses were assessed on 21 individuals and 163 tooth sockets. Dental abscesses were investigated among individuals with alveolar bone present and scored by tooth location. When alveolar bone was present and in good condition among individuals at Bestamak, each socket was counted as a possible location for abscess, resulting in 16.8% (52/309) of tooth sockets with evidence of abscess. Dental abscesses were evident in the population at Bestamak for 63.2% (12/19) of individuals. Percentage of abscesses was lower at Lisakovsk and only identified for 23.8% (5/21) of individuals. Among individuals at Lisakovsk, when alveolar bone was present and each socket counted as a possible location for abscess, only 4.3% (7/162) had evidence of drainage. A Fischer's exact test of independence (2-Tail) compared the presence or absence of abscesses by tooth socket and indicate that the difference between the two sites is significant ($p = 0.000055$). At the intra-site level there was an important difference at Bestamak between individuals based on age, where older males (35–50) exhibit a higher frequency of abscesses than younger males (18–35) based on number of tooth sockets present ($p = 0.03838$). No other significant differences in abscesses were identified based on age or sex at Bestamak or at Lisakovsk.

Antemortem tooth loss (AMTL) was calculated when alveolar bone was present and scored by tooth location. At Bestamak, AMTL was evident in 24 locations where alveolar bone was either resorbing or fully resorbed, and calculated as the percent of dentition lost antemortem at 8.2% (24/291). In contrast, at Lisakovsk, AMTL was only evident in 1 location, and calculated as 0.7% (1/147) of dentition lost antemortem. As caries rates can also be greatly affected by AMTL, the Diseased Missing Index (DMI) was calculated for each site, with Bestamak having a DMI of 2.5% (25/982) and Lisakovsk having a DMI of 0.2% (1/629). Overall these rates are low for AMTL and DMI especially in comparison with those for pastoral groups in the region (e.g. Murphy et al., 2013). A Fischer's exact test of independence (2-Tail) compared the presence and absence of AMTL by tooth socket and indicates that the difference between the two sites is significant ($p = 0.0000094$).

At the intra-site level, there was a significant difference between males and females at the site of Bestamak, where males have a greater presence of AMTL (16.5%) than females (6.1%). A Fischer's

exact test of independence (2-Tail) compared the presence of AMTL by tooth socket and indicates that the difference between males and females at Bestamak is significant ($p = 0.0086$). There was also a significant difference between younger adults (18–35) and older adults (35–50) in terms of the number of sockets with AMTL ($p = 0.00022$). At the site of Lisakovsk there were no significant differences in the proportions of AMTL identified between individuals based on age or sex categories. Due to the low number of teeth lost ante-mortem ($n = 25$) no comparative investigation of AMTL in the dental arcade was undertaken.

At Bestamak, periodontal disease was assessed on a total of 16 individuals and 315 tooth sockets, while at Lisakovsk periodontal disease was assessed on 10 individuals and 140 tooth sockets. Periodontal disease was investigated among individuals with alveolar bone present and scored by tooth location. When alveolar bone was present and in good condition, each socket was counted as a possible location for periodontal disease, resulting in 89.0% (315/354) of tooth sockets with evidence of alveolar resorption for the site of Bestamak. Periodontal disease was evident in the population at Bestamak for 84.2% (16/19) of individuals. Percentage of periodontal disease was lower at Lisakovsk and identified for 58.8% (10/17) of individuals. Among individuals at Lisakovsk, 73.6% (103/140) of sockets had evidence of alveolar resorption. A Fischer's exact test of independence (2-Tail) compared the presence or absence of alveolar resorption by tooth socket and indicates that the difference between the two sites is significant ($p = 0.000046$).

At the intra-site level, no significant differences were identified between adults and subadults at Bestamak based on periodontal disease, however there was a significant difference between children (2–12) and adolescents (12–18) ($p = 0.01679$), where the latter have higher proportions of periodontal disease. At Lisakovsk there also were no significant differences between males and females in terms of periodontal disease. However, there was a significant difference in the proportion of periodontal disease (by tooth socket) between adults and subadults ($p = 0.00193$) as well as between children and adolescents ($p = 0.00016$).

Analyses of periodontal disease that divide the teeth by upper and lower jaw indicate different patterns for the sites of Bestamak and Lisakovsk. At Bestamak, there is a similar pattern for the upper and lower jaw where the majority of sockets had proportions of periodontal disease over 80%. Only two teeth had just below 80% presence of periodontal disease, the upper right 1st molar and the upper right second incisor. There is no clear pattern at Lisakovsk when the maxilla and mandible were compared. When the teeth are divided into tooth classes (e.g. M1, M2) there are clear differences between the two sites. In this case, the site of Bestamak had proportions of periodontal disease ranging between 84.7 and 94.8 percent for each tooth class. In contrast, at Lisakovsk there is evidence for a general increase in proportion of disease presence from the first incisor to the third molar, with only the canine having a proportion that is lower than what might be expected. However, there is a much broader range in proportions at Lisakovsk, from 11.1% to 100%.

4. Interpretation and discussion

The results of this research allow for the comparative analysis of two Bronze Age communities in terms of dental health and dietary reconstruction. While slight differences exist between these two populations over time, there is relative continuity in the dental pathological lesions present, with high frequencies of calculus deposits and periodontal disease, and very low levels of caries, abscesses, and AMTL. A very low prevalence for dental caries is indicative of a noncariogenic diet, which conforms to the general pattern of expression for populations that have protein based subsistence regimes often tied to societies who focus on

hunting and gathering or pastoralism (Turner, 1979; Powell, 1985; Lillie, 1996; Murphy et al., 2013). The presence of calculus is also often associated with high protein diets that lack carbohydrates and sugars (Hillson, 1979). These findings thus conform to general patterns for prehistoric hunter-gatherer populations as well as pastoralists who have high protein and low carbohydrate diets (Powell, 1985; Lillie, 1996). Archaeological evidence at Bestamak and Lisakovsk indicates that both populations were pastoralists, and therefore consumed mostly animal products. This primary diet was likely supplemented by freshwater fish and wild plants (Ventresca Miller et al., 2014). The recovery of wild cereals, sickles, and mortar and pestles at nearby sites has been posited as evidence for horticultural or agricultural activities. Instead, these items may have had other functional or ritual uses related to animal foddering, metals processing, or medicinal plant use (Epimakhov, 2010).

For Bronze Age populations in the central Eurasian steppe, very few studies have focused on dental pathological lesions and dietary intake. Research on the MBA site of Kamennyi Ambar 5 (Fig. 1, site 1) reveals that only 2 of 35 individuals had dental caries and little tooth wear was evident (Judd et al., 2009). In addition, at the Bol'shcheykaraganskogo cemetery of Arkaim (Fig. 1, site 2), dental health of 13 individuals revealed 2 abscesses and antemortem tooth loss (AMTL) (Lindstrom, 2002). While tooth wear at this site was relatively light and no caries were present, dental calculus was observed on the majority of the dentition (Lindstrom, 2002). Research on human remains from the LBA sites of Yelovsky-2 and Chernoozerye-1 (Fig. 1, sites 3 and 4) reveal evidence of individuals suffering from tooth decay, dental calculus, as well as traumatic dental injury (Zubova, 2008a). At Yelovsky-2 it was more prevalent for men to have dental enamel hypoplasia than women, even though men tended to live longer (Zubova, 2008a). The reverse was true for individuals buried at Chernoozerye-1 where more women had hypoplasia, while incidence of dental calculus was somewhat higher for men (Zubova, 2008b). The results of these analyses purportedly show that LBA populations had higher rates of cumulative stress than the following Final Bronze Age (Zubova, 2008a). Previous research on prehistoric dental health and diet is extremely valuable from a comparative standpoint to comprehend variability at the community level. Small-scale local studies such as these form the foundation of research necessary to examine local groups in the context of the broader region, as well as to extrapolate these data to compare communities that span the MBA to LBA transition. While direct comparisons cannot be made between the current study and previous research because of inter-observer error, other studies allow for initial understandings of the dental health of nearby populations in the Bronze Age as discussed below.

While comparative and robust datasets of dental pathological conditions for prehistoric central Eurasian steppe pastoralists are limited, several publications have provided foundational examinations of dentition in relation to dietary and subsistence patterns for nearby regions (Lillie, 1996; Lindstrom, 2002; Zubova, 2008a, 2008b; Judd et al., 2009; Murphy et al., 2013). These studies are good comparative case studies of dentition from hunter-gatherer and pastoralist groups located within the greater Eurasian steppe zone. Lillie (1996) found that Mesolithic and Neolithic populations in Ukraine, characterized as either hunter-gatherer-fisher or hunter-gatherer-fisher-pastoralist, had an absence of caries and a wide range of moderate to heavy calculus deposition. Calculus was evident on 66.6% of Mesolithic individuals and 87.5% of Neolithic individuals (Lillie, 1996:138). These results were interpreted as evidence of a diet that was predominantly meat-oriented and high-protein, which was consistent with zooarchaeological remains (Lillie, 1996). Recent research in southwestern Siberia evaluated individuals at two Iron Age sites identified as nomadic

pastoralist groups (Murphy et al., 2013). At the sites of Aymyrlyg (Fig. 1, site 5) and Ai-Dai (Fig. 1, site 6) dental calculus was evident on 93.5% and 97.7% of individuals and the presence of calculus was ubiquitous but slight. Furthermore, there was a significant difference in the proportion of caries between these populations. At Aymyrlyg, caries were identified for 39.6% of individuals, while at Ai-Dai only for 13.6% (Murphy et al., 2013:5). The results of dental paleopathological research revealed that these societies had diverse diets that were primarily protein based, but consumed different proportions of carbohydrates, likely of agricultural origin (Murphy et al., 2013).

Previous research on skeletal populations indicates that differences in dental lesions may be based more on subsistence economy than time period. Compared to the two sites under study, other Bronze Age skeletal populations within central Eurasia have similar numbers of pathological lesions, with few caries identified and high degrees of dental calculus. On a broader scale of the Eurasian steppe, pathological lesions at the two sites under study correlated most closely to Neolithic and Mesolithic hunter and gatherer populations from Ukraine rather than Iron Age pastoral populations from SW Siberia. This may be due to the increased consumption of millet and other cereals by Iron Age groups (Murphy et al., 2013) which are lacking in the Bronze Age. While direct comparisons between various skeletal populations cannot be made due to variation in data collection, general comparisons between these populations must be considered. As the two Bronze Age communities under study had pathological lesions most similar to hunter/gatherer populations, they may have had similarly had dietary regimes that consisted of animal protein and wild plant materials.

The findings at Bestamak and Lisakovsk are further supported by recent stable isotopic evidence which suggests that subsistence regimes stayed quite uniform over time (Ventresca Miller et al., 2014). At the site of Bestamak, $\delta^{15}\text{N}$ values of human bone collagen ($n = 22$) ranged from 9.5 to 14.1‰ with an average of 11.8‰. The average $\delta^{15}\text{N}$ value for individuals at Lisakovsk ($n = 29$) was 12.0‰, with values ranging from 9.9 to 14.4‰. These average human nitrogen isotopic values are elevated compared to the average values reported for fish (10.5‰), cattle (8.4‰), sheep/goat (7.1‰), and horse (5.4‰). The range of $\delta^{13}\text{C}$ values for human bone collagen at Bestamak is slight (−19.6‰ to −17.6‰) with an average isotopic value of −19.0‰. Individuals from Lisakovsk had $\delta^{13}\text{C}$ isotopic values ranging from −19.7 to −17.6‰, and an average value of −18.8‰. These results fall between the isotopic range for both C₃ and C₄ plant consumption. The range of isotopic values for C₄ plants such as millet or maize often vary from −12 to −16‰, with an average of 14‰, while C₃ plants exhibit approximate $\delta^{13}\text{C}$ values of −21 to −35‰, with an average isotopic value of −28‰ (O'Leary, 1988). Furthermore, herbivores at Bestamak have $\delta^{13}\text{C}$ isotopic values ranging from −17.7 to −20.0‰ (Privat, 2004), while herbivores at Lisakovsk have values ranging from −18.8 to −20.2‰ (Ventresca Miller, 2013).

All evidence seems to point to a diet focused around ruminant domesticates, although some variation did exist. Human $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data show variability in diet indicating a supplementation of that staple diet with a range of alternate foods, possibly including wild resources such as fish and plants, as well as domestic animals, such as horses (for full dataset and discussion see Ventresca Miller et al., 2014). Furthermore, lipid analysis of proteins in vessels from the Lisakovsk cemetery and settlement show a predominance of lipids related to the remnants of ruminant dairy proteins (Outram et al., 2010: 124–5). Recent research has shown that a diet rich in fermented or probiotic milk may reduce the presence of cariogenic bacteria thereby lessening the risk of dental caries (Stecksén-Blicks et al., 2009; Lodi et al., 2010). Fermented animal milk (e.g. kymis or airag) continues to be an important component of the diet in

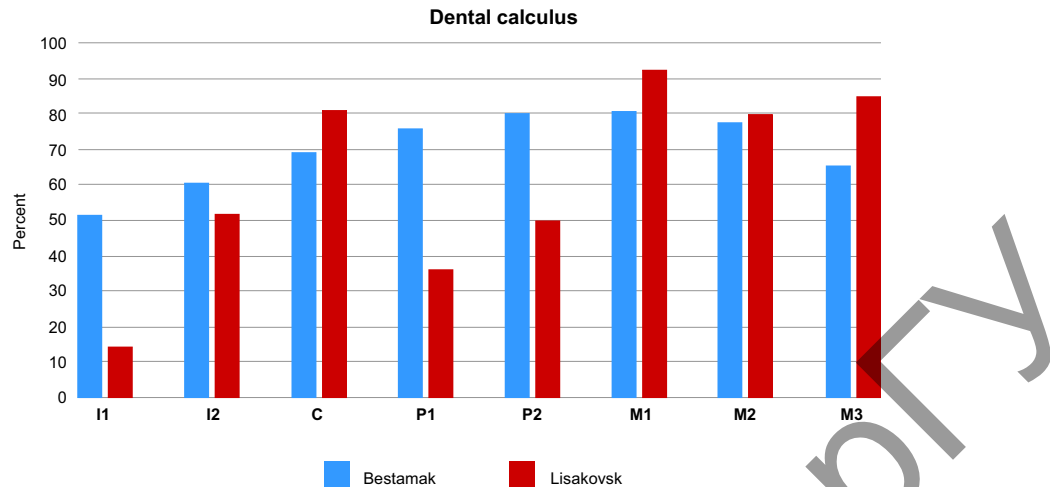


Fig. 14. Proportions of dental calculus by tooth class at Bestamak and Lisakovsk.

current day Central Asia. Therefore, these prehistoric communities may have had patterns of consumption that included high levels of fermented dairy products.

The results of this research demonstrate that the Bronze Age populations discussed here display similar types, but different degrees, of dental pathological lesions. Comparatively, individuals at Bestamak had significantly higher proportions of dental lesions than at Lisakovsk in terms of abscesses (23.8%; 4.3%), AMTL (8.2%; 0.7%), and periodontal disease (89.0%; 73.6%). This might be interpreted as the population at Bestamak being relatively less healthy in regard to dental disease. As dental pathological conditions often have multifactorial etiologies, several factors may have contributed to these differences including stress, consumption practices, environment or climate. During the earlier period (MBA) local communities consisted of aggregated populations within enclosed settlements which may have exacerbated disease processes. Differential consumption practices may also have affected the amount of dental pathological lesions. Results of carbon and nitrogen stable isotopic analyses of these two populations reveal that overall dietary intake was very similar (Ventresca Miller et al., 2014). However, carbon and nitrogen stable isotopic analyses of bone collagen test the consumption of protein over carbohydrates. Therefore, these communities may have had different proportions of wild

plant intake that was not evident in the isotopic analyses undertaken. Additionally, environmental or climatic factors may have played a part in the slight differences between proportions of dental pathological lesions, however as we know very little about these factors it is too early to tell if these had an impact on dental health.

Comparisons between the two sites reveal that Bestamak individuals were relatively less healthy in terms of dental disease, with more uniformity in the location and severity of calculus and periodontal disease. In contrast, Lisakovsk had relatively more healthy individuals but a lack of uniformity in the location of dental disease. When the sites are compared based on tooth class, it becomes evident that there was more homogeneity between the tooth classes at Bestamak than at Lisakovsk in terms of calculus (Fig. 14) and periodontal disease (Fig. 15). However, the number of teeth and tooth sockets available for these studies were much smaller for the site of Lisakovsk (often <7). Therefore the rates for which these diseases were calculated may have been affected by the poor conservation or loss of human osteological materials from these sites after excavation. Therefore, while isotopic results revealed uniformity in diet between these two communities, dental health evidence indicates that the site of Lisakovsk was comparatively healthier. This may be because we have identified only a

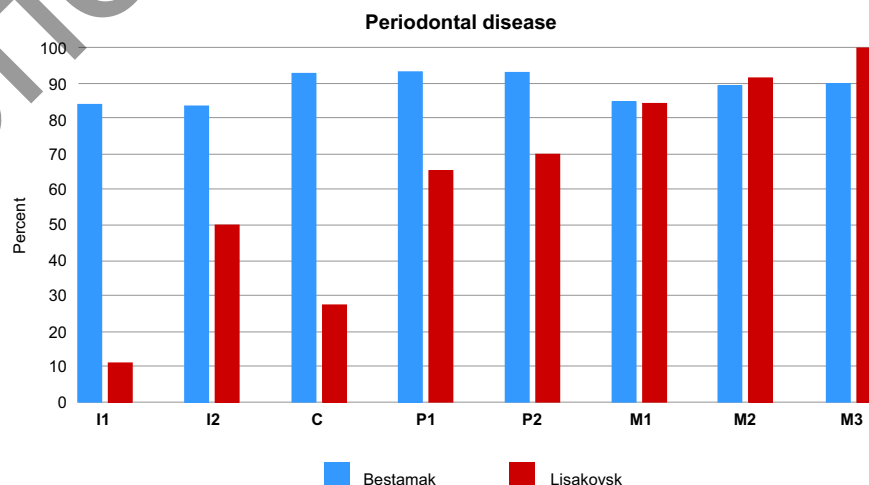


Fig. 15. Proportions of periodontal disease by tooth class at Bestamak and Lisakovsk.

portion of the health and diet datasets necessary to indicate more intricate variation within and between communities.

At the intra-site level several significant differences in proportions of dental disease were identified based on age and sex categories. At Bestamak, younger women had significantly lower proportions of calculus than other adults. In contrast, younger males had significantly fewer abscesses than older males, although these two categories were not different from other categories of adults. These trends were also evident in the findings on AMTL, where older adults had significantly more tooth loss than younger adults. Importantly, males had significantly more AMTL than females at this site. Overall, the trend is that older individuals had increased disease processes, which is expected. However, the difference between the sexes is unexpected. Comparatively, at the site of Lisakovsk, very few significant differences were identified. Adolescents had more incidence of periodontal disease than children, while adults had significantly more periodontal disease than sub-adults. This general trend of older individuals with increased disease is expected. Differences between males and females are especially interesting when compared to mortuary datasets. While the site of Bestamak had little differentiation between the sexes in terms of mortuary remains, individuals had significant differences in dental health. The opposite is true for Lisakovsk, where no significant dental differences were found between adult males and females, although significant differences in mortuary remains were evident. This will be explored further in future publications that compare these two datasets.

5. Conclusion

This study has refined our understanding of the health and diet of Middle and Late Bronze Age pastoral populations at two representative sites in Kazakhstan. In addition, this work highlights the complex nature of health and diet in pastoral communities. At the intra-site level there were no significant differences between the sexes in terms of dental pathological conditions (except for AMTL), suggesting that males and females were for the most part equally affected. The results of dental health indicate that slight, but significant, differences existed between populations at these two sites. Variation may be linked to numerous factors including minor differences in stress levels, consumption patterns, or environmental issues. Based on the results of dental analyses, the dietary intake of these two communities is similar and indicative of a noncariogenic diet associated with a high protein content and a lack of carbohydrates. These findings conform to general patterns for societies who focus on pastoralism or hunting and gathering. On a broader scale, while the archaeological record shows marked changes from the MBA to LBA in terms of settlement patterns, population, and mortuary rituals, there is also a corollary shift from less healthy to more healthy populations. This trend for increased oral health during the LBA coincides with a time when smaller communities are found dispersed across the landscape. While a slight shift in oral health was evident, it is unclear if changes in other forms of stress, herding strategies, or more complex social issues were occurring. Therefore, continued research should focus specifically on investigating local communities and the interwoven nature of health, diet, economy, and environment.

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